Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response

Consultation on the Issuance of Permits 26342 and 26606 under ESA Section 10(a)(1)(A) for Black Abalone Scientific Research and Enhancement in California.

NMFS Consultation Number: *WCRO-2022-01606*

Action Agency: NMFS West Coast Region Protected Resources Division

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely to Destroy or Adversely Modify Critical Habitat?
Black abalone (*Haliotis cracherodii*)	Endangered	Yes	No	Yes	No
White abalone (*Haliotis sorenseni*)	Endangered	No*	NA	NA	NA

*Please refer to section 2.12 for the analysis of species or critical habitat that are not likely to be adversely affected.

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Groundfish	No	No
Pacific Coast Salmon	No	No
Coastal Pelagic Species	No	No

Consultation Conducted By: National Marine Fisheries Service, West Coast Region

Issued By:

Chris Yates
Assistant Regional Administrator for Protected Resources
West Coast Region
National Marine Fisheries Service

Date: September 21, 2022

TABLE OF CONTENTS

TABLE OF TABLES

ACRONYMS

ARM	Abalone Recruitment Module
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
DQA	Data Quality Act
EFH	Essential Fish Habitat
ELH	Egg Laying Hormone
ESA	Endangered Species Act
ITS	Incidental Take Statement
MARINe	Multi-Agency Rocky Intertidal Network
MBNMS	Monterey Bay National Marine Sanctuary
MSA	Magnuson-Stevens Act
NMFS	National Marine Fisheries Service
OSPR	Office of Spill Prevention and Response
OTC	Oxytetracycline
PBF	Physical or biological feature
PCE	Primary constituent element
PFMC	Pacific Fishery Management Council
PIT	Passive Integrated Transponder
PRD	Protected Resources Division
RBOS	Refugio Beach Oil Spill
SWFSC	Southwest Fisheries Science Center
UCD-BML	University of California, Davis-Bodega Marine Laboratory
UCSB	University of California, Santa Barbara
UCSC	University of California, Santa Cruz
WCR	West Coast Region

1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

1.1. Background

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 et seq.), as amended, and implementing regulations at 50 CFR part 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson–Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR part 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available online within 2 weeks of the signature date at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at the NMFS West Coast Region Long Beach office.

1.2. Consultation History

The West Coast Region (WCR) Protected Resources Division (PRD) received two applications for permits to conduct scientific research and enhancement on endangered black abalone in California. Because the permit requests are similar in nature and duration and are expected to affect endangered black abalone, we combined them into a single consultation pursuant to 50 CFR 402.14(c), which allows a consultation to encompass "… a number of similar individual actions within a given geographical area." The permits considered in this consultation are listed and described below.

> *Permit 26342* – On December 19, 2021, the University of California, Santa Cruz (UCSC) submitted a new permit request for black abalone emergency rescue and relocation. We requested edits, which the UCSC addressed. We deemed the application complete on May 3, 2022.
>
> *Permit 26606* – On May 3, 2022, the UCSC submitted a new permit request for black abalone transplant studies and we deemed the application complete.

On May 18, 2022, we published a notice in the Federal Register asking for public comment on the applications (87 FR 30207). The public comment period closed on June 17, 2022. We did not receive any public comments on the permit applications.

On July 7, 2022, we initiated consultation on the proposed permits. This consultation analyzes the research and enhancement activities that may be authorized under the permits and their effects on ESA-listed resources, primarily endangered black abalone and their critical habitat. On July 5, 2022, the United States District Court for the Northern District of California issued an order vacating the 2019 regulations adopting changes to 50 CFR part 402 (84 FR 44976, August 27, 2019). As reflected in this document, we are now applying the section 7 regulations that governed prior to adoption of the 2019 regulations. For purposes of this consultation, we considered whether the substantive analysis and its conclusions articulated in the biological opinion and incidental take statement would be any different under the 2019 regulations. We have determined that our analysis and conclusions would not be any different.

1.3. Proposed Federal Action

Under the implementing regulations for the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (see 50 CFR 402.02).

Under the implementing regulations for the MSA, "Federal action" means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a Federal Agency (50 CFR 600.910).

The proposed actions here are NMFS' issuance of two permits for scientific research and enhancement of abalone propagation and survival, pursuant to section 10(a)(1)(A) of the ESA. The permits would cover the research and enhancement activities proposed by the applicants, described below, and authorize researchers to take a limited, specified amount of endangered black abalone. "Take" is defined in section 3 of the ESA; it means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect [a listed species] or to attempt to engage in any such conduct. ESA Section 10(a)(1)(A) allows NOAA Fisheries to issue permits for the purposeful or direct take of an ESA-listed species only for scientific purposes or to enhance the propagation (such as through hatcheries) or survival of listed species. Permits are being issued authorizing such take for scientific research purposes and enhancement activities to carry out priority recovery actions for black abalone and that will enhance their propagation and survival.

"Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration (50 CFR 402.02). We considered whether there would be any interdependent or interrelated activities associated with the proposed action and determined there would not.

1.3.1. Permit 26342 for Black Abalone Emergency Response

Permit 26342 would authorize researchers to rescue and relocate black abalone in response to future emergency events that may occur and that pose a risk to black abalone and their habitat, such as oil spills, landslides, debris flows, and vessel groundings. The purpose of these actions is to enhance survival of black abalone affected or likely to be affected by emergency events. The permit would authorize rescue and relocation activities for a period of 10 years. This permit

would directly address priority recovery actions identified in the Final ESA Recovery Plan for Black Abalone (NMFS 2020).

UCSC would assess the need for rescue and relocation based on the observed or expected effects and risks posed by the emergency event on black abalone and its habitat. UCSC would notify NMFS prior to conducting rescue and relocation activities. The proposed activities include collection of black abalone and removal from the wild, captive holding for one day to several months, reintroduction to the wild, and post-release monitoring. Researchers will photograph, measure (shell length), weigh, visually assess health and gonad condition, genetically sample (via a swab sample or an epipodial clipping), and tag the rescued abalone. Researchers will select relocation sites and may prepare pre-identified crevices by removing encrusting organisms prior to releasing the rescued abalone. Researchers will conduct post-release monitoring within a few days of release and as frequently as every tide cycle over the first three months, at six-months, and then annually. Monitoring will involve recording the location and habitat of tagged abalone and collecting empty, tagged shells to track the survival and movements of the released abalone. See Section 2.5.2 (Effects of the Action on Black Abalone) for a more detailed description of each activity and the methods.

UCSC estimates rescuing and relocating up to an average of 1,000 black abalone per year, averaged over five years. Actual numbers will vary depending on the frequency, scope, and nature of events requiring a rescue response. Collection and handling may injure or kill some of the abalone. Severely injured abalone will be held in captivity for rehabilitation. Based on previous rescue and relocation efforts conducted in response to the Mud Creek landslide in 2017 and the 2021 Big Sur debris flow event, UCSC estimates that up to 220 black abalone may die due to injuries associated with collection and handling and up to 102 black abalone may die following release. In addition to live abalone, the permit would allow UCSC to collect dead or obviously unhealthy black abalone observed in the field or in captivity. Dead or obviously unhealthy abalonewill be preserved and available for analysis at approved labs. Dead abalone are those that are unresponsive and not attached to the substrate. Obviously unhealthy abalone are those that are noticeably shrunken, unable to adhere firmly to the substrate, and do not actively attempt to right themselves when placed upside down on the substrate. Such abalone are expected to die within days.

The permit would also allow a subset (up to 100 per year) of the rescued black abalone to be used in spawning studies—provided they have ripe gonads. The purpose would be to take advantage of this unique opportunity (abalone with ripe gonads) to develop reliable spawning induction methods for black abalone. Prior to conducting spawning studies, UCSC would coordinate with NMFS, the California Department of Fish and Wildlife (CDFW), and the Black Abalone Recovery Team (a formal team appointed by NMFS to facilitate implementation of the Final Recovery Plan) to develop an agreed-upon spawning, culturing, and grow-out plan. Spawning and culturing will follow the methods described in the University of California, Davis-Bodega Marine Laboratory's (UCD-BML) White Abalone Spawning and Culture Guide (Kawana and Aquilino 2020), with modifications to evaluate the following factors on spawning induction: prolonged desiccation, elevated water temperatures, seasonal tidal cycles, and hormone injections.

The permit would allow up to two spawning events to be conducted per year. If spawning is successful, an estimated 2 million larvae may be produced per year. The captive-bred progeny may be used in larval or post-settlement outplanting trials, or transferred to the black abalone captive research program (under Permit 19571-2R issued to the Southwest Fisheries Science Center, SWFSC) for long-term holding and grow-out.

Outplanting methods include settling the larvae onto abalone recruitment modules (ARMs) made of stacked tiles, cobbles rocks contained in vexar mesh bags, or stone/concrete blocks contained in vexar mesh. At one-day to three months post-settlement, the ARMs would be transported to and installed at selected outplanting sites, adjacent to crevices and potential juvenile settlement habitat. The permit would also allow larval outplanting, particularly if large numbers of larvae are produced. Larvae that are ready to settle will be transported in seawater-filled bags in coolers and released within an enclosed space (e.g., a tide pool, or a mesh tent deployed in a tide pool) to allow the larvae to settle.

Post-outplant monitoring would occur six months to one year after outplanting, with subsequent monitoring at least once per year and up to three times per year (every four months). Monitoring would involve disassembling the ARMs to count and measure any black abalone and reassembling the ARMs, as well as searching adjacent habitat for juveniles.

1.3.2. Permit 26606 for Black Abalone Transplanting Studies

Permit 26606 would authorize researchers to conduct studies to evaluate transplanting as a tool to establish and enhance black abalone, at up to five sites within and adjacent to the area affected by the Refugio Beach Oil Spill (RBOS). The purpose is to restore black abalone and rocky intertidal habitat affected by the RBOS, which would enhance black abalone propagation and survival. The permit would authorize black abalone collection and transplant activities for a period of five years. This permit would directly address priority recovery actions identified in the Final ESA Recovery Plan for Black Abalone (NMFS 2020).

The proposed transplantation studies involve four main tasks:

1. Assess the genetic structure of black abalone at the "donor" sites and any black abalone at the transplantation site;
2. Prepare habitat (i.e., remove fouling organisms, if needed) for transplantation of donor individuals;
3. Transplant donor individuals to achieve an initial target density of three abalone per m^2 and maintain a density of at least two abalone per m^2 in subsequent years; and
4. Monitor transplanted individuals and subsequent recruitment of new individuals to assess success.

Researchers will survey potential donor sites and the transplantation sites prior to conducting collection and transplant activities, to assess black abalone abundance, density, spatial distribution, and habitat. Abalone will not be removed or handled during these pre-collection and pre-transplant surveys. The proposed activities include collection and removal of black abalone from one to multiple donor sites, captive holding for one to several days, reintroduction to the wild at the transplantation site, and post-transplant monitoring. Researchers will photograph, measure (shell length), weigh, visually assess health and gonad condition, genetically sample

(via a swab sample or an epipodial clipping), and tag the collected abalone. Collection and handling may injure or kill some of the abalone. Severely injured abalone will be held in captivity for rehabilitation. In addition to healthy abalone, the permit would allow UCSC to collect dead or obviously unhealthy black abalone to be preserved and available for analysis at approved labs. See Section 2.5.2 (Effects of the Action on Black Abalone) for a more detailed description of each activity and the methods.

This permit would allow collection and transplanting of up to an average of 250 black abalone (juveniles and adults) per year, averaged over five years. An initial transplant effort will be conducted at one site, with subsequent collection and transplanting to maintain a target density of two abalone per m^2. Transplant efforts may be conducted at an additional four sites, including the transplant of juveniles from the initial transplantation site to adjacent sites using ARMs. Transplantation sites will be up to approximately 400 m by 100 m in area. Within a site, researchers will identify up to 10 transplantation plots (cracks and crevices) and up to ten control plots, each to evaluate the effects of habitat preparation and the effects of transplanting on resident abalone (20 control plots total per site). Each plot will be approximately $25m^2$ and contain cracks and crevices that are typically 1-5 m in length and 0.5-1m in depth (about $5m^2$ per plot). Transplantation and control plots will primarily be selected within good habitat, which makes up a small portion of each site (about 1-5 percent of the total area).

Researchers will collect black abalone from one or multiple donor sites for transplanting. Donor sites will be selected based on the status, viability, and genetic structure of black abalone at the site; the geographic location; and the number of black abalone that can be collected. No more than 10 percent of the black abalone at a site will be collected for transplanting. The following criteria will also be used by the researchers to determine how many black abalone to collect per site to ensure that the collection of black abalone for transplanting does not reduce long-term viability at the donor sites. Researchers will also re-survey the donor sites at about six months post-collection to assess these criteria:

- Maintain a density greater than the expected density for that site based on habitat. We define "expected density" as the density of black abalone that a site can support, based on the habitat quality and quantity at the site (NMFS 2020). Density refers to the density within suitable habitat for black abalone.
- Maintain a minimum density of at least two black abalone per m^2 for good to moderate habitat.
- Maintain the proportion of black abalone within reproductive clusters (i.e., the proportion of black abalone that are within groups of three or more individuals within one meter of one another).

Researchers will conduct post-transplant monitoring to evaluate transplant survival, density within the transplantation plots, and juvenile recruitment (as confirmation of successful reproduction). Researchers will conduct monitoring within a few days of transplanting and as frequently as every tide cycle over the first three months, then at six-months and annually. Monitoring will involve recording the location and habitat of tagged abalone and collecting empty, tagged shells to track transplant survival and movements. Focused juvenile surveys will

be conducted during the 6-12 month surveys and may include installing and monitoring up to 30 ARMs (about three per transplantation plot) to facilitate detection of juveniles.

The permit would also allow transplanting black abalone using the ARMs. ARMs with black abalone on them would be removed from the initial transplantation site, transported in coolers, and installed at up to four additional sites. Post-transplant monitoring would be conducted as described above.

Following an initial annual transplant effort of up to 250 black abalone, any collection and transplanting activities in the subsequent year would first need to be approved by NMFS subject to NMFS' review of activities to date and consideration of the following success metrics:

- Survival of black abalone during collection, transport, and captive holding.
- Survival of transplanted abalone: Survival and mortality rates are difficult to assess in the field. A transplanted abalone may not be re-sighted because it died, lost its tag(s), moved deep into a crevice, or moved out of the study area. UCSC will evaluate and report the resighting rate (the proportion of transplanted abalone observed in post-transplant surveys) and the confirmed mortality rate (the proportion of empty, tagged shells found).
- Density: Maintain a target average density of at least two abalone per m^2 across all transplantation plots during the initial transplant and in subsequent years.
- Recruitment: Observe recruitment as confirmation of successful reproduction, recognizing that this metric may not be achieved until 5-10 years post-transplant.
- Effects on donor site: A follow-up survey will be conducted at the donor site(s) at about 6 months post-collection, to evaluate the status of black abalone and whether the density and reproductive cluster criteria continue to be met.

1.3.3. Permit Conditions

Research and enhancement permits lay out the conditions to be followed before, during, and after the permitted activities are conducted. These conditions are intended to (a) manage the interaction between researchers and listed abalone by requiring that activities be coordinated among permit holders and between permit holders and NMFS, (b) minimize impacts on listed species, and (c) ensure that NMFS receives information about the effects the permitted activities have on the species concerned. NMFS will use the annual reports to monitor the actual number of listed abalone taken every year by scientific research and enhancement activities and will adjust permitted take levels if they are deemed to be excessive or if cumulative take levels rise to the point where they are detrimental to the listed species.

The proposed permit conditions refer to the following personnel under the permit: Permit holder, principal investigator, and co-investigator. "Permit holder" means the person, institution, or agency that is ultimately responsible for all activities of any individual who is operating under the authority of the permit. "Permit holder" refers to the permit holder or any employee, contractor, or agent of the permit holder. "Principal investigator" means the individual primarily responsible for the taking, importation, exportation, and any related activities conducted under

the permit. “Co-investigator” means an individual who is qualified and authorized to conduct or directly supervise activities conducted under the permit without the on-site supervision of the Principal Investigator.

Both Permit 26342 and Permit 26606 include the following proposed permit conditions:

General Conditions

1. The Permit Holder must ensure that listed species are taken, as that term is defined under the ESA, only at the levels, by the means, in the areas, and for the purposes stated in the permit applications, and according to the conditions in these permits.
2. The Permit Holder must not intentionally kill, or cause to be killed, any listed species unless and to the extent that the permit specifically allows intentional lethal take.
3. All personnel operating under these permits must exercise the utmost caution and care to avoid unnecessary disturbance or harm to endangered black abalone and critical habitat for this species.
4. All personnel operating under these permits must handle black abalone with care and provide adequate transport and holding conditions for abalone health, including water temperatures within the optimal range for black abalone, proper aeration and oxygen levels, and routine removal of waste products as outlined in the Updated Protocol for Black Abalone Collection, Transport, and Holding (NMFS 2021).
5. If a mass mortality of black abalone is detected while conducting activities under this permit, the Permit Holder must notify NMFS of the location(s) and potential cause(s) of the mass mortality as soon as possible but no later than two days after detecting the mass mortality.
6. The person(s) actually carrying out the research and enhancement activities must carry a copy of the relevant permit while conducting the authorized activities.
7. Co-investigators must coordinate permitted activities with the Principal Investigator before conducting field work.
8. The Permit Holder must keep an inventory of the number of abalone collected, released, and monitored and share these data with NMFS and the co-investigators on the permit.
9. The Permit Holder must allow any NMFS employee or representative to accompany personnel while they conduct the research and enhancement activities.
10. The Permit Holder must allow any NMFS employee or representative to inspect any records or facilities related to the permit activities.
11. The Permit Holder may not transfer or assign these permits to any other person as defined in Section 3(12) of the ESA. These permits cease to be in effect if transferred or assigned to any other person without NMFS’ authorization.
12. NMFS may amend the provisions of these permits after giving the Permit Holder reasonable notice of the amendment.
13. The Permit Holder must obtain all other required Federal, state, and local permits/authorizations for the research and enhancement activities.
14. These permits do not authorize takes of any protected species other than black abalone,

including those species under the jurisdiction of the U.S. Fish and Wildlife Service. Should other protected species be encountered during the research and enhancement activities authorized under these permits, researchers should exercise caution and remain a safe distance from the animal(s) to avoid take, including harassment. Also see Condition 3 under "Duration of Permit."

15. The Permit Holder is responsible for all costs incurred by research and enhancement activities, including determinations of cause of death of abalone during any of the activities authorized under these permits.
16. If the Permit Holder violates any permit condition, they will be subject to any and all penalties provided by the ESA. NMFS may revoke these permits if the authorized activities are not conducted in compliance with the permits and the requirements of the ESA or if NMFS determines that its ESA section 10(d)[1] findings are no longer valid.

Duration of Permit

1. Permit 26606 expires on December 31, 2027 and Permit 26342 expires on December 31, 2032. Researchers may conduct activities authorized by these permits only through the expiration dates and only until authorized take or mortality levels are reached. Annual review and authorization is required to document annual take and evaluate compliance with the permit conditions. A renewal or amendment for these permits can be applied for through the NOAA Fisheries APPS website (https://apps.nmfs.noaa.gov/index.cfm). A completed application must be submitted before the expiration date in order to be considered for the renewal or amendment without a break in coverage.
2. If authorized take or mortality is exceeded, researchers must cease permitted activities and notify the NMFS contact listed on the first page of these permits as soon as possible, but no later than within two business days. The Permit Holder must also submit a written incident report. NMFS may amend the permit, granting authorization to resume some or all permitted activities based on review of the incident report and in consideration of the Terms and Conditions of these permits.
3. In the event that any ESA-listed species is taken (as defined by the ESA) in a manner not authorized by these permits, or not otherwise allowed by another permit or exemption during the course of the activities authorized under these permits, the Permit Holder shall document and notify the NMFS contact of the subject taking. Such notification shall be made to the NMFS contact within a reasonable period of time, but in no case later than 48 hours after the discovery of an unauthorized take. Pending review of the circumstances surrounding the unauthorized take, NMFS may suspend or terminate the authorized activities or amend these permits prior to allowing the permitted activities to continue.

[1] Section 10(d) of the ESA states that the Secretary of Commerce may issue scientific research and enhancement permits under Section 10(a)(1)(A) of the ESA based on findings that such permits: (1) were applied for in good faith; (2) will not operate to the disadvantage of such endangered species; and (3) will be consistent with the purposes and policy set forth in section 2 of the ESA.

Conditions related to field collection, release, and monitoring activities

1. Collection: Only experienced personnel may conduct collection activities. Collection tools may only be inserted on the rear or sides of the abalone, avoiding the head. If an abalone clamps down, personnel must wait until the abalone relaxes and can be safely removed without injury.
2. Habitat preparation: When conducting habitat preparation activities (e.g., removing fouling organisms), researchers must search the cracks and crevices at the relocation or restoration site for any black abalone. Researchers must not remove fouling organisms within 10 cm of any abalone, to avoid disturbing the abalone.
3. Genetic sampling: When collecting epipodial samples, the samples must be collected from epipodial tentacles on the sides or posterior of the animal and must be taken at least 1-2 mm from the base of the tentacle. Swab samples may be collected by wiping a flexible, soft-tipped swab against the surface of the abalone's shell or soft tissue (e.g., the foot muscle or by inserting the swab into a respiratory pore). NMFS SWFSC will serve as the final repository for genetic samples.
4. Researchers must wash all field gear and equipment with fresh water between field sites to avoid the potential introduction and spread of disease and non-indigenous species between sites.
5. Collection of dead and obviously unhealthy black abalone: Black abalone may be collected for further analysis if they are determined to be dead or obviously unhealthy (as defined in Moore 2019 and summarized below).
    a. Dead abalone are those that are unresponsive and not attached to the substrate.
    b. Obviously unhealthy abalone are those that are noticeably shrunken (i.e., epipodial tentacles do not extend beyond the margin of the shell and can no longer be seen); unable to adhere firmly to the substrate (e.g., the abalone can be dislodged easily from the substrate by hand); and do not actively attempt to right themselves when placed upside down on the substrate. Abalone that fit this description are expected to die within days and may be collected to determine the cause of death.

Conditions related to captive holding activities

1. The duration that the permit holder may retain or possess live black abalone will be minimized to the extent possible and limited to the least amount of time necessary for conducting a particular research and enhancement activity.
2. Newly collected abalone must be quarantined for at least four weeks and examined daily for signs of disease, mortality, or behavioral disorders.
3. Shell waxing may be conducted when necessary to prevent damage to the shell by boring organisms (e.g., when there is evidence of live Polydora covering the shell, or more than 50 percent of the surface of the shell shows evidence of boring organisms). Researchers should try to keep the animals moist and minimize the time they are kept out of water (the procedure should take less than 10 minutes).

4. Shell notching: To mark individual abalone, researchers may cut a notch into the growing edge of the shell. Researchers must avoid cutting the soft tissue of the abalone. Researchers must keep the abalone moist and abalone may not be kept out of the water for more than 10 minutes.
5. Use of anesthetics: Researchers may use anesthetics to remove abalone from tanks or other holding containers, to relax the abalone and minimize injury. To minimize stress to the abalone, researchers must limit the concentration of the anesthetics and exposure time to the minimum needed to relax the abalone and remove them from the substrate.
    a. For juvenile abalone: Exposure to low concentrations of ethanol (e.g., less than 3%) for a short period of time (e.g., 5-10 minutes) has been effective for sedating mass numbers of small juvenile abalone.
    b. For larger abalone: Researchers may use ethanol (non-denatured) at a maximum concentration of 3% (30 mL/L) and a maximum exposure time of 10 minutes.
6. Prior to transferring black abalone to an approved facility, the responsible official of the facility must be designated as a co-investigator on these permits or possess a separate scientific research and/or enhancement permit.
7. Prior to transfer to a new facility which has not previously held black abalone, husbandry and research protocols including disease screening and prevention of disease transmission at the facility must be submitted to NMFS for approval.
8. When transferring black abalone, the Permit Holder must follow best practices such as those described in the Updated Protocol for Black Abalone Collection, Transport, and Holding (NMFS 2021). The Permit Holder must handle the animals with care and provide a healthy environment, including appropriate temperature, oxygen, and water levels.
9. Public display of captively held animals is authorized provided that it is incidental to and does not interfere with attaining the survival or recovery objectives as described in these permits. Such incidental public display may only occur as part of an educational program. A portion of this program must describe the research and/or enhancement activities.
10. Researchers may euthanize obviously unhealthy abalone to preserve them for necropsy to determine the cause of death.
11. Before installing ARMs, researchers must search the cracks and crevices at the relocation or restoration site for any black abalone. If black abalone are present, researchers must install the ARMs far enough away (at least 10 cm from any individual) to avoid disturbing the abalone.
12. Prior to moving ARMs to field sites, researchers must remove any non-native species and unnecessary native species. Unnecessary native species include other snails or invertebrates that are not used by black abalone, for example, as habitat, camouflage, or food.
13. Researchers must handle black abalone with extreme care, especially when monitoring the ARMs. When moving black abalone from the ARMs, researchers must carefully remove the abalone to avoid injuring the animals, using kelp, a plastic spatula, or another instrument with a thin profile if needed.
14. Researchers will observe how individual abalone respond to habitat preparation activities,

installation and monitoring of ARMs, and transplanting activities, and summarize these observations in the annual and final reports to NMFS (specified in items 2 and 4 under "Reporting Requirements" below).

Number and Kind(s) of Protected Species, Location(s), and Manner of Taking

1. The take table in the permit applications outline the number of black abalone that may be taken, and the locations, manner, and period in which they may be taken. These numbers are subject to annual review and authorization by NMFS.
2. Researchers working under these permits may collect visual images (e.g., still photographs, motion pictures) as needed to document the permitted activities, provided the collection of such images does not result in the taking of protected species.
3. The Permit Holder may use visual images collected under these permits in printed materials (including commercial or scientific publications) and presentations, provided the images and recordings are accompanied by a statement indicating that the activity was conducted pursuant to these Permits. This statement must accompany the images and recordings in all subsequent uses or sales.
4. Upon written request from the Permit Holder, approval for photography, filming, or audio recording activities not essential to achieving the objectives of the permitted activities, including allowing personnel not essential to the research (e.g. a documentary film crew) to be present, may be granted by NMFS.
    a. Where such non-essential photography, filming, or recording activities are authorized, they must not influence the conduct of permitted activities or result in takes of protected species.
    b. Personnel authorized to accompany the Researchers during permitted activities for the purpose of non-essential photography, filming, or recording activities are not allowed to participate in the permitted activities.
    c. The Permit Holder and Researchers cannot require or accept compensation in return for allowing non-essential personnel to accompany Researchers to conduct non-essential photography, filming, or recording activities.
5. Biological Samples:
    a. The Permit Holder is responsible for all of the biological samples collected from listed species, including whole specimens, tissue samples, and shells. Such samples are subject to the Terms and Conditions of these Permits.
    b. All biological samples collected from black abalone obtained under the permits shall be identified by a unique number and maintained according to accepted curatorial standards. After completion of initial research goals, any remaining samples or specimens shall be maintained by the Permit Holder or deposited into a bona fide scientific collection that meets the minimum standards of collection, curation, and data cataloging as established by the scientific community.
    c. The Permit Holder may not transfer biological samples to researchers other than those specifically identified in the application without prior written approval from

NMFS.

6. Take is not authorized for activities not specifically authorized by these permits (e.g., commercial culture and sale of black abalone, including shells).

Reporting Requirements

1. The Permit Holder must submit annual, final, and incident reports (preferably through the NOAA Fisheries APPS website), and papers or publications resulting from the research authorized herein to NMFS.
2. The Permit Holder must submit an annual report to NMFS at the conclusion of each year for which the permits are valid. Annual reports are due by January 31st for the previous reporting year. Falsifying annual reports or permit records is a violation of these permits. Annual reports must describe the research and enhancement activities.
3. The Permit Holder and co-investigators must maintain a tracking system (e.g., a database, spreadsheet) documenting the following information collected as part of the permit activities, to inform future analyses and implementation of the permit activities. The Permit Holder must summarize the information in the annual reports and provide data as requested by NMFS.
4. The Permit Holder must submit a final report to NMFS within 90 days after expiration of the permits, or, if the research concludes prior to permit expiration, within 90 days of when the research ends.
5. The Permit Holder must submit written incident reports related to mortality events and serious injury, or to exceeding authorized takes, to NMFS as soon as possible but not more than two days from when the incident or exceedance occurred. The incident report must include a complete description of the events and identify the steps that will be taken to reduce the potential for additional research-related mortality or exceedance of authorized take.
6. Research results must be published or otherwise made available to the scientific community in a reasonable period of time, taking care to protect sensitive location data for abalone in the wild.

1.3.3.1 Permit 26342 - Specific Conditions

The following are proposed permit conditions specific to Permit 26342:

Conditions related to field rescue, relocation, and monitoring activities

1. The Permit Holder must provide written notification to NMFS of the need to rescue and relocate black abalone prior to implementing any rescue and relocation operation. The notification must include the following:
    a. Justification for the rescue and relocation effort;
    b. The name and location of the site where rescue activities will occur;
    c. A brief description of the specific conditions prompting the rescue;

d. An estimate of the number of black abalone expected to be rescued;

e. The name and location of the captive facility (or facilities) where rescued black abalone will be held, the estimated duration of captive holding (e.g., days to months), and the point of contact for the facility(ies);

f. The name and location of potential relocation site(s); and

g. A description of how the status of relocated abalone will be monitored over time.

Conditions related to spawning, culturing, and outplanting activities

1. Prior to conducting spawning studies, the Permit Holder must develop a spawning, culturing, and grow-out plan that is agreed upon by NMFS, CDFW, and co-investigators. The plan must address the following:

    a. The specific purpose and goal of the spawning studies;

    b. The roles, responsibilities, and primary point of contact for each facility that will carry out spawning, culturing, and grow-out activities;

    c. The number of black abalone to be used in spawning studies and how those abalone will be selected;

    d. The number of spawning trials to be conducted;

    e. The spawning induction methods to be evaluated;

    f. The disposition of the rescued abalone used in spawning studies (e.g., release to the wild, long-term holding) and how that will be decided; and

    g. The disposition of any progeny produced, including the life stage to which progeny will be grown-out in captivity, the life stage at which progeny will be outplanted, and the proportion that may be sampled for early life stage development.

2. Prior to conducting outplanting trials, the Permit Holder must develop an outplanting plan agreed upon by NMFS, CDFW, and co-investigators. The plan must address the following:

    a. The specific purpose and goal of the outplanting trials;

    b. The life stage (larval or post-settlement juvenile) to be outplanted;

    c. Outplanting methods to maximize survival and post-outplant monitoring, including the use of modules;

    d. Potential outplant sites, including consideration of the genetic structure of the rescued abalone and populations at the outplant sites;

    e. Post-outplant monitoring plan; and

    f. Personnel, supplies, equipment, and other resources needed.

3. All abalone used in spawning trials must be individually identifiable (e.g., by tagging).

4. Two genetic samples (swab and/or epipodial samples) must be collected from each abalone used in spawning trials. One sample will be maintained by the Permit Holder and one sample

will be sent to the NMFS SWFSC in La Jolla (Hyde Lab).

5. Disposition: The Permit Holder is responsible for individuals resulting from captive breeding of black abalone, and all disposition alternatives are subject to the Terms and Conditions of this permit. For each year class, the Permit Holder must confer with NMFS on the proportion of individuals to be raised for each disposition option listed below. The following dispositions have been considered for this permit:
    a. Use in authorized research activities (e.g., experimental outplanting),
    b. Transfer to facilities for settlement and grow-out, educational purposes, and/or research activities, and
    c. Destroying.

1.3.3.2 Permit 26606 - Specific Conditions

The following are proposed conditions specific to Permit 26606:

Conditions related to collection of black abalone from donor sites

1. Collection of black abalone from donor sites is authorized to occur in phases. In the first phase (Phase I), up to 250 black abalone may be collected from donor sites. Authorization to collect additional black abalone is contingent upon approval by NMFS pending review of the following information, to be submitted in writing by the Permit Holder:
    a. A summary of collection, transplant, and post-transplant monitoring efforts to date;
    b. Survival rates of black abalone during collection, transport, and captive holding;
    c. Minimum confirmed survival rate of transplanted abalone, based on the resighting rate (the proportion of transplanted abalone observed in post-transplant surveys);
    d. Confirmed mortality rate of transplanted black abalone (the proportion of empty, tagged shells found);
    e. A description of factors affecting the resighting of live abalone and observation/collection of empty, tagged shells;
    f. The number and density of black abalone at the transplantation site(s) during the initial transplant effort and subsequent monitoring surveys, to determine how well the target minimum average density of two abalone per m^2 has been met across transplantation plots;
    g. The number and proportion of recruits observed at the transplantation site(s);
    h. The effects of transplant activities on resident black abalone at the transplantation site(s); and
    i. The effects of collection activities on black abalone at the donor site, including a summary of the status of black abalone (e.g., number, density, proportion in reproductive clusters) at the donor site prior to and after collection activities. Results from follow-up surveys should be included to evaluate whether density

remains greater than the expected density based on habitat and greater than a minimum of two abalone per m^2, and whether the proportion of black abalone in reproductive clusters remains stable or has increased.

2. The following collection criteria are intended to ensure that the collection of black abalone for transplanting does not reduce the long-term viability of the remaining black abalone at the donor sites. The number of black abalone to collect from any one donor site will be determined based on the following:
    a. Researchers may collect no more than 10% of the black abalone from any one donor site;
    b. The density of the remaining black abalone must be at least two abalone per m^2 for good to moderate habitat and must be greater than the expected density for that site based on the habitat; and
    c. The proportion of abalone within reproductive clusters must be the same or greater than the proportion prior to collection activities.
    d. Following review of Phase I, NMFS may apply the same or less restrictive criteria for the collection of additional black abalone for transplanting.
3. The Permit Holder must submit a collection plan to NMFS at least two weeks prior to conducting collection activities. Required elements of the collection plan include:
    a. The donor site(s) and date(s) when collection activities will occur;
    b. Names of participants and their roles;
    c. A description of survey methods, collection methods, and data collection;
    d. A description of how the abalone will be transported;
    e. The captive holding facility or facilities, including points of contact; and
    f. The planned transplantation location(s) and date(s).
4. The Permit Holder must submit a collection report to NMFS not more than 90 days following the collection activities. Required elements of the collection report include:
    a. The donor site(s) and date(s) when collection activities occurred;
    b. Names of participants and their roles;
    c. A summary of the survey results, including the number and density of black abalone observed, the expected density based on the habitat, and the proportion of abalone in reproductive clusters;
    d. A summary of collection activities, including the number of black abalone collected and the density and proportion in reproductive clusters for the remaining black abalone at each donor site;
    e. For the collected black abalone: size distribution, transport method and duration, captive facility location, duration of holding, general holding conditions and activities, tagging methods, and transplant date and location; and
    f. A summary of any injuries and dead or obviously unhealthy/dying abalone

observed and/or collected in the field and in the captive facility and the ultimate disposition of those animals.

Conditions related to transplanting and monitoring activities

1. The Permit Holder must submit a transplantation plan to NMFS prior to conducting transplant activities. Required elements of the transplantation plan include:
    a. The site(s) and date(s) when transplant activities will occur;
    b. Names of participants and their roles;
    c. A description of the site(s), including a summary of information on black abalone, other abalone species, habitat quality, and any habitat preparation activities conducted at the site;
    d. A summary of the black abalone to be transplanted, including the number of black abalone, size distribution, donor site(s), captive holding facility(ies), and tag type/numbers;
    e. A description of how the abalone will be transported; and
    f. A description of transplant methods.
2. The Permit Holder must submit a report to NMFS no more than 90 days following the transplant activities. Required elements of the collection report include:
    a. Dates and location(s) of transplant activities;
    b. Names of participants and their roles;
    c. A summary of the transplant activities, the effects on the transplanted abalone and any abalone already present at the site(s), and any deviations from the transplantation plan; and
    d. A description of planned post-transplant monitoring activities and a summary of results to date.

2. ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species or to adversely modify or destroy their designated critical habitat. Agency action includes actions authorized, funded, or carried out by the agency, in whole or in part. 50 CFR 402.02. Per the requirements of the ESA, Federal action agencies consult with NMFS, and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provide an opinion stating how the agency's actions would affect listed species and their critical habitats. Section 7(b)(4) requires that when an action agency has complied with section 7(a)(2), NMFS will provide an ITS that specifies the impact of any incidental taking of endangered species and provide reasonable and prudent measures (RPMs) to minimize such impacts and terms and conditions to implement the RPMs.

NMFS determined that the proposed action (scientific research and enhancement activities under two NMFS-issued permits, Permit 26342 and Permit 26606) is likely to adversely affect endangered black abalone and designated black abalone critical habitat. This opinion analyzes the effects of the proposed action on black abalone and designated black abalone critical habitat.

NMFS also determined that the proposed action may affect but is not likely to adversely affect white abalone (*Haliotis sorenseni*). Our analysis is documented in the "Not Likely to Adversely Affect" Determinations section (Section 2.12).

2.1. Analytical Approach

This biological opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (50 CFR 402.02).

The designation(s) of critical habitat for black abalone use(s) the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the critical habitat regulations (50 CFR 424.12) replaced this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of

whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their critical habitat using an exposure–response approach.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species; or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative to the proposed action.

2.2. Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each listed species that is likely to be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' "reproduction, numbers, or distribution" for the jeopardy analysis. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the function of the PBFs that are essential for the conservation of the species.

Two factors affecting the rangewide status of black abalone and its critical habitat are climate change and ocean acidification. Climate change effects may increase susceptibility to disease, reduce kelp growth, and alter the distribution of rocky intertidal habitat along the coast. Ocean acidification can affect reproduction, development, growth, and survival of black abalone, as well as the growth of important algal species. In the sections below, we discuss the potential effects of climate change and ocean acidification in more detail.

2.2.1. Rangewide status of black abalone

Black abalone were listed as endangered under the ESA in 2009 (74 FR 1937, 14 January 2009). Black abalone are marine snails with one shell and a large muscular foot used for movement as well as to hold tightly onto hard substrates to avoid being dislodged by wave action (Cox 1960). Black abalone occupy rocky habitats from the upper intertidal to six meters depth. Historically, black abalone occurred from Crescent City (Del Norte County, California) to southern Baja California (Geiger 2004), but the current range is from Point Arena, California, to Bahía Tortugas, Mexico (74 FR 1937, 14 January 2009). Black abalone 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 (Leighton 1959, 2005; Cox 1960; Leighton and Boolotian 1963; Douros 1985, 1987; Miller and Lawrenz-Miller 1993; VanBlaricom et al. 1993; Haaker et al. 1995). They are able to withstand extreme variations in temperature, salinity, moisture, and wave action, and are usually strongly aggregated, with some individuals stacking two or three on top of each other (Cox 1960; Leighton 2005).

Abalone are broadcast spawners, meaning individuals release their gametes into the water column and rely on external fertilization. Thus, abalone must be in close enough proximity to one another to successfully reproduce. Abalone have a short planktonic larval stage (about 3-10 days) before settlement and metamorphosis (McShane 1992). Larval black abalone are believed to settle on rocky substrate with crustose coralline algae, which serves as a food source for post-metamorphic juveniles, along with microbial and diatom films (Leighton 1959; Leighton and Boolotian 1963; Bergen 1971). Black abalone reach reproductive maturity at a size of about 50 mm shell length in females and about 40 mm in males (Leighton 1959; Ault 1985). Spawning has not been observed in the wild, but likely occurs from spring to early autumn (Leighton 1959, 2005; Leighton and Boolotian 1963; Webber and Giese 1969) and may extend into winter months (VanBlaricom et al. 2009).

2.2.1.1 Population Trends

Based on fisheries and long-term monitoring data since the 1970s, black abalone are believed to be naturally rare at the northern (north of San Francisco) (Morris et al. 1980) and southern (south of Punta Eugenia; P. Raimondi, pers. comm., cited in VanBlaricom et al. 2009) extremes of the species' range. Areas of highest abundance occurred 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 baseline against which 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 the elimination of subsistence harvests by indigenous peoples and large reductions in sea otter populations. Thus, our understanding of black abalone abundance and distribution for this time period may not accurately represent conditions prior to commercial and recreational harvest of black abalone in California.

Beginning in the mid-1980s through the 1990s, black abalone populations declined dramatically due to the spread of withering syndrome (Tissot 1995), a disease caused by a pathogen that

affects the animal's digestion and causes starvation leading to foot muscle atrophy, lethargy, and death (Friedman and Finley 2003; Braid et al. 2005). Withering syndrome results in rapid (within a few weeks) and massive (reductions of over 80%) mortalities in affected populations (Neuman et al. 2010a). Overall, populations throughout southern California and as far north as Cayucos declined in abundance by more than 80%; populations south of Point Conception declined by more than 90% (Neuman et al. 2010a). Commercial and recreational harvest of black abalone contributed to some degree, but the primary cause of these declines was withering syndrome. The disease has also affected populations in Baja California, but little is known about the species' status in Mexico.

Populations north of Cayucos have not yet exhibited signs of the disease, but all are likely infected by the pathogen. Abalone may be exposed to and infected by the pathogen without showing symptoms; however, once symptoms develop, the animals rapidly succumb to death (Friedman et al. 1997a, 2000, 2002). The pathogen has been detected in all coastal marine waters off southern California to Sonoma County and at Southeast Farallon Island (Moore et al. 2002; Friedman and Finley 2003) (pers. comm. with Jim Moore, CDFW, 20 November 2015; pers. comm. with Jim Moore, CDFW, cited in VanBlaricom et al. 2009).

Most populations affected by disease-related mass mortalities remain at low densities and are below the estimated levels needed to support successful reproduction and recruitment (e.g., 0.34 abalone per m^2) (Neuman et al. 2010b). Sites north of Cayucos have not yet experienced disease-related mass mortalities and have densities greater than this threshold value (1.1 to 10.5 abalone per m^2), whereas sites south of Cayucos that have experienced disease-related mass mortalities have densities below this threshold (0 to 0.5 abalone per m^2) (Neuman et al. 2010b).

Despite these low densities, researchers have observed evidence of recent recruitment and increases in abundance at several locations throughout southern California, including the Palos Verdes Peninsula, Laguna Beach, Santa Cruz Island, San Miguel Island, and San Nicolas Island (Richards and Whitaker 2012; Eckdahl 2015; Kenner 2021). These observations for black abalone, and similar observations for other California abalone species, indicate that we need to consider additional factors when assessing population viability. Recent studies also indicate the potential for disease resistance in wild black abalone populations. A bacteriophage has been discovered that infects the pathogen, reduces its lethal effects, and improves the survival of infected abalone (Crosson et al. 2012; Friedman and Crosson 2012; Friedman et al. 2014). Genetically-based disease resistance may also exist and is the subject of ongoing studies at the University of Washington (VanBlaricom et al. 2009).

2.2.1.2 Other Range-wide Threats

Illegal harvest of black abalone is an ongoing threat, particularly because of the relative accessibility of black abalone compared to other abalone species, but the relative effect on the species' status and recovery is poorly understood and requires further evaluation. In 2020, CDFW and researchers throughout the California coast noted an increase in the number of people visiting the rocky intertidal and harvesting or temporarily removing invertebrates, most likely due to the economic and social effects of the COVID-19 pandemic (unpublished observations by John Ugoretz, CDFW, Multi-Agency Rocky Intertidal Network (MARINe) meeting, 3 October 2020). This increase in human use activities poses a direct threat to black

abalone because of the potential increase in illegal harvest as well as trampling of intertidal habitats. The increased harvest activities may also indirectly affect black abalone by altering the intertidal invertebrate community.

Elevated water temperatures resulting from local discharges, warm water events, and climate change could exacerbate disease effects on black abalone. Disease transmission and manifestation is intensified when local sea surface temperatures increase by as little as 2.5 ºC above ambient levels and remain elevated over a prolonged period of time (i.e., a few months or more) (Friedman et al. 1997b; Raimondi et al. 2002; Harley and Rogers-Bennett 2004; Vilchis et al. 2005). The disease appears to progress northward along the coast with increasing coastal warming and El Niño events (Tissot 1995; Altstatt et al. 1996; Raimondi et al. 2002), and poses a continued threat to the remaining healthy populations. In 2015-2016, researchers observed increased numbers of diseased individuals at the long-term monitoring sites, likely due to warmer water conditions (pers. comm. with Karah Ammann, UCSC, on 8 March 2016). It is not yet known how elevated water temperatures may affect the bacteriophage and genetic resistance.

Climate change and ocean acidification may also have range-wide effects on black abalone. In addition to increasing susceptibility to disease, warming ocean temperatures could reduce the growth of macroalgae (an important food source) and shift the distribution of black abalone if temperatures in the southern part of the range increase above the optimal range. Sea level rise could alter the distribution and availability of rocky intertidal habitat. Black abalone may be able to adapt to changes in their habitat conditions, depending on the timeframe over which these changes occur, but some populations and habitats may be lost.

Ocean acidification could hinder normal growth, development, and survival of black abalone by altering pH levels, carbonate availability, and the growth of crustose coralline algae (Crim et al. 2011). Studies on other abalone species indicate varying effects depending on the species, life stage, the degree to which pH levels decrease, and the presence of other stressors. Potential effects of ocean acidification on black abalone include reduced reproduction, abundance, and recruitment. Studies specific to black abalone are needed to evaluate effects on different life stages and under multiple stressors.

Sedimentation events have also emerged as an important threat to black abalone and their habitat, because they can result in direct burial and mortality. The 2017 Mud Creek landslide resulted in the burial of approximately 518 linear meters (1,700 linear feet) of shoreline and an estimated two acres of rocky intertidal habitat, as well as the loss of an unknown number of black abalone within that habitat. In August 2020, severe wildfires burned along the central California coast, followed by an atmospheric river rain event in January 2021, resulting in massive debris flows that buried large expanses of rocky intertidal habitat and black abalone. In response to both events, UCSC coordinated with NMFS, CDFW, and the Monterey Bay National Marine Sanctuary (MBNMS) to rescue and relocate black abalone within affected areas Researchers continue to evaluate the effects of these events on black abalone at the population and species level, as well as monitor how the affected populations recover. Climate change may increase the frequency, severity, and extent of wildfires and subsequent effects on nearshore habitats and communities, including black abalone and their habitat.

Oil spills and spill response activities also pose a threat to black abalone and their habitat. The severity of effects depends on the location, size, and scope of the spill. In the past ten years, two oil spills have occurred along the California coast: the 2015 Refugio Beach Oil Spill (Santa Barbara County) (Refugio Beach Oil Spill Trustees 2021) and the October 2021 oil spill off Orange County (Southern California Spill Response 2021). Response efforts included deployment of booms and berms to protect sensitive habitats, surveys to assess impacts to shoreline and subtidal habitats, and clean-up activities. We discuss the effects of the Refugio Beach Oil Spill on black abalone and their habitat in Section 2.4 (Environmental Baseline). For the 2021 Orange County oil spill, assessments are ongoing and include evaluating effects on black abalone and their habitat within the affected areas.

2.2.1.3 Overall Status and Recovery needs

Black abalone face high risk in each of four demographic risk criteria: abundance, growth and productivity, spatial structure and connectivity, and diversity (VanBlaricom et al. 2009). Although we know withering syndrome has affected populations in Baja California, little information exists regarding the species' status in that portion of the range. Long-term monitoring in California indicates that populations affected by disease-related mass mortalities remain at low abundance and density. The declines in abundance have potentially resulted in a loss of genetic diversity, though this remains to be evaluated. Some sites in southern California have shown evidence of recruitment; however, natural recovery of severely-reduced populations will likely be a slow process. Illegal harvest is a concern, particularly in areas with relatively easy public access. Withering syndrome and other diseases continue to pose a threat to the remaining healthy populations (Raimondi et al. 2002; NMFS 2020). Elevated water temperatures and ocean acidification are range-wide threats that have the potential to exacerbate disease effects, reduce habitat quality and availability, and reduce the survival, growth, and development of black abalone. In addition, emergency events such as oil spills, landslides, and debris flows can affect large stretches of coast and result in the loss of populations.

Recovering the species will involve protecting the remaining healthy populations and increasing the abundance and density of populations that have declined, while also finding practical ways to address ongoing and emerging threats. Continued long-term monitoring will be critical to track and evaluate the species' status and the progression of withering syndrome along the coast. We must also raise the public's awareness, improve enforcement, and develop recovery tools such as those addressed in the proposed permits: habitat preparation, transplanting, and captive propagation and outplanting. In addition, emergency response activities such as those addressed by Permit 26342 will protect and preserve at-risk black abalone and provide an opportunity to enhance or re-establish populations. Lessons learned from rescue and relocation efforts can also help refine transplanting and outplanting protocols for future transplantation efforts.

NMFS issued a Final ESA Recovery Plan for Black Abalone (NMFS 2020) to guide the implementation of priority recovery actions. Recovery actions identified in the plan include long-term monitoring, population and habitat preparation, disease research and management plans, emergency response planning, coordination with Mexico, and outreach and education. NMFS has appointed a recovery implementation team to coordinate and facilitate on-the-ground recovery efforts for black abalone. These actions are expected to enhance the propagation and survival of the affected species and will advance recovery for black abalone. The proposed

issuance of Permit 26342 and Permit 26606 would address priority recovery actions for population and habitat restoration and emergency response planning.

2.2.2. Rangewide status of designated black abalone critical habitat

NMFS designated black abalone critical habitat on October 27, 2011 (76 FR 66806). The designation encompasses rocky intertidal and subtidal habitat (to a depth of 6m) within five segments of the California coast between Del Mar Landing Ecological Reserve to the Palos Verdes Peninsula, as well as on the Farallon Islands, Año Nuevo Island, San Miguel Island, Santa Rosa Island, Santa Cruz Island, Anacapa Island, Santa Barbara Island, and Santa Catalina Island. Essential habitat features include rocky substrate (e.g., rocky benches formed from consolidated rock or large boulders that provide complex crevice habitat); food resources (e.g., bacterial and diatom films, crustose coralline algae, and detrital 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.

Critical habitat areas north of Cayucos (where black abalone have not experienced disease-related mass mortalities) were generally identified as areas of high conservation value. These areas serve as a refuge from withering syndrome, support stable populations with evidence of recruitment in some areas, and contain habitat of good to excellent quality that is able to support larger numbers of black abalone. South of Cayucos (where black abalone have experienced disease-related mass mortalities), changes to critical habitat features have occurred. For example, at some sites once dominated by black abalone, the decline in numbers has resulted in a shift in the invertebrate and algal community. Increased growth of encrusting organisms like Phragmatopoma tube worms may reduce habitat suitability for adults (e.g., by filling in cracks and crevices) and for larval settlement (e.g., by reducing the surface area for crustose coralline algae to grow) (Toonen and Pawlik 1994; Miner et al. 2006; VanBlaricom et al. 2009; NMFS 2011). In general, however, these critical habitat areas continue to provide a high conservation value to the species, because they contain habitat of good to excellent quality that is able to support black abalone, with evidence of recruitment observed at a few sites (e.g., on San Nicolas Island and Santa Cruz Island) (VanBlaricom et al. 2009).

Climate change and ocean acidification may have range-wide effects on black abalone critical habitat. As discussed above, elevated water temperatures associated with climate change may reduce the quantity and quality of food resources (macroalgae) and shift water temperatures above the optimal range for black abalone, affecting the survival, health, and growth of abalone. Sea level rise could result in the loss of rocky intertidal habitat, shifting populations to subtidal conditions. Ocean acidification is predicted to reduce pH levels, affecting water quality to support normal growth and development of black abalone as well as the growth of crustose coralline algae to support juvenile settlement (Crim et al. 2011; O'Leary et al. 2017). Changes in pH levels at the local scale may vary and will be important for assessing the effects on black abalone and their critical habitat (Feely et al. 2004, 2008, 2009; Hauri et al. 2009).

2.3. Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02).

For both proposed permits, the action area consists of rocky intertidal habitats within the U.S. portion of the range of black abalone, from Point Arena (Mendocino County) to the U.S./Mexico border and including the Farallon Islands, Año Nuevo Island, and the eight Channel Islands.

2.4. Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02, See "Effects of the Action").

Because the action area overlaps with the species' range throughout California and encompasses the entire critical habitat designation, the description of the status of the species and critical habitat in Section 2.2 of this opinion applies to the action area. In this environmental baseline, we discuss how specific factors and activities have affected black abalone and their critical habitat within the action area. These factors and activities include the effects of ongoing research, past rescue and relocation efforts, and the Refugio Beach Oil Spill.

2.4.1. Effects of Ongoing Research

Ongoing research activities include population monitoring conducted under Permit 18761-2R issued by NMFS to UCSC and captive holding and propagation conducted under Permit 19571-2R issued by NMFS to the SWFSC La Jolla lab.

The Multi-Agency Rocky Intertidal Network (MARINe) and other abalone researchers have been monitoring black abalone throughout the California coast since the mid-1970s as part of long-term monitoring surveys, abalone habitat surveys, and surveys related to projects or unexpected events and circumstances. Prior to the ESA listing in 2009, no ESA permit was required. After the ESA listing, monitoring activities were conducted under Permit 14400 issued by NMFS to the Channel Islands National Park from 2010 to 2016, under Permit 18761 issued by NMFS to UCSC from 2016 to 2020, and under Permit 18761-2R issued by NMFS to UCSC from 2020 to the present.

Researchers monitor black abalone throughout the California coast to evaluate their abundance, density, size frequency, distribution, habitat, and health, using methods similar to those described in the proposed permits. These monitoring activities have resulted in little to no observable disturbance to black abalone and their critical habitat. At a few sites, researchers also tagged black abalone with visual tags and PIT tags attached to the shell with marine epoxy, to track the movements of individuals. Tagging caused minor, temporary stress to the abalone. Researchers have also deployed ARMs at a few sites at the Channel Islands, Point Reyes National Seashore,

and Golden Gate National Recreation Area. Although few black abalone have been observed on the ARMs, these test deployments confirmed that the ARMs can withstand intertidal conditions. Researchers have also collected genetic samples using the swab method, noting minimal disturbance to black abalone, and have collected dead and obviously unhealthy black abalone for further analysis.

Currently, there are 51 black abalone at three captive holding facilities in California: the SWFSC La Jolla lab (21 black abalone), the CDFW Shellfish Health Laboratory (13 black abalone), and the Monterey Bay Aquarium (17 black abalone). Between January 2017 and December 2019, SWFSC researchers conducted several spawning attempts and were able to induce females to release eggs (SWFSC 2021). Researchers will continue to maintain the black abalone in captivity and evaluate methods to improve reproductive conditioning and induce spawning.

Overall, past and ongoing research activities have resulted in minor disturbance to black abalone and their critical habitat. These effects are greatly outweighed by the benefits of the research. Monitoring provides critical information to assess the status and trends of black abalone over time and the effects of different threats, such as disease, landslides, oil spills, and poaching. Captive holding and propagation studies are important to produce black abalone for future laboratory research and outplanting efforts. The Final Recovery Plan highlights long-term monitoring and captive propagation studies as important recovery actions for the species.

2.4.2. Effects of Past Rescue and Relocation Efforts

Two recent rescue and relocation efforts were conducted for black abalone in response to the 2017 Mud Creek Landslide and the 2021 Big Sur debris flows. In both events, sediment had already buried segments of the coast, resulting in the loss of black abalone and their critical habitat, prompting an emergency response to minimize further losses of black abalone.

In May 2017, the Mud Creek landslide buried about 1,700 linear feet (518 linear meters) of rocky intertidal habitat along the Big Sur coastline in Monterey County, California (Caltrans 2021). Prior to the slide, the area was not accessible for monitoring. Thus, data are not available to estimate the number of black abalone lost due to burial by the landslide. Based on surveys of adjacent areas, the area buried by the landslide likely included good quality habitat that supported healthy black abalone populations. Following the initial landslide, wave action and nearshore ocean currents caused continued erosion and movement of slide materials, resulting in burial of adjacent habitats (Caltrans 2021). In November 2017, a team led by Caltrans and UCSC rescued 45 black abalone within an area at-risk of burial adjacent to the landslide (Caltrans 2021). The abalone were held overnight at The Abalone Farm in Cayucos, where they were measured, weighed, photographed, assessed for injuries, and genetically sampled by collecting an epipodial clip. Five were sacrificed and preserved for necropsy due to severely shrunken feet indicative of withering syndrome (n=2) or severe injuries sustained during collection (n=3). Nine were less severely injured and transported to the SWFSC La Jolla lab for rehabilitation and long-term holding. The remaining 31 abalone were tagged and released at the selected relocation site. Post-release monitoring through November 2019 recorded five confirmed mortalities based on collection of empty tagged shells (Bell and Raimondi 2020).

In August 2020, severe wildfires burned along the central California coast, followed by an atmospheric river rain event in January 2021, resulting in massive debris flows that buried large expanses of rocky intertidal habitat and black abalone populations. In response, UCSC coordinated with NMFS, CDFW, and the MBNMS to rescue about 200 black abalone within affected areas of the coast. The black abalone were held for several months at the CDFW-OSPR facility. Several died while in captivity, likely due to injuries sustained during the emergency event as well as during collection. In April and July 2021, all of the rescued black abalone (n=165) were released at selected relocation sites. Post-release monitoring is ongoing, as well as efforts to estimate the loss of black abalone and critical habitat due to the debris flow event.

2.4.3. Effects of the Refugio Beach Oil Spill

In 2015, the Refugio Beach Oil Spill in Santa Barbara County impacted approximately 1,500 acres of shoreline habitat, including rocky intertidal and sandy beach habitat (Refugio Beach Oil Spill Trustees 2021). Three black abalone were found within the affected area (pers. comm. with Jack Engle, UCSB, and Pete Raimondi, UCSC, on June 5-6, 2015). The Damage Assessment and Restoration Plan includes support for transplantation efforts to restore black abalone populations and thus restore the rocky intertidal habitat within the impacted area (Refugio Beach Oil Spill Trustees 2021). This transplantation effort is the subject of the proposed Permit 26606.

2.5. Effects of the Action

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

We use the "exposure-response-risk" approach throughout the below subsections to analyze the effects of the proposed research and enhancement activities on black abalone and its critical habitat. This approach involves first evaluating the exposure of individual black abalone and critical habitat to the effects of the action. Next, we evaluate how individual black abalone and critical habitat are likely to respond to those effects. We then evaluate how those responses would be expected to reduce an individual's fitness (i.e., growth, survival, annual reproductive success, and lifetime reproductive success) or the conservation value of those critical habitat areas. Finally, we evaluate the risk to black abalone at the individual, population, and species level, to evaluate whether the proposed action could appreciably reduce the species' likelihood of surviving and recovering in the wild. We also evaluate the risk posed to critical habitat to evaluate whether the proposed action could appreciably reduce the conservation value of critical habitat.

2.5.1. Effects of the Action on Black Abalone Critical Habitat

Monitoring activities, habitat preparation (removal of fouling organisms), and deployment of ARMs under the proposed permits would occur within black abalone critical habitat and may affect rocky substrates and juvenile settlement habitat. We expect the potential effects to critical habitat to be minor.

Researchers will use non-destructive search methods to survey abalone and will minimize trampling effects, for example, by avoiding stepping on sensitive species. Monitoring activities will be limited to a few days each year per site, with the frequency of monitoring decreasing over time.

Habitat preparation will involve removing fouling organisms within selected cracks and crevices, affecting a small area within each site (cracks and crevices are approximately 1-5 m in length and 0.5-1m in depth). We expect the removal of fouling organisms to enhance juvenile settlement habitat by creating surface area for crustose coralline algae to grow. It is also possible that the fouling organisms that are removed will quickly re-colonize the cracks and crevices, making the effects temporary and short-lived.

Installation of recruitment modules will affect rocky substrate, but we expect the effects to be minor and affect a small area (approximately 15 cm by 15 cm surface area per module). Effects will also be temporary because all modules will be removed at the end of the studies. Mounting materials (epoxy, screws, anchors) may be left in place, but would affect small areas of rocky substrate (a few square cm) and would not reduce the habitat value or function for black abalone. To minimize the risk of spreading non-native species, the permit will require researchers to remove any non-native species and unnecessary native species (e.g., other snails or invertebrates not used by black abalone for habitat, camouflage, or food) from the ARMs before moving them from one site to another.

We conclude that the proposed research and enhancement activities are not likely to destroy or adversely modify designated black abalone critical habitat.

2.5.2. Effects of Research and Enhancement Activities on Black Abalone

In the following subsections, we describe the types of activities that would be authorized by issuance of the permits. We describe each type of activity broadly enough to apply to both permits. In the next section (Section 2.5.3, Permit-specific Effects on Black Abalone), we identify the specific activities proposed under each permit, describe details about how the activities will be carried out, and analyze the effects of the proposed activities on black abalone.

Trained professionals will carry out the activities using established protocols, the use of which will be required in the permits. We document and discuss the effects of the activities in detail below. No researcher would receive a permit unless the activities incorporate NMFS's measures to minimize adverse effects on the species and its habitat. We describe these measures in Section 1.3.3 (Permit Conditions) of this Opinion and have incorporated these measures (where relevant) into every permit as part of the conditions to which a researcher must adhere.

2.5.2.1 Monitoring

Researchers will use non-destructive survey methods (i.e., rocks are not turned over or broken apart) to monitor black abalone at the field sites. Monitoring activities include counting and measuring the shell length of individual abalone. Data on the number and size of abalone at a site are important to estimate abundance, density, and size frequency, as well as to evaluate growth,

survival, and recruitment (e.g., based on the presence of small abalone). Researchers may visually search for abalone, as well as reach into crevices and under rocks to feel for abalone that cannot be seen. As much as possible, researchers will avoid touching living tissues, such as the mantle, and will limit any contact with the shell or mantle to a few seconds. Researchers will not remove abalone from the substrate during monitoring activities.

We expect abalone to respond by temporarily clamping down more tightly to the substrate. Rarely, an abalone may become more active and move, which could expose it to greater risk by predators. More often, this results in the abalone seeking shelter and better protection. We expect these activities to cause minor stress, but not to harm, injure, or kill individual abalone. The effects on individual abalone would be similar to that of another organism (e.g., another abalone, drift macroalgae) touching it. Overall, we expect observing, counting, and measuring abalone to result in minor, temporary stress to individuals, with little to no long-term effects.

There is the possibility that researchers may step on an abalone during monitoring activities and may kill, injure, or cause the abalone to clamp down more tightly to the substrate, depending on the amount of pressure exerted on the individual. The likelihood of stepping on a black abalone is very low and the likelihood of death as a result is even lower. Abalone are generally found in crevices and researchers generally wear soft shoes and are very careful where they step on the reef. Thus, we consider it very unlikely for researchers to step on black abalone when conducting monitoring activities.

2.5.2.2 Collection

Live black abalone may be collected for rescue/relocation or transplanting. Researchers will identify abalone that are easily accessible (i.e., not deep in a crack or crevice) and can be collected without injury. Researchers will follow best practices for collection (NMFS 2008, 2015, 2021), such as using abalone irons or other instruments with a blunt edge and thin profile and only inserting these instruments on the posterior end or sides (avoiding the head) of the abalone. If an abalone clamps down and cannot be removed on the first attempt, researchers will wait for the abalone to relax before attempting again. To minimize injuries, only experienced personnel will be allowed to collect abalone.

Even with these measures, abalone may be injured during collection activities and some may die if the injuries are severe. For example, from 2016 to 2019, thirteen white abalone were collected from the wild to serve as broodstock for the captive propagation program (under ESA Permit 14344-2R issued to the UCD-BML). Two of the collected white abalone (15%) died within six months of collection. In 2017, 45 black abalone were rescued in response to the Mud Creek Landslide; of those, 13 (29%) were severely injured and seven (16%) died as a result of those injuries (Bell and Raimondi 2020). In 2021, about 22% of the black abalone rescued from the Big Sur debris flows died following collection and captive holding; the higher rate of mortality was likely due to a combination of injuries from the debris flow and from collection (pers. comm. with Wendy Bragg, UCSC, August 29, 2021). However, most or all of these animals would likely have died if not for the rescue efforts, so we expect rescue activities to increase the survival of black abalone following emergency events.

2.5.2.3 Transport

Transport involves different methods depending on the black abalone life stage. For embryos and larvae, transport involves placing the abalone in seawater-filled containers in a cooler. For juveniles and adults, transport involves removing the abalone from the substrate and placing them in coolers with kelp or seawater soaked towels to keep the abalone moist. Coolers will be transported via air, vehicle, and/or vessel. The abalone will be out of the water for several hours (less than 24 hours). Researchers will minimize stress, injury, and mortality to the animals by implementing the best practices described in established transport protocols (NMFS 2008, 2015, 2021) and required under the permits. These best practices include maintaining adequate oxygen levels and appropriate temperatures throughout transport, within two degrees of temperatures at the original site/captive facility.

Researchers have successfully transported adult black abalone between facilities using these established methods. Twelve black abalone were successfully transferred from UCSB to the Navy's SSC Pacific facility in 2013 and then to the SWFSC in 2014. Two died while at the SSC Pacific facility (Lapota 2015) and two died at the SWFSC La Jolla lab (pers. comm. with Paula Sylvia, SWFSC, on April 4, 2015), most likely due to health issues rather than the effects of transport. In 2016, an additional eight black abalone were transferred from UCSB to the SWFSC Lab with no mortalities. In the 2017 Mud Creek Landslide response, nine of the rescued black abalone were severely injured and transported to the SWFSC Lab for rehabilitation; three died due to injuries sustained during collection (Bell and Raimondi 2020).

Researchers have also successfully transported abalone eggs, larvae, and juveniles using established methods. Researchers in the white abalone captive breeding program (covered under Permit 14344-2R issued to the UCD-BML) routinely transport fertilized eggs, larvae, and juveniles between facilities by vehicle and by air. Injuries and mortality associated with transport activities appear to be low. For example, in 2015, researchers transported 200 juvenile white abalone in coolers by vehicle from UCD-BML to several southern California facilities, with only two mortalities reported within two months of transport (pers. comm. with Kristin Aquilino, UCD-BML, on September 8, 2015; with John Hyde, SWFSC, on December 29, 2015; and with Kiersten Darrow, Cabrillo Marine Aquarium, on January 3, 2016).

Overall, we expect abalone to experience minor, temporary stress from transport activities. Based on the implementation of established protocols and best practices and the above information from previous transport activities, we expect injuries and mortality associated with transport activities to be limited to a few individuals.

2.5.2.4 Captive Holding

Abalone will be held in land-based facilities and handled on a regular basis to measure, weigh, and assess their health and gonad condition. Researchers will optimize holding conditions and implement best practices for general health and husbandry, such as maintaining water quality, water temperature, regular feeding, and regular tank cleaning (NMFS 2021).

We expect removal and handling to cause minor, temporary stress to individual black abalone. Removal from the substrate also has the potential to cause minor injuries (e.g., cuts to the foot

muscle). Researchers will implement measures to minimize stress and injury. First, researchers will limit the number of times abalone are removed and handled to the minimum necessary to assess their health and condition. As much as possible, all assessments will be conducted at the same time to reduce the frequency of handling. Second, researchers will minimize injury by carefully removing abalone from the holding tanks by hand or by using a plastic spatula and/or abalone iron. When needed, researchers may use anesthesia (see Section 2.5.2.6 Anesthetics) to sedate the abalone prior to removal. Finally, researchers will limit the time out of water and minimize contact with soft tissues as much as possible.

2.5.2.5 Tagging

Several methods may be used to tag abalone, including shell notching, colored glue dots or numbered/colored tags attached to the shell, and Passive Integrated Transponder (PIT) tags. Individual abalone may be tagged using one or more of these methods, to account for tag loss and/or malfunction (e.g., of PIT tags).

Shell notching requires using a rotary tool to cut a notch (1mm thick by 2-4 mm deep) into the growing edge of the shell. The procedure should take less than 10 minutes. Shell notching is essentially permanent because the notch can be felt even as the shell grows additional layers. For abalone in crevices, a notch in the shell can be felt by researchers, whereas visual and PIT tags may not be seen, read, or detected.

External tags attached to the shell include colored dots, numbered/colored tags (e.g., Floy tags), and PIT tags. Colored dots are simply dots of glue (e.g., Coraffix) mixed with colored powder and applied to the shell. Numbered/colored tags and PIT tags will be attached to the shell with adhesive (e.g., Coraffix). Numbered/colored tags are typically small, flat plastic tags with a unique color and number. These tags are small compared to the size of the shell and smaller than the size of organisms (e.g., barnacles, tubeworms) that typically grow on the shell of wild abalone. To attach, researchers clean and dry a small section of shell before applying the tag with glue. PIT tags are also glued to the shell, but typically to the underside of the shell just below where the mantle covers the shell surface. This placement facilitates nacre deposition over the PIT tag, to more permanently attach the tag to the shell.

Shell notching was used to mark rescued black abalone prior to relocation for the Mud Creek and 2021 Big Sur debris flow events; researchers did not observe injuries or long-term negative effects on the abalone's health (Bell and Raimondi 2020) (pers. comm. with Wendy Bragg, UCSC, August 29, 2021). External tags attached to the shell have also been used in the lab and in the field with minimal effects on abalone (Hale et al. 2012; Richards and Whitaker 2012). We expect tagging activities to cause minor, temporary stress to individual abalone due to being handled and kept out of the water for a short time. To minimize stress, researchers will keep the animals moist by placing them on a wet towel and limiting the time out of the water (e.g., to a few minutes). Researchers will avoid injuring the soft tissue of the abalone, particularly when shell notching. If multiple tagging methods will be used, researchers will conduct all tagging at the same time to minimize the frequency of handling.

2.5.2.6 Anesthetics

Several anesthetics are commonly used in abalone culture and research to reduce the risk of injury when removing abalone from the substrate. The most commonly used are those that produce the lowest mortality, are easy to acquire, and are economically viable: carbon dioxide, ethanol, magnesium sulfate, and phenoxyethanol. The effectiveness of anesthetics varies with temperature and is typically much slower at lower temperatures (White 1995). In general, the use of anesthetics over mechanical removal results in fewer injuries to abalone; however, use of anesthetics could also result in greater, measurable physiological effects than mechanical removal (Edwards et al. 2000; Chacon et al. 2003; Hooper et al. 2011, 2014).

We expect abalone to experience minor, temporary stress due to exposure to anesthetics, with no long-term adverse effects on individuals. To minimize stress to the abalone, the following maximum concentrations and exposure times have been identified for each anesthetic, based on studies using other abalone species (Table 1). We summarize the studies below. If studies involving black abalone have not yet been conducted (e.g., for CO_2, $MgSO_4$, and Phenoxyethanol), the use of these anesthetics should be tested with a small number of black abalone, starting with the lowest concentration and exposure times and increased up to the maximums listed in Table 1, as needed. Abalone should be closely monitored through the studies.

Table 1. Maximum concentrations and exposure times for anesthetics for use on ESA-listed abalone, based on studies involving other abalone species.

Anesthetic	Maximum concentration	Maximum exposure time
Carbon dioxide (11.3% CO_2, 88.7% O_2)	Flow rate of 12L/min	10 minutes
Ethanol (non-denatured)	3% (30 mL/L)	10 minutes
Epsom salt ($MgSO_4$)	22% (220 g/L)	10 minutes
Phenoxyethanol	1% (10ml/L)	5 minutes

Carbon dioxide is a commonly used, effective, and safe method of anesthesia for abalone but is less used than other methods in commercial abalone culture due to the cost and volume of CO_2 gas mix needed. White et al. (1996) provides dosages, rate of anesthesia, and rate of recovery for size classes up to 90 mm of *Haliotis midae,* known commonly as the South African abalone or the perlemoen abalone, using a gas mixture of 11.3% CO_2 and 88.7% O_2. For the three size classes (5-15mm, 20-50mm, 60-90mm) the dosages of 4L/min, 4L/min, and 12L/min, respectively, were the most effective doses for sedation in 3-5 min at 18°C with no observed mortality. White (1995) showed a strong effect of temperature on response to anesthesia with CO_2, likely due to changes in metabolic rate. Although the White (1995) and White et al. (1996) studies did not specifically address the effects of CO_2 on black abalone, the concentrations given here should be used primarily as a guide for species other than South African abalone, which may be adapted to and held at different temperatures than those presented by White (1995) and White et al. (1996). No specific studies have been done using CO_2 on black abalone.

Ethanol is a commonly used anesthetic for invertebrates including abalone (Edwards et al. 2000; Gilbertson and Wyatt 2016; Hsu and Gwo 2017; Aprilia et al. 2018). Edwards et al. (2000) found that 3% ethanol was an effective anesthetic for *H. laevigata* and *H. rubra* at 17°C and that

it lowered VO_2 for the first hour after sedation. Aprilia et al. (2018) tested 1, 2, and 3% ethanol solutions on 15-25 mm *H. squamata* and found higher concentrations of ethanol sedated animals faster, but the highest concentration (3%) resulted in a significantly higher mortality than was observed for 1% and 2% solutions. Ethanol (non-denatured) mixed with seawater has been routinely used at the SWFSC and BML to sedate juvenile abalone of several species (red, white green, pink, and black abalone) and has proven a safe and effective method for these species. Solutions of 1%, 2% and 3% ethanol in seawater are sufficient to sedate abalone ranging in size from 5-25 mm, 25-90 mm, and >90 mm, respectively, within 4-10 minutes with no observable mortality (J. Hyde, SWFSC, and K. Aquilino, UCD-BML, unpublished data).

Magnesium salts, both $MgSO_4$ and $MgCl_2$, act similarly and are common anesthetics for invertebrates and used widely in abalone culture. Magnesium sulfate (Epsom salt) is the more commonly used of the two given its availability, low cost, and effectiveness. White et al. (1996) provide dosages, rate of anesthesia, and rate of recovery for size classes up to 90 mm of *H. midae*. For the three size classes (5-15 mm, 20-50 mm, 60-90 mm), dosages of 4% ,14%, and 22%, respectively, were the most effective doses for sedation within 5-8 min at 18°C with no observed mortality. White (1995) showed a strong effect of temperature on response to anesthesia with $MgSO_4$, likely due to changes in metabolic rate. As such, the concentrations given here should be used primarily as a guide for other species which may be adapted to and held at different temperatures than those presented by White (1995) and White et al. (1996). No specific studies have been done using $MgSO_4$ on black abalone.

Phenoxyethanol is a commonly used anesthetic for fish and invertebrates, including for cultured abalone. Though most studies using this anesthetic have shown no mortality in abalone (White et al. 1996; Edwards et al. 2000; Chacon et al. 2003; Mercer et al. 2014), evidence suggests phenoxyethanol is not suitable for long-term use (White 1995). Abalone can develop tolerance after repeated use, which may result in mortality, likely due to overdose from the high dosage eventually required to sedate the abalone. Otherwise, phenoxyethanol is an effective and apparently safe anesthetic when used on naïve abalone. Chacon et al. (2003) noted that abalone treated with phenoxyethanol exhibited higher VO_2 (1.5 times the control) for up to two hours after treatment, which may explain the faster recovery time for this anesthetic. White et al. (1996) provide dosages, rate of anesthesia, and rate of recovery for size classes up to 90 mm of *H. midae*. Dosages of 0.5%, 2%, and 3% phenoxyethanol were the most effective to sedate *H. midae* ranging in size from 5-15 mm, 20-50 mm, and 60-90 mm, respectively, in 1-2 min at 18°C with no observed mortality. Phenoxyethanol is not very soluble in seawater but if mixed 1:1 with ethanol the solubility is greatly increased (J. Hyde, SWFSC, unpublished data). No specific studies have been done using phenoxyethanol on black abalone.

2.5.2.7 Genetic Sampling

Researchers will use two methods to collect genetic samples that do not require removing the abalone from the substrate. The first method involves taking a small clip of the epipodial tentacles on the sides or posterior of the abalone. Researchers will clip the epipodia no closer than 1-2 mm from the base, to avoid injuring the foot muscle. This method is well-established and has been used to collect epipodial samples from abalone in the field and in captivity, with minimal effects to the abalone (Hamm and Burton 2000; Gruenthal and Burton 2005; Gruenthal et al. 2014; Coates et al. 2014).

Researchers may also obtain genetic samples by swabbing the abalone shell or foot. Researchers will use the tip of a flexible, soft-tipped swab to swab the surface of any exposed soft tissue or the shell, or insert the swab into a respiratory pore. Duplicate swabs may be collected for each abalone. Samples will be placed in vials filled with preservative solution (e.g., 70% or higher concentration of ethanol), if needed, and sent to approved facilities for analysis.

We expect genetic sampling to cause minor, temporary stress to individual abalone. Although the epipodial clipping method involves cutting off a small piece of the tentacle, we expect injuries to be minor and unlikely to cause long-term harm or injury to the abalone, based on routine use of this sampling method on captive abalone throughout the coast (Gruenthal and Burton 2005; Gruenthal et al. 2014; Coates et al. 2014). The benefits of this sampling greatly outweigh the minor effects on individual abalone. For example, the samples can be used to evaluate the genetic diversity of wild populations and track the origin of the sampled abalone (i.e., resident or relocated/transplanted).

2.5.2.8 Fecal Sampling

Researchers may collect fecal samples from abalone to evaluate their health, specifically whether an individual is infected with the CaXC (the pathogen that causes withering syndrome). Fecal samples may be collected by inserting a flexible nylon swab between the epipodium and mantle, along the gills, to collect fecal material near the anus (Neuman et al. 2012). Alternatively, a water sample may be collected from the respiratory pores using a syringe. These sampling methods do not require removing the abalone from the substrate. Both methods have been used to collect fecal samples from abalone in lab and field settings; observable responses include clamping down more tightly to the substrate and moving the shell from side to side (Neuman et al. 2012). Based on these observations, we expect fecal sampling to cause minor, short-term stress, but not to injure or cause long-term harm to the abalone.

2.5.2.9 Health Assessment and Treatment

When bringing abalone into captivity for holding, researchers will visually examine the abalone to assess their health. The three main health concerns for abalone in captivity are: (1) withering syndrome; (2) shell-boring organisms; and (3) parasitic sabellid polychaete worms.

Researchers will regularly assess captive abalone for signs of withering syndrome and quarantine infected abalone as needed, to minimize the spread of infection. If recommended by the CDFW Shellfish Health Lab, abalone will be treated with oxytetracycline (OTC), an antibiotic capable of eliminating the pathogen from infected individuals. OTC treatment will follow the methods described Moore (2015). The treatment involves immersing the abalone in an OTC bath solution. This treatment has been applied to captive abalone throughout California, including black abalone, to successfully remove the pathogen with little negative effects on the abalone (Moore 2015).

Shell-boring organisms can infest and weaken the abalone's shell, leading to shell damage and potentially death. Researchers will apply a wax treatment (Moore and Marshman 2015) to remove heavy infestations of shell-boring organisms. Wax treatment involves removing the

abalone from the substrate, scrubbing the shell surface with a brush, and coating the shell surface with a wax mixture (beeswax and coconut oil), taking care not to cover the respiratory pores. Abalone are then returned to the holding tanks. The wax suffocates and kills the shell-boring organisms and eventually flakes off the shell on its own.

Parasitic sabellid polychaete worms can infest the growing edge of shells and cause shell deformity, slow growth, and brittleness. An eradication program has essentially removed the worms from farms and prevented new infestations. CDFW implements a sabellid-free certification program to monitor captive facilities and certify that animals have not been infested with sabellids. The sabellid-free certification involves regular inspections by CDFW where abalone are removed from the holding tanks and visually inspected for the presence of sabellid worms. Depending on the number of abalone at the facility, all or a subset may be examined. The abalone are out of the water for no more than 30 minutes. The shell waxing treatment may also be used to remove sabellid worms from the shell.

2.5.2.10 Release/Reintroduction to Field Sites

Release/reintroduction involves surveying the field site(s) to: evaluate habitat quality, quantity, and capacity; identify specific cracks and crevices to place the abalone; and record the number of resident black abalone already present within those cracks and crevices. In selecting the site(s) and specific cracks and crevices, researchers will consider the presence of resident black abalone and the availability of space and food resources to support additional black abalone. In some cases, researchers will conduct habitat preparation (e.g., removal of fouling organisms) to prepare the cracks and crevices prior to releasing the black abalone. Researchers will then transport and release the black abalone at the selected sites and conduct post-release monitoring of both the released and resident black abalone.

We expect release/reintroduction of abalone to cause short-term stress to the abalone. To minimize stress and optimize survival, researchers will select cracks and crevices with good quality habitat for black abalone and place each individual black abalone within the pre-selected cracks and crevices, ensuring that the abalone adheres to the substrate. We expect some black abalone to die following release, due to factors such as injuries and predation. In the Mud Creek rescue/relocation effort, a total of 31 black abalone were relocated to a field site; of those, four (13%) confirmed deaths were recorded over about two years of post-release monitoring (Bell and Raimondi 2020). In the 2021 Big Sur debris flow rescue/relocation, about 200 black abalone were relocated to a field site and post-release monitoring during the first two months indicates about 1% mortality based on empty shells found (pers. comm. with Wendy Bragg, UCSC, August 29, 2021). We note that survival and mortality rates are difficult to monitor in the field. An abalone may not be observed again because it moved deep into a crevice or out of the survey area, lost its tag(s), or died. In addition, empty shells may wash away outside of the survey area. Thus, the confirmed mortalities recorded for the Mud Creek and Big Sur rescue/relocation efforts should be considered minimum mortality rates. However, we also expect that the mortality rate associated with rescue and relocation activities is likely much lower than leaving the abalone in place, as most or all of the black abalone would likely have died if not for the rescue effort.

We also expect the release of black abalone to cause short-term stress to resident black abalone already at the field site. For the Mud Creek rescue/relocation effort, researchers observed

movement of the resident abalone, with some leaving the cracks and crevices where rescued black abalone were placed but eventually returning (Bell and Raimondi 2020). The resident abalone may have detected the injuries of the rescued black abalone and moved to avoid predation. Since 2017, black abalone numbers at the Mud Creek relocation site have been stable (Bell and Raimondi 2020).

Several studies have involved the release of abalone (i.e., red, green, and pinto abalone) in the Southern California Bight and the San Juan Islands, Washington. Preliminary results support the importance of appropriate site selection and habitat preparation as measures to improve survival and growth of the released abalone (Hofmeister et al. 2018) (Barilotti et al. unpublished data). The studies also suggest that increases in local abalone densities may not be measurable until several years after the initial release efforts. For example, Washington Department of Fish and Wildlife outplanted juvenile pinto abalone to sites around the San Juan Islands and restocked the sites at least once every three years over a five to eight year period; these efforts resulted in increased adult pinto abalone densities (J. Bouma and M. Ulrich, unpublished data).

2.5.2.11 Habitat preparation

Habitat preparation involves scraping fouling organisms (e.g., sponges, Phragmatopoma sandcastle worms) from cracks and crevices to improve habitat quality for adult abalone and encourage the growth of crustose coralline algae for juvenile recruitment. Black abalone present within the crevices may experience mild stress due to vibrations from scraping. Researchers will minimize disturbance by not scraping the habitat within about 10 cm of any black abalone found within the cracks and crevices. We believe this 10 cm buffer will be sufficient to minimize disturbance by keeping the habitat around each individual intact. To evaluate and confirm that a 10 cm buffer is sufficient, researchers will observe how black abalone respond to habitat preparation activities and report the observations to NMFS in the annual reports.

Removal of fouling organisms will change the habitat and species composition within the selected cracks and crevices. We expect these changes to benefit black abalone. The organisms to be removed are those that have filled in the cracks and crevices following the decline of black abalone. Removing these organisms will provide more space for adult black abalone and the growth of crustose coralline algae, an important component of juvenile settlement habitat.

2.5.2.12 ARMs: Deployment and Transplantation Between Sites

ARMs will be deployed for the purpose of monitoring juveniles as well as outplanting or transplanting juveniles to field sites. ARMs will be made of stacked tiles, cobbles/rocks contained in vexar mesh bags, or stone/concrete blocks contained in vexar mesh. Researchers will deploy the ARMs in and/or adjacent to cracks and crevices and monitor the ARMs on a regular basis for juvenile black abalone (e.g., every 3, 6, or 12 months). At the end of the studies, researchers will remove all ARMs but may leave mounting materials (screws, anchors, epoxy) in place. Researchers will move any black abalone remaining on the ARMs to suitable habitat (e.g., rocky substrate with cracks and crevices to provide protection from predators).

We expect installation of the ARMs to have minor effects on a small area of rocky substrate (approximately 15cm by 15cm surface area per module). The effects on habitat will be

temporary and short-lived, because the ARMs will be removed at the end of the studies. If mounting materials are left in place, the area affected would be small (a few square cm). We also expect installation to disturb black abalone present within the cracks and crevices. To minimize disturbance, researchers will not install ARMs within 10 cm of any abalone.

We expect black abalone to experience mild, temporary stress when monitoring the ARMs. We expect the abalone to respond by clamping down more tightly to the substrate or becoming more active and moving. We also expect black abalone to experience mild, temporary stress when moving abalone from the ARMs to natural substrate at the end of the studies. Some individuals may be injured (i.e., small cuts to foot muscle). To minimize stress and injuries during monitoring, researchers will carefully disassemble and reassemble the ARMs to minimize disturbing and avoid crushing abalone on the ARMs. To minimize stress and injuries when moving abalone from the ARMs, researchers will use plastic spatulas or another instrument with a thin profile and blunt edge to carefully remove the abalone.

We expect black abalone to experience mild, temporary stress when removing, transporting, and installing the ARMs for outplanting or transplanting abalone to field sites. Some black abalone may also be injured during these activities. To minimize stress and injury, researchers will handle the ARMs carefully when removing and installing them. During transport, researchers will wrap the ARMs with seawater soaked towels (to provide moisture and padding) or place them directly into seawater-filled coolers and maintain appropriate temperatures and dissolved oxygen levels. As described above in Section 2.5.2.3 (Transport), we expect mortality to be limited to a small number of abalone.

2.5.2.13 Collection of Empty Shells

Researchers may collect empty shells for further analyses, including evaluating shell length frequency, the presence of tags, mortality rates, signs of predation (e.g., holes bored by octopus), age estimates, isotope composition, or the feasibility of collecting genetic material from shells. Shells may also be used for outreach and education. Shells may not be sold. We do not expect the collection of empty shells to adversely affect abalone populations, because the individuals have already died.

2.5.2.14 Collection of Dead and Obviously Unhealthy Abalone

Researchers may collect dead or obviously unhealthy abalone for further analysis to determine the cause of death and to evaluate population health. Dead or obviously unhealthy abalone may be encountered in the field (e.g., during release and monitoring activities) and in captive holding facilities. The following criteria will be applied to identify dead or obviously unhealthy abalone. “Dead” abalone are those that are not attached to the substrate and unresponsive. “Obviously unhealthy” abalone are those that are (a) noticeably shrunken (i.e., epipodial tentacles do not extend beyond the margin of the shell and can no longer be seen); (b) unable to adhere firmly to the substrate (e.g., the abalone can be dislodged easily from the substrate by hand); and (c) do not actively attempt to right themselves when placed upside down on the substrate. Abalone showing these symptoms are expected to die within days. In captive facilities, reduction or cessation of feeding and extreme lethargy are also signs indicating an abalone may be sick or unhealthy.

We do not expect collection and removal of dead abalone to result in direct or indirect effects on the remaining abalone or their habitat, because the individuals would already be dead. Collection and removal of obviously unhealthy abalone would kill the individual abalone; however, these individuals are expected to die within a few days whether or not they are collected.

Collection of dead and/or obviously unhealthy abalone would allow researchers to conduct necropsies before the tissues deteriorate and provide information about the individual and/or population's health as well as early detection of disease outbreaks. In addition, removal of dead and obviously unhealthy abalone may benefit the remaining abalone by reducing the potential spread of pathogens.

Researchers will follow the procedures described in Moore (2014, 2019) to identify dead and obviously unhealthy abalone and sacrifice/preserve such individuals for analysis. Researchers may freeze whole animals or dissect the relevant tissues (gut and foot muscle) and either freeze the tissues or fix them in formalin before placing in ethanol. Whole specimens, tissues, and parts will be available for analysis at approved facilities. Additional facilities may be added to the list of approved facilities.

2.5.2.15 Spawning and Culturing

Researchers will use standard and modified methods to induce spawning in black abalone. Standard methods include desiccation, thermal treatments, and hydrogen peroxide treatments (Kawana and Aquilino 2020). Adult male and female abalone will be placed in separate containers and undergo a brief desiccation period (1-2 hours) followed by exposure to elevated temperatures and a solution of Tris-buffered seawater and hydrogen peroxide (6% H_2O_2). Once spawning occurs, or after about three hours of exposure to the Tris/H_2O_2 solution, the abalone are removed from the solution and placed in filtered seawater. Researchers will collect any eggs or sperm released and mix them to promote fertilization.

Modified methods will be the same as those being evaluated under Permit 19571-2R (issued to the SWFSC in 2021) and include the use of extended desiccation periods (up to 12 to 18 hours), elevated water temperatures (17-21˚C), simulated seasonal tidal cycles, and hormone treatments. To simulate tidal cycles, researches will vary the water level in holding tanks to create variable periods of submersion similar to what black abalone would experience in their natural intertidal environment. For hormone treatments, the SWFSC has successfully induced the release of eggs from black abalone using the Egg Laying Hormone (ELH) and APGW-amide. Researchers may try other neuropeptide hormones used on abalone (e.g., whitnin, myomodulin, and FMRF-amide) (SWFSC 2021). Researchers will inject the abalone through the foot muscle prior to spawning trials. Different dosage schedules may be used. For example, the SWFSC (2021) used an injection of APGW-amide followed by an injection of both APGW-amide and ELH about 24 hours prior to the spawning trial.

Researchers will follow well-established methods for larval rearing and settlement and juvenile grow-out (Kawana and Aquilino 2020). These methods include passive larval transfers, settlement using GABA as a settlement cue, and early juvenile grow-out on benthic diatom (e.g., Navicula sp.) coated substrates. To determine survival rates through all stages of development,

researchers will collect a sample at each stage to assess initial numbers (e.g., of released eggs, swimming trochophores, developing veligers) and enumerate settled veligers using a microscope. Researchers will also preserve a small number of abalone at each life stage to document early life development.

We expect spawning activities to cause temporary stress to black abalone due to removal from the substrate, handling, and exposure to varying conditions. Removing abalone from the substrate may cause minor cuts to the foot muscle. We do not expect hormone injections to cause injuries, based on trials involving red abalone conducted by the SWFSC (2021). If spawning is successful, we expect natural mortality across the early life stages; for example, natural mortality for captive-raised white abalone can range from 99.5 to 100 percent for the larval to one-year old juvenile stage (unpublished data from K. Aquilino, UCD-BML, January 20, 2016).

Throughout the spawning trials, researchers will closely monitor the abalone for signs of stress. Researchers will minimize stress and injury to individual black abalone by carefully removing abalone by hand or using a flat instrument. Researchers will also minimize handling time and maintain water circulation and proper holding conditions throughout the trials. Researchers will not expose the abalone to conditions outside their natural range for water temperatures, desiccation periods, and tidal cycles. Experienced researchers will conduct spawning, larval rearing and settlement, and juvenile grow-out activities.

2.5.2.16 Experimental Outplanting

If spawning is successful, researchers will conduct experimental outplanting with captive-bred progeny at the early life stages (e.g., larval to early juvenile stage). Outplanting may occur at any time of year.

Larval outplanting will use methods similar to those used for white abalone outplanting (under ESA Permit 18116, issued to NMFS WCR in 2019). Briefly, larvae that are ready to settle will be transported in seawater-filled bags in coolers and released within an enclosed space at the selected field site (e.g., a tide pool, or a mesh tent deployed in a tide pool) to allow the larvae to settle. Post-outplant monitoring will be conducted at 6 to 12 months.

Outplanting of post-settlement to early juvenile stages will involve settling the abalone onto ARMs and transporting and installing the ARMs at field outplanting sites. The ARMs will be the same or similar in design to those used for monitoring juvenile recruitment (see Section 2.5.2.12 ARMs: Deployment and Transplantation Between Sites). Researchers will transport the ARMs to the field in seawater-filled coolers, maintaining appropriate temperatures and dissolved oxygen levels throughout transport. At the field site, researchers will install the ARMs using screws in the rock or with epoxy. The ARMs will be placed adjacent to or in crevices, or next to solid boulders or rock shelves, for protection from wave action and rolling rocks and proximity to preferred juvenile habitat. Post-outplant monitoring will occur on a regular basis and involve carefully disassembling and reassembling the ARMs, as well as searching adjacent areas, to record the presence of juveniles. At the end of the study, all modules will be removed from the sites and any black abalone remaining on the modules will be carefully removed and placed on natural substrates. Mounting materials may be left in place for additional outplanting efforts. We

discussed the effects of the ARMs on abalone and their habitat in Section 2.5.2.12 (ARMs: Deployment and Transplantation Between Sites).

We expect outplanting activities to cause stress, injury, or mortality to larval and juvenile black abalone, due to handling, transport, and exposure to varying conditions in the field. To minimize stress and injury during handling and transport, researchers will contain the abalone to minimize handling and maintain appropriate temperatures and oxygen levels throughout transport. As described in Section 2.5.2.3 (Transport) above, similar methods have been used to transport early life stages of abalone between North Central California and Southern California. We expect handling and transport to result in minor stress and any injury/mortality to be limited to a small number of abalone.

To maximize survival in the field, researchers will outplant the abalone to suitable habitat and use appropriate methods (e.g., mesh tent, ARMs) to contain and protect the abalone upon initial release. We expect that a large proportion, or potentially all, of the abalone that are outplanted could die before reaching the settlement or one-year old stage due to high natural mortality at these early life stages. For example, for the white abalone captive propagation program, the survival rate from the larval stage to one year of age ranges from 0.002 to 0.5 percent (unpublished data presented by Kristin Aquilino, UCD-BML, on January 20, 2016). Researchers will regularly monitor the outplant sites (e.g., at 6 to 12 months) to evaluate survival, growth, and habitat use. A measurable response may not be observable until 5-8 years post-outplant, based on results from other abalone outplanting studies (Bouma and Ulrich, unpublished data).

2.5.3. Permit-specific Effects on Black Abalone

In the previous section (Section 2.5.2, Effects of Research and Enhancement Activities on Black Abalone), we describe different research and enhancement activities and their effects on black abalone. In the following subsections, we describe and discuss the specific activities proposed in Permits 26342 and 26606 and their effects on black abalone. We first evaluate the effects of each permit on individual fitness and the numbers, density, and spatial distribution of black abalone at the local level. Because numbers, density, and spatial distribution are directly related to the viability of local populations, we use this evaluation of effects at the individual level to assess the potential effects of the proposed permits at the population and species levels.

2.5.3.1 Permit 26342 – Black Abalone Emergency Response

Under Permit 26342, NMFS would issue a permit to the UCSC to conduct emergency rescue and relocation of black abalone in response to an emergency event's observed or expected effects on and risks posed for black abalone and its habitat. Permit activities include collection of black abalone and removal from the wild, captive holding for one day to several months, reintroduction to the wild, and post-release monitoring. Rescued abalone would be photographed, measured (shell length), weighed, visually assessed for health and gonad condition, genetically sampled, and tagged. Ethanol may be used to sedate abalone and minimize injury when removing abalone from the substrate in the field or in captivity. Relocation sites would be selected and pre-identified cracks and crevices may be prepared by removing encrusting organisms prior to releasing the rescued abalone. Post-release monitoring would be conducted within a few days of release and as frequently as every tide cycle over the first three months, followed by a six month

and then annual monitoring. Monitoring would involve recording the location and habitat of tagged abalone and collecting empty, tagged shells to track the survival and movements of the released abalone.

Permit 26342 would also allow a subset of the black abalone collected under Permit 26342 to be used in spawning trials to inform the development of reliable spawning induction methods for black abalone. Any progeny produced would be outplanted at the larval to early juvenile stages (up to 3-months post-settlement), with post-outplant monitoring conducted at least once per year and up to three times per year. For juvenile outplanting, the number of ARMs would vary depending on the number of black abalone produced and the larval settlement density. Different larval settlement densities would be evaluated to determine optimal densities for black abalone outplanting.

Table 2 summarizes the requested annual take of black abalone for Permit 26342. The researchers have requested to rescue/collect and relocate up to an average of 1,000 black abalone per year (averaged over a five-year period); actual numbers would vary depending on the frequency, scope, and nature of events requiring emergency response. Severely injured abalone would be held in captivity for rehabilitation. Dead abalone would be preserved and available for analysis at approved labs. The researchers estimate that up to 220 black abalone (22%) may die due to collection-related injuries and up to 102 black abalone (13%) may die following release to the field (total mortalities: up to 322 black abalone per year), based on confirmed mortality rates for the 2017 Mud Creek and 2021 Big Sur rescue and relocation efforts. The researchers estimate monitoring and measuring up to 1,000 black abalone at the field sites and collecting up to 500 dead or obviously unhealthy black abalone and up to 100 empty shells per year.

The researchers have also requested to conduct up to two spawning trials with up to 100 rescued black abalone per year. Only black abalone with ripe gonads would be used in spawning studies and individual black abalone would not be subjected to more than one spawning trial. Once the studies are complete, the black abalone would be eligible for release to the wild. The researchers estimate producing and settling up to 2 million larvae per year. Based on data from red abalone and white abalone captive breeding, it is possible that all of the captive-bred progeny may die during the larval rearing to post-outplanting stages. In the best case, outplanting could result in an additional 40 to 10,000 juvenile black abalone at the outplant sites.

We expect most of the proposed rescue and relocation activities to result in minor, temporary stress to the black abalone; however, some black abalone may be injured or killed, resulting in longer-term losses and effects at the population level. We do not have a total population abundance estimate for black abalone, but we do know that the population in California consists of at least 7,750 black abalone, based on the number of black abalone observed in long-term monitoring surveys in 2019. The proposed rescue and relocation activities could result in the loss of up to 323 black abalone per year, representing about 4 percent of the known population in California. We consider that all of the rescued black abalone would have been at risk of injury and death due to the effects of the emergency event if they were not rescued. Permit 26342 would allow researchers to save a portion of the black abalone that may be lost due to the emergency event and would provide an opportunity to relocate those abalone to establish or

enhance populations at another site. In addition, spawning and outplanting activities could increase the number of black abalone in the wild.

The collection of up to 500 dead or obviously unhealthy black abalone per year represents up to 6.5% of the known population in California. These abalone would already be dead or expected to die within a few days whether or not they are collected. Removal of dead or obviously unhealthy abalone may benefit other abalone at the sites by reducing the potential for further spread of disease. We do not expect researchers to encounter 500 dead or obviously unhealthy black abalone per year, unless there is a mass mortality event. We expect implementation of the protocols and best practices to prevent researchers from accidentally collecting and killing a healthy abalone.

In summary, we expect the proposed rescue and relocation activities under Permit 26342 to support and advance the survival and recovery of black abalone. Although the proposed activities may injure and kill some black abalone, it is likely that many more would die if left in place due to the effects of an emergency event. Permit 26342 would allow researchers to remove at-risk abalone and relocate them, to establish or enhance populations at other sites. The abalone may also be used in spawning and experimental outplanting trials, to inform the development of captive propagation as another recovery tool for black abalone. Permit 26342 would directly address an important recovery action highlighted in the Final ESA Recovery Plan for Black Abalone (NMFS 2020), to plan and prepare for the removal and relocation of black abalone in response to emergency events such as oil spills, landslides, and other sedimentation events and would enhance the propagation and survival of the species.

Table 2. Total requested annual take and unintentional mortalities for black abalone by life stage, origin, and action in Permit 26342.

Life Stage	Origin	Take Action	Requested Take	Unintentional mortality[a]
Adult, juvenile	Wild	Collect, transport, handle, hold, release	1,000[b]	322
Adult, juvenile	Wild	Monitoring, measure, sample	1,000	1
Adult, juvenile	Wild	Collect dead or obviously unhealthy abalone	500	500
Adult, juvenile	Wild	Collect empty shells	150	0
Adult	Wild	Spawning	100	0
Egg, larvae	Captive	Culturing, rearing, settlement	2 million	2 million
Juvenile	Captive	Transport, outplanting, monitoring	2 million	2 million

[a] The "Requested Take" is the estimated maximum number of black abalone directly taken per year as part of permitted actions (e.g., collection and relocation) and the "Unintentional mortalities" is the estimated number of those black abalone that may be unintentionally killed while carrying out the permit activities.
[b] The researchers request to rescue and relocate up to an average of 1,000 black abalone per year, averaged over a five-year period.

2.5.3.2 Permit 26606 – Black Abalone Transplantation Activities

Under Permit 26606, NMFS would issue a permit to the UCSC to conduct transplanting studies to evaluate and optimize transplantation as a tool for black abalone recovery. The proposed

activities include pre-collection surveys at potential donor sites and pre-transplant surveys at transplantation sites to assess black abalone abundance, density, spatial distribution, and habitat; collection of black abalone and removal from one to multiple donor sites; captive holding for one to several days; reintroduction to the wild at the transplantation site; and post-transplant monitoring. Collected abalone would be photographed, measured (shell length), weighed, visually assessed for health and gonad condition, genetically sampled, and tagged. Ethanol may be used to sedate and minimize injury when removing abalone from the substrate in the field or in captivity.

At the transplantation sites, researchers may prepare the cracks and crevices by removing encrusting organisms prior to releasing the abalone. Post-release monitoring would be conducted within a few days of release and as frequently as every tide cycle over the first three months, at six-months post release, and then annually. Monitoring would involve recording the location and habitat of tagged abalone and collecting empty, tagged shells to track the survival and movements of the released abalone. Researchers may deploy ARMs to facilitate monitoring of juvenile recruitment, as well as to transplant juveniles to adjacent transplantation sites.

Table 3 summarizes the requested take of black abalone for Permit 26606. The researchers have requested to collect and transplant up to an average of 250 black abalone per year (averaged over a five-year period). Severely injured abalone would be held in captivity for rehabilitation. Dead abalone would be preserved and available for analysis at approved labs. The researchers estimate that up to 38 black abalone (15%) may die due to collection-related injuries and up to 33 black abalone (13%) may die following release to the field (total mortalities: up to 71 black abalone per year), based on confirmed mortality rates for the 2017 Mud Creek and 2021 Big Sur rescue and relocation efforts. The researchers have also requested to transplant up to 600 black abalone juveniles per year (averaged over a five-year period) using the ARMs and expect a small number (2 black abalone) to die due to these transplanting activities. The researchers estimate monitoring and measuring up to 3,000 black abalone at the donor and transplantation sites and collecting up to 500 dead or obviously unhealthy black abalone and up to 100 empty shells per year. As discussed above, the collection of up to 500 dead or obviously unhealthy black abalone per year represents a substantial portion of the known population in California; however, these abalone would already be dead or expected to die within a few days whether or not they are collected.

We expect most of the proposed transplanting activities to result in minor, temporary stress to the black abalone; however, some black abalone may be injured or killed, resulting in longer-term losses and effects at the population level. The proposed transplanting activities could kill up to 74 black abalone per year, representing about 0.95 percent of the known population in California. The proposed transplanting activities would also reduce the abundance of black abalone at the donor sites (by up to a maximum of 10 percent).

We do not expect these reductions in abundance to have a substantial or long-term effect on the productivity, spatial structure, or diversity of black abalone at the donor sites, in the overall population in California, or for the species as a whole. First, Permit 26606 would establish collection criteria to maintain appropriate densities and spatial structure at the donor sites, to support the viability of the remaining black abalone. Second, the donor abalone would be used to establish or enhance black abalone populations at the transplantation site(s), to strengthen the

species' resiliency and increase the reproductive potential of local populations. Finally, the estimated mortality of 74 black abalone is likely an overestimate, because it is based on the observed mortality rates for the Mud Creek and Big Sur rescue and relocation efforts, where injuries may have resulted from the collection activities and the effects of the emergency event. We expect actual mortality rates to be lower for the proposed transplanting studies.

In summary, we expect the proposed transplanting activities under Permit 26606 to support and advance the survival and recovery of black abalone. Although the proposed activities may injure and kill some black abalone, we do not expect the potential reduction in abundance to result in a substantial or long-term effect on the productivity, spatial structure, or diversity of black abalone at the donor sites, in the overall population in California, or for the species as a whole. Permit 26606 would allow researchers to conduct transplanting studies to establish or enhance black abalone populations, to increase the reproductive potential and viability of local populations. The activities authorized by Permit 26606 would directly address an important recovery action highlighted in the Final ESA Recovery Plan for Black Abalone (NMFS 2020), to evaluate and develop transplantation as a tool to restore black abalone populations throughout the species' range and would enhance the propagation or survival of listed species.

Table 3. Total requested annual take and mortalities for black abalone by life stage, origin, and action in Permit 26606.

Life Stage	Origin	Take Action	Requested Take	Unintentional Mortality[a]
Adult, juvenile	Wild	Collect, transport, handle, hold, release/transplant	250[b]	71
Adult, juvenile	Wild	Monitoring, measure, sample (at donor and transplantation sites)	3000	1
Adult, juvenile	Wild	Transport (on ARMs), handle, release/transplant (to adjacent sites)	600	2
Adult, juvenile	Wild	Collect dead or obviously unhealthy abalone	500	500
Adult, juvenile	Wild	Collect empty shells	150	0

[a] The "Requested Take" is the estimated maximum number of black abalone directly taken per year as part of permitted actions (e.g., collection and transplantation) and the "Unintentional mortalities" is the estimated number of those black abalone that may be unintentionally killed while carrying out the permit activities.
[b] The researchers request to collect and transplant up to an average of 250 black abalone per year, averaged over a five-year period.

2.6. Cumulative Effects

"Cumulative effects" are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation [50 CFR 402.02]. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-Federal activities are reasonably certain to occur within the action area and contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described earlier in the discussion of the environmental baseline (Section 2.4).

Illegal harvest (described in Section 2.2, Rangewide Status of the Species and Critical Habitat) is reasonably certain to occur as a result of future State (e.g., abalone harvest regulations and enforcement) and private activities and to continue to affect black abalone and its critical habitat into the future. A contributing factor is increased human use activities in California's intertidal zones. These human use activities include collection of intertidal invertebrates for consumption as well as for observation and could result in increased illegal harvest of black abalone. In southern California, even low levels of harvest could wipe out black abalone populations that are just beginning to increase in numbers. We do not know how much human use activities in the intertidal may increase in the future. Although harvest of all abalone was prohibited in 2018, additional enforcement, outreach, and education are needed to protect abalone populations.

NMFS issued a final recovery plan for black abalone in November 2020 to guide recovery activities (NMFS 2020). Recovery actions identified in the plan include long-term population monitoring, population and habitat preparation where populations have declined, disease research and management plans, emergency response plans, coordination with Mexico, and outreach and education. Implementation of this recovery plan by non-Federal partners is expected to increase collaboration and on-the-ground recovery efforts for black abalone.

Other than those described above, we did not identify additional state or private activities that are reasonably certain to occur within the action area and that could result in cumulative effects on black abalone and black abalone critical habitat. In general, development activities are not allowed in rocky intertidal habitat. Oil spills, sedimentation events, and the introduction of pathogens could occur within the action area; however, we would not consider these activities to be reasonably certain to occur, given the unpredictability and uncertainty in the timing, location, scope, and severity of such events.

2.7. Integration and Synthesis

The Integration and Synthesis section is the final step in assessing the risk that the proposed action poses to listed species and critical habitat. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.7.1. Black Abalone

Black abalone have declined throughout a large portion of their range (south of Cayucos), primarily due to historical overfishing and disease-related mass mortalities. In areas affected by disease, abundance and density continue to be low and the remaining black abalone are subject to demographic risks such as reduced reproduction and recruitment, loss of genetic diversity, and poor connectivity with other sites. Recruitment has been observed at a few sites in southern California, indicating natural recovery is occurring. Black abalone at sites north of Cayucos remain healthy and stable, but face continued threats from withering syndrome and other diseases, illegal harvest, elevated water temperatures, oil spills, and sedimentation events. The threat of sedimentation and illegal harvest may increase in the coming years, given the massive fires and increases in intertidal harvest and human use activities observed in 2020 and 2021. At the same time, ongoing and future conservation efforts provide benefits to the species by increasing public awareness of abalone conservation and enhancing management, protections, and enforcement. These efforts include implementation of California's Abalone Recovery and Management Plan, marine protected areas under California's MLPA process, disease research, and the Final ESA Recovery Plan (NMFS 2020).

Currently issued research and enhancement permits allow field monitoring (Permit 18761-2R issued to the UCSC) and captive holding, spawning, and grow out (Permit 19571-2R issued to the SWFSC), but do not allow collection and release of wild black abalone. In contrast, the proposed Permits (26342 and 26606) would allow researchers to collect, handle, transport, captively hold, release, and monitor black abalone at field sites and are expected to result in higher levels of mortality than previous permits (Table 4). Combined activities under the two proposed permits may kill up to 397 black abalone per year (Table 4), representing about 5 percent of the known population in California. This represents a substantial reduction in black abalone abundance throughout California. However, we consider that the majority of these abalone (n=323) would have been at risk of injury and death due to the effects of emergency events and many more would likely be killed if rescue and relocation were not permitted. Rescue efforts would improve their chances of survival and provide an opportunity to use the abalone to re-establish or enhance populations. For Permit 26606, we consider the estimated mortality of 74 black abalone to be an overestimate and that any reduction in abundance due to transplanting activities would not result in a substantial or long-term effect on the productivity, spatial structure, or diversity of black abalone at the donor sites, in the overall population in California, or for the species as a whole. We expect the collection criteria to adequately protect and maintain the viability of the remaining black abalone at donor sites and the relocated abalone to increase the reproductive potential and viability of black abalone at the transplantation sites.

Considering the status of the species, the environmental baseline, and cumulative effects, we do not expect the research and enhancement activities under Permit 26342 and 26606 to reduce fitness at the population or species level. Permits 26342 and 26606 would address priority actions identified in the Final ESA Recovery Plan by supporting transplantation studies and rescue and relocation efforts in response to emergency events. Overall, we expect the proposed research and enhancement activities would promote survival and recovery of black abalone in the wild and provide critical information to inform and advance future recovery efforts.

Table 4. Total requested take of black abalone for the two proposed permits covered in this Biological Opinion (26342 and 26606) and two issued permits (18761-2R and 19571-2R).

ESA Permit #	Life Stage	Origin	Requested Take	Unintentional Mortality	Percent taken[a]	Percent killed[a]
18761-2R (Monitoring)[b]	Adult, juvenile	Wild	10,300	4	>100%	0.05%
19571-2R (Captive Program)	Adult, juvenile	Wild	251	251	3%	3%
	All	Captive-bred	Unlimited	Unlimited	0%	0%
26342 (Rescue and Relocation)[b]	Adult, juvenile	Wild	2,000	323	26%	4.2%
	Egg, larval, juvenile	Captive-bred	2 million	2 million	0%	0%
26606 (Transplantation)[b]	Adult, juvenile	Wild	3,850	74	50%	0.95%

[a] Percentage of the known black abalone population in California (7,750 abalone, based on the number observed in the 2019 long-term monitoring surveys).
[b] Permits 18761-2R, 26342, and 26606 also include collection of up to 500 dead/obviously unhealthy black abalone per year.

2.7.2. Black Abalone Critical Habitat

Black abalone critical habitat remains in good condition to support the species' survival and recovery. Most effects on black abalone critical habitat have been limited to narrow geographic areas. For example, changes in community structure have been observed at a few sites following the decline of black abalone. Thermal effluent from a coastal power plant has increased local water temperatures at one of the sites. Landslides, debris flows, and other sedimentation events have buried localized areas of critical habitat along the central California coast. Factors that could affect critical habitat on a larger geographic scale include sea level rise, ocean acidification, and elevated water temperatures resulting from climate change. The effects of these factors on critical habitat are highly uncertain. Continued fires are expected to increase sedimentation and runoff along the central and southern California coast. Researchers are assessing the potential risks to black abalone critical habitat.

We expect the research and enhancement activities under Permits 26342 and 26606 to have little to no effect on black abalone critical habitat. Monitoring activities would result in minor trampling of the habitat, with little effect overall as shown by past monitoring activities. Habitat preparation, deployment of ARMs, and removal/release of black abalone would have minor effects on small areas within a few sites. Considering the status of critical habitat, the environmental baseline, and cumulative effects, we do not expect research and enhancement activities under Permits 26342 and 26606 to reduce the conservation value of designated black abalone critical habitat. We expect the proposed research and enhancement activities to provide

valuable information on the effects of emergency events on the quality and quantity of critical habitat and to inform future efforts to improve critical habitat features for black abalone, for example, if habitat preparation appears to promote recruitment of juvenile black abalone.

2.8. Conclusion

After reviewing and analyzing the current status of endangered black abalone and their critical habitat, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of endangered black abalone or destroy or adversely modify its designated critical habitat.

2.9. Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Harass" is further defined by interim guidance as to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering." "Incidental take" is defined as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) of the ESA provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

For the action considered in this opinion, there is no incidental take at all. The reason for this is that all the take contemplated in this opinion would be carried out under permits that allow the permit holder to directly take black abalone, consistent with section 10(a) of the ESA, which allows such direct take in limited circumstances present here. The actions are considered to be direct take rather than incidental take because in every case their actual purpose is to take the animals as a lawfully permitted activity. Thus, the take cannot be considered "incidental" under the definition given above. Nonetheless, one of the purposes of an incidental take statement is to specify the amount or extent of take that may not be exceeded without being in possible violation of section 9 of the ESA. That purpose is fulfilled here by the amounts of direct take specified in the effects section above (Table 2 and Table 3 in Section 2.5.3). Those amounts constitute hard limits on both the amount and extent of take that could occur during the permitted activities in a given year. This concept is also reflected in the reinitiation clause below.

2.10. Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. "Conservation recommendations" are suggestions of the consulting agency

(NMFS or FWS) regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). The following are conservation recommendations in association with this action:

(1) The permit holder and researchers under Permit 26342 should consider developing the following to share best practices and lessons learned with resource managers and partners involved in emergency response, to streamline and facilitate effective response efforts and minimize the loss of black abalone and their habitat:

    a. Emergency rescue and relocation protocols;
    b. Captive holding protocols;
    c. Decision trees (e.g., for assessing risk, when to conduct rescue and relocation);
    d. Best practices for evaluating success;
    e. Experienced personnel contact list; and
    f. A list of captive facilities, including their capacity and ability to hold oiled abalone.

(2) The permit holder and researchers under Permit 26606 should consider developing the following to share best practices and lessons learned with resource managers and black abalone recovery partners, to inform and facilitate implementation of recovery efforts:

    a. Collection and transplantation protocols;
    b. Best practices for monitoring and evaluating success;
    c. Experienced personnel contact list; and
    d. A list of captive facilities and their capacity.

We request notification if these conservation recommendations are implemented, to stay informed of actions to minimize or avoid adverse effects, or benefit listed species and their habitat.

2.11. Reinitiation of Consultation

This concludes formal consultation for NMFS' proposal to issue Permit 26342 (Black Abalone Emergency Response) and Permit 26606 (Black Abalone Transplantation Studies) to the UCSC to take black abalone for research and enhancement purposes pursuant to the provisions of Section 10(a)(1)(A) of the ESA.

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

In the context of this opinion, no incidental take is anticipated and the reinitiation trigger set out in (1) is not applicable. If any of the direct take amounts specified in this opinion's effects analysis section (2.5) are exceeded, reinitiation of formal consultation will be required because the regulatory reinitiation triggers set out in (2) and/or (3) will have been met.

2.12. "Not Likely to Adversely Affect" Determinations

NMFS does not anticipate the proposed action will adversely affect white abalone, which are listed as endangered under the ESA. When evaluating whether the proposed action is not likely to adversely affect listed species or critical habitat, we consider whether the effects are expected to be completely beneficial, insignificant, or discountable. Completely beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat. Insignificant effects relate to the size of the effect and should never reach the scale where take occurs. Effects are considered discountable if they are extremely unlikely to occur.

2.12.1. White Abalone

White abalone range from Point Conception, CA, to Baja California and occupy subtidal rocky habitat from 5 to 60 meters depth. Thus, we do not expect the proposed field activities to affect white abalone in the wild. However, the proposed captive holding of black abalone under Permits 26342 and 26606 may occur at approved facilities that hold endangered white abalone (*Haliotis sorenseni*). Captive holding of black abalone at these facilities may increase the risk of disease and parasite infections for captive white abalone, which are also susceptible to withering syndrome, sabellid worms, and other shell-boring organisms. To minimize effects on captive white abalone at the facilities, researchers will quarantine newly acquired black abalone and treat the animals for disease if needed. Researchers will also hold black abalone in separate tanks and systems from other abalone at the facilities. The proposed permit activities will only involve black abalone and will not directly involve white abalone at the facilities.

We expect these measures to sufficiently minimize the potential risk to white abalone and other abalone species held at the approved captive facilities. The potential for the proposed permit activities to increase the risk of disease and parasite infections for white abalone is extremely unlikely and are thus discountable. Therefore, we conclude that the proposed permit activities are not likely to adversely affect white abalone.

3. MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the physical, biological, and chemical properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH [CFR 600.905(b)].

This analysis is based, in part, on the effects analysis in Section 2.5 of this biological opinion and descriptions of EFH for Pacific Coast groundfish (Pacific Fishery Management Council (PFMC 2005)), coastal pelagic species (PFMC 1998), and Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

In this instance, because no adverse effects on habitat are expected, no effects on EFH are anticipated either. The proposed research and enhancement actions are not likely, singly or in combination, to adversely affect the habitat upon which Pacific groundfish, salmon, and coastal pelagic species depend. All the actions are of limited duration, minimally intrusive, and are discountable in terms of their effects, short- or long-term, on any habitat parameter important to the fish.

The action agencies must reinitiate EFH consultation if plans for these actions are substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for the EFH conservation recommendations (we did not identify any EFH conservation recommendations for the proposed action) (50 CFR Section 600.920(k)).

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1. Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended user of this opinion is the NMFS WCR PRD. Other interested users could include the permit applicant (UCSC, Peter Raimondi), co-investigators listed on the permit applications, and abalone researchers. Individual copies of this opinion were provided to the NMFS WCR PRD. The document will be available online within 2 weeks of the date of signature at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adhere to conventional standards for style.

4.2. Integrity

"Integrity" refers to security—the protection of information from unauthorized access or revision, to ensure that the information is not compromised through corruption or falsification. This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3. Objectivity

"Objectivity" focuses on whether the disseminated information is being presented in an accurate, clear, complete, and unbiased manner, and as a matter of substance, is accurate, reliable, and unbiased.

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR part 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. REFERENCES

Personal Communications and Unpublished Data

Ammann, Karah. Research technician, UCSC, Santa Cruz, CA. March 8, 2016. Personal communication, via email to Melissa Miner (UCSC), Jim Moore (CDFW), Melissa Neuman (NMFS), and Susan Wang (NMFS), regarding observations of withered black abalone in California in 2015-2016 compared to the past 5-10 years.

Aquilino, Kristin. September 8, 2015. Personal communication, via white abalone coordination call, regarding successful transport of 200 juvenile white abalone from BML to four southern California facilities.

---. January 20, 2016. Unpublished data on the white abalone captive breeding program, presented at the NMFS Abalone Workshop on January 20-21, 2016 in Long Beach, CA.

---. April 1, 2016. Unpublished data, via conference call, regarding the use of ethanol as an anesthetic to move and transfer juvenile white abalone between facilities.

Barilotti, A.A. and T. Ford, H.L. Burdick, P.H. House (The Bay Foundation) and D. Witting, M.J. Neuman, and S.S. Wang (NMFS). April 30, 2018. Unpublished data presented on the White Abalone Restoration Coordination Call, titled "Green Abalone Restoration off the Palos Verdes Peninsula."

Bouma, Josh (Biologist, Puget Sound Restoration Fund) and Michael Ulrich (Biologist, Washington Department of Fish and Wildlife). Unpublished data on experimental outplanting studies with pinto abalone in Washington.

Bragg, Wendy. PhD student, UCSC, Santa Cruz, CA. August 29, 2021. Personal communication, via comments on a draft document, regarding the effects of the 2021 Big Sur debris flow rescue and relocation effort on black abalone.

Darrow, Kiersten. Research curator, Cabrillo Marine Aquarium (CMA), San Pedro, CA. January 3, 2016. Personal communication, via email to Susan Wang (NMFS), regarding one mortality of a juvenile white abalone at CMA.

Engle, Jack, Research Biologist, UC Santa Barbara, CA, and Peter Raimondi, Professor, UCSC, CA. June 5-6, 2015. Personal communication, via email to Melissa Neuman (NMFS) and call with Sarah Wilkin (NMFS), regarding three black abalone found within the impact zone for the Refugio Beach oil spill.

Hyde, John. Research biologist, NMFS Southwest Fisheries Science Center (SWFSC), La Jolla, CA. December 29, 2015. Personal communication, via email to Susan Wang (NMFS), regarding one mortality of a juvenile white abalone at the SWFSC.

---. September 24, 2016. Unpublished data, via email to Susan Wang (NMFS), regarding the use of phenoxyethanol and ethanol as anesthetics to remove abalone from substrates.

---. July 25, 2019. Unpublished data regarding the use of different anesthetics to remove abalone from substrates.

Moore, Jim. Professor, BML, Bodega Bay, CA. November 20, 2015. Personal communication, via email to Susan Wang (NMFS), regarding the distribution of WS-RLO and the effects of the bacteriophage on the pathogenicity of the WS-RLO.

Sylvia, Paula. Research biologist, SWFSC, La Jolla, CA. April 14, 2015. Personal communication, via email to Melissa Neuman (NMFS) and Susan Wang (NMFS), regarding the death of two black abalone held at the SWFSC La Jolla lab in February 2015.

Ugoretz, John. Program Manager, CDFW, Ventura, CA. October 3, 2020. Unpublished observations, via presentation at the MARINe Fall Webinar, regarding the increase in human use activities in the rocky intertidal throughout California.

Literature References

Altstatt, J., R. Ambrose, J. Engle, P. Haaker, K. Lafferty, and P. Raimondi. 1996. Recent declines of black abalone Haliotis cracherodii on the mainland coast of central California. Marine Ecology Progress Series 142(1–3):185–192.

Aprilia, F. N., S. Agoes, and F. M. Rasyid. 2018. Abalone (Haliotis squamata) anesthesia with ethanol on grading process. RJOAS 2(74):239–242.

Ault, J. S. 1985. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) -- black, green, and red abalones. U.S. Department of the Interior, U.S. Fish&Wildlife Service Biological Report 82 (11.32), U.S. Army Corps of Engineers, TR EL-82-4, Washington, D.C.

Bell, C., and P. Raimondi. 2020. Translocation manual as part of an emergency response for the Federally Endangered Black Abalone (Haliotis cracherodii). Page 76 pp. Prepared by University of California, Santa Cruz for the Monterey Bay National Marine Sanctuary, NCND6000-18–00621.

Bergen, M. 1971. Growth, feeding, and movement in the black abalone, Haliotis cracherodii Leach 1814. Master's Thesis, University of California, Santa Barbara.

Braid, B., J. Moore, T. Robbins, R. Hedrick, R. Tjeerdema, and C. Friedman. 2005. Health and survival of red abalone, Haliotis rufescens, under varying temperature, food supply, and exposure to the agent of withering syndrome. Journal of Invertebrate Pathology 89(3):219–231.

Caltrans. 2021. Mud Creek Landslide: Biological Assessment. Page 64 pp. California Department of Transportation, Prepared by Caltrans, District 5, Central Coast Environmental Division.

Chacon, O., M. T. Viana, A. Farias, C. Vazquez, and Z. Garcia-Esquivel. 2003. Circadian metabolic rate and short-term response of juvenile green abalone (Haliotis fulgens Philippi) to three anesthetics. Journal of Shellfish Research 222:415–421.

Coates, J., K. Hovel, J. Butler, and A. Bohonak. 2014. Recruitment and recovery of pink abalone (Haliotis corrugata) in a historically overexploited kelp forest: Are local populations self-sustaining? Journal of Experimental Marine Biology and Ecology 460:184–192.

Cox, K. W. 1960. Review of the abalone of California. California Department of Fish and Game, Marine Resources Operations.

Crim, R. N., J. M. Sunday, and C. Harley. 2011. Elevated seawater CO2 concentrations impair larval development and reduce larval survival in endangered northern abalone (Haliotis kamtschatkana). Journal of Experimental Marine Biology and Ecology 400(1–2):272–277.

Crosson, L., S. Roberts, G. VanBlaricom, and C. Friedman. 2012. A transcriptomic approach in search of disease resistance in endangered black abalone (Haliotis cracherodii). Journal of Shellfish Research 31(1):272–272.

Douros, W. J. 1985. Density, growth, reproduction, and recruitment in an intertidal abalone: Effects of intraspecific competition and prehistoric predation. Master's Thesis, University of California, Santa Barbara.

Douros, W. J. 1987. Stacking behavior of an intertidal abalone: An adaptive response or a consequence of space limitation? Journal of Experimental Marine Biology and Ecology 108:1–14.

Eckdahl, K. A. 2015. Endangered black abalone (Haliotis cracherodii) abundance and habitat availability in southern California. Master's Thesis, California Status University, Fullerton, Fullerton, California.

Edwards, S., C. Burke, S. Hindrum, and D. Johns. 2000. Recovery and growth effects of anesthetic and mechanical removal on greenlip (Haliotis laevigata) and balcklip (Haliotis rubra) abalone. University of Cape Town, South Africa.

Feely, R., S. Doney, and S. Cooley. 2009. Ocean Acidification: Present Conditions and Future Changes in a High-CO2 World. Oceanography 22(4):36–47.

Feely, R., C. Sabine, J. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. Evidence for upwelling of corrosive "acidified" water onto the continental shelf. Science 320(5882):1490–1492.

Feely, R., C. Sabine, K. Lee, W. Berelson, J. Kleypas, V. Fabry, and F. Millero. 2004. Impact of anthropogenic CO2 on the CaCO3 system in the oceans. Science 305(5682):362–366.

Friedman, C., K. Andree, K. Beauchamp, J. Moore, T. Robbins, J. Shields, and R. Hedrick. 2000. "Candidatus Xenohaliotis californiensis", a newly described pathogen of abalone, Haliotis spp., along the west coast of North America. International Journal of Systematic and Evolutionary Microbiology 50:847–855.

Friedman, C., W. Biggs, J. Shields, and R. Hedrick. 2002. Transmission of withering syndrome in black abalone, Haliotis cracherodii leach. Journal of Shellfish Research 21(2):817–824.

Friedman, C., and L. Crosson. 2012. Putative Phage Hyperparasite in the Rickettsial Pathogen of Abalone, "Candidatus Xenohaliotis californiensis." Microbial Ecology 64(4):1064–1072.

Friedman, C., and C. Finley. 2003. Anthropogenic introduction of the etiological agent of withering syndrome into northern California abalone populations via conservation efforts. Canadian Journal of Fisheries and Aquatic Sciences 60(11):1424–1431.

Friedman, C. S., W. Biggs, J. D. Shields, P. L. Haaker, C. Chun, and R. P. Hedrick. 1997a. An examination of four potential etiologies of WS: Temperature, food availability, renal coccidia, and Rickettsiales-like procaryotes. Third International Abalone Symposium: Biology, fisheries, and culture, Monterey, CA, October 26-31, 1997.

Friedman, C., M. Thomson, C. Chun, P. Haaker, and R. Hedrick. 1997b. Withering syndrome of the black abalone, Haliotis cracherodii (Leach): Water temperature, food availability, and parasites as possible causes. Journal of Shellfish Research 16(2):403–411.

Friedman, C., N. Wight, L. Crosson, G. VanBlaricom, and K. Lafferty. 2014. Reduced disease in black abalone following mass mortality: phage therapy and natural selection. Frontiers in Microbiology 5.

Geiger, D. L. 2004. AbMap: The abalone mapping project. http://www.vetigastropoda.com/ABMAP/text/index.htm. Accessed: May 11, 2016.

Gilbertson, C. R., and J. D. Wyatt. 2016. Evaluation of euthanasia techniques for an invertebrate species, land snails (Succinea putris). Journal of the American Association for Laboratory Animal Science 55(5):577–581.

Gruenthal, K., and R. Burton. 2005. Genetic diversity and species identification in the endangered white abalone (Haliotis sorenseni). Conservation Genetics 6(6):929–939.

Gruenthal, K., D. Witting, T. Ford, M. Neuman, J. Williams, D. Pondella, A. Bird, N. Caruso, J. Hyde, L. Seeb, and W. Larson. 2014. Development and application of genomic tools to the restoration of green abalone in southern California. Conservation Genetics 15(1):109–121.

Haaker, P., D. Parker, and C. Chun. 1995. Growth of black abalone, Haliotis cracherodii Leach, at San Miguel Island and Point Arguello, California. Journal of Shellfish Research 14(2):519–525.

Hale, J. R., J. V. Bouma, B. Vadopalas, and C. S. Friedman. 2012. Evaluation of passive integrated transponders for abalone: Tag placement, retention, and effect on survival. Journal of Shellfish Research 31(3):789–794.

Hamm, D., and R. Burton. 2000. Population genetics of black abalone, Haliotis cracherodii, along the central California coast. Journal of Experimental Marine Biology and Ecology 254(2):235–247.

Harley, C., and L. Rogers-Bennett. 2004. The potential synergistic effects of climate change and fishing pressure on exploited invertebrates on rocky intertidal shores. California Cooperative Oceanic Fisheries Investigations Reports 45:98–110.

Hauri, C., N. Gruber, G. Plattner, S. Alin, R. Feely, B. Hales, and P. Wheeler. 2009. Ocean acidification in the California current system. Oceanography 22(4):60–71.

Hofmeister, J. K. K., S. Kawana, B. J. Walker, C. Catton, I. Taniguchi, D. M. Stein, K. Sowul, and L. Rogers-Bennett. 2018. Temporal and spatial patterns in behavioral responses of marine predators to a sudden influx of abalone prey (Haliotis rufescens). Hydrobiologia 813:123–136.

Hooper, C., R. Day, R. Slocombe, K. Benkendorff, and J. Handlinger. 2011. Effect of movement stress on immune function in farmed Australian abalone (hybrid Haliotis laevigata and Haliotis rubra). Aquaculture 315:348–354.

Hooper, C., R. Day, R. Slocombe, K. Benkendorff, and J. Handlinger. 2014. Histopathology and haemolymph biochemistry following anaesthesia and movement in farmed Australian abalone. Aquaculture 422–423:202–210.

Hsu, T.-H., and J.-C. Gwo. 2017. Genetic diversity and stock identification of small abalone (Haliotis diversicolor) in Taiwan and Japan. PLoS ONE 12(6):e0179818.

Karpov, K. A., P. Haaker, I. Taniguchi, and L. Rogers-Bennett. 2000. Serial depletion and the collapse of the California abalone fishery. Pages 11–24 *in* A. Campbell, editor. Workshop on rebuilding abalone stocks in British Columbia. Canadian Special Publications, Fish and Aquatic Sciences.

Kawana, S., and K. Aquilino. 2020, March. White abalone spawning and culturing guide. UC Davis Bodega Marine Laboratory.

Kenner, M. C. 2021. Black abalone surveys at Naval Base Ventura County, San Nicolas Island, California—2020, annual report. Page 33 p. U.S. Geological Survey Open-File Report 2021–1023.

Lapota, D. 2015. Annual report for ESA Permit 17405, Recovery tool for the endangered black abalone. Report period: 2013-2014. Page 8 pp. SPAWAR Systems Center, San Diego, CA.

Leighton, D., and R. A. Boolotian. 1963. Diet and growth in the black abalone, Haliotis cracherodii. Ecology 44:227–238.

Leighton, D. L. 1959. Diet and its relation to growth in the black abalone, Haliotis cracherodii Leach. Master's Thesis, University of California, Los Angeles.

Leighton, D. L. 2005. Status review for the black abalone, Haliotis cracherodii Leach 1814. National Marine Fisheries Service, Southwest Region, Protected Resources Division, Unpublished document produced for the Black Abalone Status Review Team, Long Beach, California.

McShane, P. E. 1992. Early life history of abalone: A review. Pages 120–138 *in* S. A. Shepherd, M. J. Tegner, and S. Guzman-Del Proo, editors. Abalone of the world. Biology, fisheries, culture. Proceedings of the 1st International Symposium on Abalone. Blackwell Scientific Publications Ltd., Oxford, U.K.

Mercer, G., J. Harris, and M. Deveney. 2014. Development and optimization of anaesthetics for use in the abalone aquaculture industry. Presentation.

Miller, A. C., and S. E. Lawrenz-Miller. 1993. Long-term trends in black abalone, Haliotis cracherodii Leach, 1814, populations along the Palos Verdes Peninsula, California. Journal of Shellfish Research 12(2):195–200.

Miner, C., J. Altstatt, P. Raimondi, and T. Minchinton. 2006. Recruitment failure and shifts in community structure following mass mortality limit recovery prospects of black abalone. Marine Ecology Progress Series 327:107–117.

Moore, J. 2014, May. White Abalone Standard Operating Procedure: Processing Moribund or Dead White Abalone at BML Partner Institutions: Aquarium of the Pacific, Cabrillo Marine Aquarium, Ty Warner Sea Center, University of California at Santa Barbara. CDFW Shellfish Health Laboratory.

Moore, J. 2015, August. BML White Abalone Standard Operating Procedure: Bath Administration of Oxytetracycline to Eliminate the Agent of Withering Syndrome. CDFW Shellfish Health Laboratory.

Moore, J. 2019. White abalone standard operating procedure: Processing unhealthy or dying white abalone encountered during outplant monitoring surveys. Page 4. CDFW Shellfish Health Laboratory.

Moore, J., C. Finley, T. Robbins, and C. Friedman. 2002. Withering syndrome and restoration of southern California abalone populations. California Cooperative Fisheries Investigations Reports 43:112–117.

Moore, J., and B. Marshman. 2015, June. BML White Abalone Standard Operating Procedure: Killing Shell Epibionts With A Beeswax/Coconut Oil Mixture. CDFW Shellfish Health Laboratory.

Morris, R. H., D. L. Abbott, and E. C. Haderlie. 1980. Intertidla invertebrates of California. University Press, Palo Alto, CA.

Neuman, M., B. Tissot, and G. Vanblaricom. 2010a. Overall Status and Threats Assessment of Black Abalone (*Haliotis Cracherodii* Leach, 1814) Populations in California. Journal of Shellfish Research 29(3):577–586.

Neuman, M., B. Tissot, and G. Vanblaricom. 2010b. Overall status and threats assessment of black abalone (Haliotis cracherodii Leach, 1814) populations in California. Journal of Shellfish Research 29(3):577–586.

Neuman, M., D. Witting, K. Gruenthal, J. Williams, T. Ben-Horin, S. Wang, B. Scheiwe, A. Bird, T. Ford, D. Pondella, R. Hiemstra, and N. Caruso. 2012. Restoration and conservation of green abalone (Haliotis fulgens) in Southern California: Developing methods for culture, genetic, and disease risk management. Oral presentation.

NMFS. 2008. White Abalone Recovery Plan (Haliotis sorenseni). National Marine Fisheries Service, Long Beach, California.

NMFS. 2011. Final Designation of Critical Habitat for Black Abalone: Final Biological Report. Page 59. NMFS Southwest Region Protected Resources Division, Long Beach, California.

NMFS. 2015. Abalone Risk Management Guidance Document. Page 41 pp. National Marine Fisheries Service.

NMFS. 2020. Final Endangered Species Act Recovery Plan for Black Abalone (Haliotis cracherodii). Page 112. National Marine Fisheries Service, West Coast Region, Protected Resources Division, Long Beach, California.

NMFS. 2021. Updated protocol for black abalone collection, transport, and holding. Page 11. NMFS West Coast Region, Protected Resources Division, Long Beach, California.

O'Leary, J. K., J. P. Barry, P. W. Gabrielson, L. Rogers-Bennett, D. C. Potts, S. R. Palumbi, and F. Micheli. 2017. Calcifying algae maintain settlement cues to larval abalone following algal exposure to extreme ocean acidification. Nature Scientific Reports 7:5774.

PFMC. 1998. Description and identification of essential fish habitat for the Coastal Pelagic Species Fishery Management Plan. Appendix D to Amendment 8 to the Coastal Pelagic Species Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2005. Amendment 18 (bycatch mitigation program), Amendment 19 (essential fish habitat) to the Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington groundfish fishery. Pacific Fishery Management Council, Portland, Oregon.

PFMC. 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Pacific Fishery Management Council.

Raimondi, P., C. Wilson, R. Ambrose, J. Engle, and T. Minchinton. 2002. Continued declines of black abalone along the coast of California: are mass mortalities related to El Nino events? Marine Ecology Progress Series 242:143–152.

Refugio Beach Oil Spill Trustees. 2021. Refugio Beach Oil Spill Final Damage Assessment and Restoration Plan/Environmental Assessment. Page 183 pp. Prepared by the California Department of Fish and Wildlife, California State Lands Commission, California Department of Parks and Recreation, Regents of the University of California, U.S. Department of the Interior, U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration.

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

Rogers-Bennett, L., P. Haaker, T. Huff, and P. Dayton. 2002. Estimating baseline abundances of abalone in California for restoration. California Cooperative Oceanic Fisheries Investigations Reports 43:97–111.

Southern California Spill Response. 2021, October 3. Newport Beach Oil Spill Response - Unified Command Release and Update 1: Unified command continues response to oil spill off Newport Beach.

SWFSC. 2021. Final report for ESA Permit 19571, Recovery tool for the endangered black abalone; Report period 2016-2020. Page 4 pp. NMFS Southwest Fisheries Science Center, La Jolla, California.

Tissot, B. N. 1995. Recruitment, growth, and survivorship of black abalone on Santa Cruz Island following mass mortality. Bulletin of the Southern California Academy of Sciencies 94:179–189.

Toonen, R. J., and J. R. Pawlik. 1994. Foundations of gregariousness. Nature 370:511–512.

VanBlaricom, G., J. Butler, A. DeVogelaere, R. Gustafson, C. Mobley, M. Neuman, D. Richards, S. Rumsey, and B. Taylor. 2009. Status review report for black abalone (Haliotis cracherodii Leach, 1814). Page 135 pp. NMFS Southwest Region, Long Beach, California.

VanBlaricom, G., J. Ruediger, C. Friedman, D. Woodard, and R. Hedrick. 1993. Discovery of Withering Syndrome among black abalone Haliotis cracherodii Leach, 1814, populations at San Nicolas Island, California. Journal of Shellfish Research 12(2):185–188.

Vilchis, L., M. Tegner, J. Moore, C. Friedman, K. Riser, T. Robbins, and P. Dayton. 2005. Ocean warming effects on growth, reproduction, and survivorship of Southern California abalone. Ecological Applications 15(2):469–480.

Webber, H. H., and A. C. Giese. 1969. Reproductive cycle and gametogenesis in black abalone Haliotis cracherodii (Gastropoda - Prosobranchiata). Marine Biology 4(2):152–159.

White, H. I. 1995, December. Anaesthesia in Abalone, Haliotis midae. Master's Thesis, Rhodes University.

White, H. I., T. Hecht, and B. Potgieter. 1996. The effect of four anaesthetics on Haliotis midae and their suitability for application in commercial abalone culture. Aquaculture 140(1–2):145–151.