Recovery Plan Outline
for
Black Abalone
(*Haliotis cracherodii*)

Photo credit: David Witting, NOAA

Prepared by
National Marine Fisheries Service
West Coast Region

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Disclaimer

This outline is meant to serve as an interim guidance document to outline recovery efforts, including recovery planning, for black abalone, until a full recovery plan is developed and approved. A recovery outline is not subject to formal review and is not a regulatory document. This outline is intended primarily for internal use by NMFS as a pre-planning document and the recommendations and statements found herein are non-binding and intended to guide, rather than require, actions. Nothing in this outline should be considered as a commitment or requirement for any governmental agency or member of the public. Formal public participation will be invited upon the release of the draft recovery plan for black abalone. However, any new information or comments that members of the public may wish to offer as a result of this recovery outline will be taken into consideration during the recovery planning process. Recovery planning has been initiated and a draft recovery plan is targeted for completion by early 2017. NMFS invites public participation in the planning process. Interested parties may contact Melissa Neuman, Abalone Recovery Coordinator, 501 West Ocean Blvd, Suite 4200, Long Beach, CA 90802, Melissa.Neuman@noaa.gov, 562-980-4115.

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1. Introduction

1.1. Recovery Outline Purpose

The Federal Endangered Species Act of 1973 (ESA), mandates the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) to develop and implement recovery plans for the conservation and survival of NMFS-listed species. According to the 2004 NMFS Interim Recovery Planning Guidance:

> Recovery is the process by which listed species and their ecosystems are restored and their future safeguarded to the point that protections under the ESA are no longer needed. A variety of actions may be necessary to achieve the goal of recovery, such as the ecological restoration of habitat or implementation of conservation measures with stakeholders. However, without a plan to organize, coordinate, and prioritize the many possible recovery actions, the effort may be inefficient or even ineffective. The recovery plan serves as a road map for species recovery – it lays out where we need to go and how best to get there.

This recovery outline presents a preliminary conservation strategy that will guide recovery actions in a systematic, cohesive way until a recovery plan is available. Its secondary function is to guide and document pre-planning considerations for recovery plan development and decision-making.

1.2 General Information

Species Name: Black Abalone (*Haliotis cracherodii*)

Listing Status: Endangered

Date Listed: January 14, 2009 (74 FR 1937)

Critical Habitat Designated: October 27, 2011 (76 FR 66806)

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Type and quality of available information: Recovery planning and implementation will benefit greatly from past and ongoing long-term monitoring programs for black abalone and ongoing disease research. Long-term monitoring data provide valuable information on population trends over time and have allowed us to identify disease and the resulting low densities as the major threats that need to be addressed to recover the species.

Significant data gaps and uncertainties: Important data gaps remain, including the species' status in Baja California, the species' resistance to the disease, the rate at which the disease may affect the remaining healthy populations, and how recovery may be affected by other threats such as other pathogens, oil spills, ocean acidification, habitat loss, and sea otter predation. The recovery plan will incorporate adaptive recovery strategies and clearly identify uncertainties and the research and monitoring needs to address data gaps.

2. Recovery Status

To develop a recovery plan, we must first understand the species' current status, ongoing and future threats, and recovery needs. The recovery status indicates how the species is doing at present and how this may affect the species' recovery potential and needs. We considered three components to determine the recovery status: (1) the biological requirements of the species, (2) the threats that negatively impact the species, and (3) the conservation efforts that positively impact the species. The final status review (VanBlaricom et al. 2009) and listing decision (74 FR 1937; January 14, 2009) provide a thorough review of the species' biology, status, and conservation efforts. In addition, we have initiated the five-year status review update for black abalone to assess information that has become available since the 2009 status review. In the following sections, we briefly summarize the best available information on the species' biology, status, threats, and conservation efforts and discuss how these relate to and affect recovery of the species.

2.1. Biological Assessment

Abalone are marine gastropods that occur throughout most of the world (Cox 1962). All are benthic and relatively sedentary, occur on hard substrata, and feed on attached or drifting algal material. The black abalone is one of approximately 60 extant species worldwide and seven extant species of abalone native to the west coast of North America (Geiger 1999). The species occupies rocky intertidal and subtidal habitats from the high intertidal zone to about 6 m depth from approximately Point Arena (Mendocino County, California) to the area around Punta Eugenia at the northern border of Baja California Sur, Mexico. We provide a brief overview of the status of black abalone, highlighting aspects of their life history and biology that may affect the species' recovery.

Our understanding of the species' status in California is based largely on fisheries landings data from 1970-1993 and long-term monitoring data collected since 1975. These data show that since the mid-1980s, black abalone have experienced major declines in abundance over a large portion of their geographic range. Populations throughout southern California and as far north as Cayucos (San Luis Obispo County) have experienced declines in abundance of more than 80%; those south of Point Conception have experienced declines of more than 98% (Neuman et al. 2010). Although historical abalone harvest contributed to some degree, the primary cause of these declines has been the disease called withering syndrome. The disease has also affected populations in Baja California, but little is known about the species' status in Mexico.

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. The most abundant and dense populations 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 predation by sea otters. Thus, our understanding of black abalone abundance and distribution for this time period may not accurately represent historical baseline conditions (i.e., conditions prior to commercial and recreational harvest of black abalone) in California.

Beginning in the mid-1980s, black abalone populations began to decline dramatically due to the spread of withering syndrome (Tissot 1995), a disease caused by a bacterium in the *Rickettsiales* order, *Candidatus* Xenohaliotis californiensis that affects the animal's digestion and causes starvation leading to pedal atrophy, lethargy, and death (Friedman et al. 2000, Friedman et al. 2003, Braid et al. 2005). Withering syndrome results in rapid (within a few weeks) and mass (reductions of over 90%) mortalities in affected populations (Neuman et al. 2010). The first recorded mass mortality associated with the disease was observed at Santa Cruz Island in 1985 (Lafferty and Kuris 1993). Withering syndrome spread progressively to all of the Channel Islands from 1986 to the mid-1990s, as well as to the mainland, with the first detection at Diablo Canyon in 1988 and mass mortalities in populations as far north as Cayucos by 1998-1999 (Altstatt et al. 1996, Raimondi et al. 2002). Based on long-term monitoring data from 1975 through 2006, populations at sites south of and including Cayucos have experienced declines of 81 to 99% due to withering syndrome, with local extinction at 11 of the 32 monitoring sites (Neuman et al. 2010). Withering syndrome was also observed in central Baja California around Bahia Tortugas during El Niño events in the late 1980's and 1990s (Altstatt et al. 1996; Pedro Sierra-Rodriquez, pers. comm., cited in VanBlaricom et al. 2009) and may be linked to declines in the abalone fishery there in the 1990s.

Data from long-term, ongoing monitoring show that many, but not all, populations north of Cayucos, CA, have been unaffected by the disease and appear to be healthy and stable. The data show that, from 1975 through 2006, populations at 8 of the 9 monitoring sites north of Cayucos had not experienced any decline, and average abundance actually increased by 56% (Neuman et al. 2010). However, the disease appears to be moving progressively northward along the coast. Although populations north of Cayucos have not yet experienced mass mortalities due to the disease, all are likely to have been infected by the *Candidatus* Xenohaliotis californiensis that is believed to cause withering syndrome. In some locations, such as Carmel (Monterey County; pers. comm. with Pete Raimondi, UCSC, 27 July 2016) and Scott's Creek (Santa Cruz County; Friedman and Finley, 2003), withered animals have been observed and were tested positive for *Candidatus* Xenohaliotis californiensis. In other locations, individuals may be infected and carry *Candidatus* Xenohaliotis californiensis without exhibiting symptoms of the disease.

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. 1997, Raimondi et al. 2002, Harley and Rogers-Bennett 2004, Vilchis et al. 2005). Thus, the northward progression of the disease appears to be associated with increasing coastal warming and El Niño events (Tissot, 1995; Altstatt et al., 1996; Raimondi et al., 2002), and poses a continuing threat to the remaining healthy populations.

Two major factors in the recovery of black abalone are the species' susceptibility to withering syndrome and to Allee effects associated with low densities. Black abalone are relatively long-lived (estimated to live up to 30 years), have separate sexes, and are "broadcast" spawners, meaning that both sexes shed their gametes into the sea and fertilization is entirely external. Successful reproduction depends on spatial and temporal synchrony among spawning individuals; that is, males and females in close proximity to one another (within meters) and spawning simultaneously have a higher likelihood of reproductive success. Natural recovery of severely-reduced abalone populations is likely a very slow process, because having few reproductive adults reduces reproductive success and eventual recruitment of larval abalone.

To support successful reproduction and recruitment, studies indicate that a population must have an adult density greater than a critical threshold value (Tegner 1992). Estimates of this threshold value range from 0.34 abalone per m^2 (based on empirical data from three long-term studies; Neuman et al. 2010) to one abalone per m^2 (Tissot 2007). Mean density estimates for 2002-2006 indicate that populations not yet affected by the disease (north of Cayucos) are above this threshold (range: 1.1 to 10.5 abalone per m^2), whereas populations affected by the disease (south of Cayucos) are below the estimated critical thresholds, many significantly so (range: 0 to 0.5 abalone per m^2) (Neuman et al. 2010).

Despite these low densities, researchers have observed evidence of recent recruitment and increases in abundance at several southern California locations south of Cayucos (e.g., Palos Verdes Peninsula and Laguna Beach, Eckdahl 2015; Santa Cruz Island and San Miguel Island, Richards and Whitaker 2012; and San Nicolas Island, VanBlaricom 2015). Such observations for black abalone and other abalone species indicate that factors other than the number of abalone per square meter need to be considered when assessing population viability. For example, Blaud (2013) found that clustering and use of crevice habitat by black abalone may increase reproductive and recruitment success despite low densities. Clearly, recovering the species will require studies to better understand the disease and methods to protect and enhance populations, including increasing the abundance and density of populations within WS-impacted areas. We will also need to continue long-term monitoring of populations throughout the species' range to better understand and evaluate black abalone population dynamics and trends.

Another important factor in species recovery is the quantity and quality of available habitat. NMFS designated critical habitat (76 FR 66806; October 27, 2011) for black abalone along segments of the California coast between the Del Mar Landing Ecological Reserve (Sonoma County) and the Palos Verdes Peninsula (Los Angeles County), 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. This designation includes rocky intertidal and subtidal habitats within these areas from the mean higher high water (MHHW) line to a depth of -6 m relative to the mean lower low water (MLLW) line, as well as the marine waters above rocky habitats. Essential habitat features include rocky substrate that includes rocky benches formed from consolidated rock; 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 larval settlement within appropriate intertidal habitat.

A concern is the potential for habitat changes to occur in the absence of black abalone, reducing the quality of rocky substrates and juvenile settlement habitat. For example, in some areas where black abalone populations have experienced severe declines or have been locally extirpated, the invertebrate and algal communities have changed, making the areas less suitable for adults (e.g., by *Phragmatopoma,* or sandcastle worms, filling in cracks and crevices) and for settling abalone larvae (e.g., reduced crustose coralline cover) (Toonen and Pawlik 1994, Miner et al. 2006, NMFS 2011). We must also consider that black abalone larvae have limited dispersal distances and primarily recruit to local areas (based on genetic analyses; Hamm and Burton 2000, Chambers et al. 2006, Gruenthal and Burton 2008). This has two implications: first, that maintaining habitat quality is important to support local recruitment; and second, that the benefits of good larval production and recruitment in one area may not contribute substantially to recruitment in other areas. We must consider these factors in assessing the habitat available to support recovery and the actions needed to recover the species (e.g., actions to maintain, protect, and restore habitat for abalone as well as actively enhance populations through translocation and/or outplanting).

Overall, black abalone populations have severely declined in a large portion of the species' geographic range, in the areas that once supported the majority of the adult abalone populations in California. Most disease-impacted populations remain at low abundance/density and withering syndrome continues to progress northward along the coast with warming events (Raimondi et al. 2002), indicating that black abalone populations are likely to continue to decline on a large scale. The low population abundance/density at local areas may also make the populations more vulnerable to other factors affecting the species. Recovery will involve protecting the remaining healthy populations to the north that have not yet been affected by withering syndrome, as well as recovering the populations to the south that have already been affected by the disease.

Finally, several aspects of black abalone biology and life history are unknown or uncertain, but important for assessing the status and recovery of the species. In particular, we have little knowledge of the species' spawning habits (e.g., habitat, seasons, frequency) and recruitment dynamics, largely due to the difficulties associated with working in rocky intertidal habitats, the cryptic nature of newly settled larvae and juveniles, and the lack of consistent methods to spawn black abalone in captivity. Recovery of the species will involve addressing these data gaps to inform recovery efforts and assess the species' progress to recovery.

2.2 Threats Assessment

The ESA establishes a framework for analyzing the threats that a species faces and according to that framework threats are placed into one or more of five listing factor categories at the time of the ESA listing: (1) the present or threatened destruction, modification or curtailment of its habitat or range; (2) overutilization; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural and manmade factors. The status review (VanBlaricom et al. 2009) and final listing decision (74 FR 1937; January 14, 2009) provide a thorough analysis of the threats to black abalone. Here, we briefly summarize the threats and highlight how they have contributed to the decline of black abalone in the past and how they may affect the persistence and recovery of the species into the future.

The recovery team assessed the threats and identified the six threats listed below as threats of greater concern for black abalone recovery. In the following sections, we organize these six threats under the five listing factor categories and discuss these threats in more detail.

- The effects of oil spills and response activities on black abalone and their habitat (see Section 2.2.1)
- Low densities and potentially reduced genetic diversity due to overfishing and mass mortalities caused by withering syndrome (see Sections 2.2.2 and 2.2.3)
- Disease impacts on wild populations, particularly the continued spread of withering syndrome, but also the spread of other pathogens or invasive species known to affect abalone, via aquaculture and research, food, and hobby markets (see Section 2.2.3)
- Continued illegal take of black abalone despite prohibitions on harvest (see Section 2.2.4)
- Elevated water temperatures associated with El Niño/Southern Oscillation (ENSO) events and the Pacific Decadal Oscillation (PDO) (see Section 2.2.5)
- Ocean acidification, associated with long-term climate change (see Section 2.2.5)

2.2.1 The Present or Threatened Destruction, Modification or Curtailment of the Species' Habitat or Range

Among the threats affecting black abalone habitat, the recovery team identified two threats of greater concern: spills and associated response activities, and increased water temperatures.

Regarding spills and spill response activities, we primarily focused on oil spills but recognize that spills of other materials could also affect abalone habitat. Sources of spills could include offshore drilling platforms, pipelines, or various types of vessels. Thus, spills could occur anywhere within the species' range. Habitat impacts include destruction of other intertidal organisms that black abalone rely upon for settlement cues (e.g., coralline algae), food (e.g., diatoms, macroalgae), and shelter. The magnitude of impacts may vary widely, depending on the type of material involved in the spill and local habitat features and conditions. For example, black abalone intertidal habitat is characterized by high wave energy, so some materials may be washed out naturally by waves, whereas other materials may persist in cracks and crevices, prolonging exposure and effects to the habitat as well as to individual abalone. Also, we cannot predict when, where, and how often spills will occur, although risk may be greater in areas adjacent to offshore oil fields (e.g., Santa Barbara), or large, industrial coastal cities (e.g., Los Angeles) that experience intense vessel traffic. Careful planning and coordination are needed to guide spill response and post-monitoring activities, to minimize and assess damage to abalone and their habitat. Spills and associated response activities can also directly affect the health and survival of individuals; we discuss this further under Section 2.2.5 Other Natural or Manmade Factors.

Increased water temperatures pose a serious threat to the species' persistence, because elevated water temperatures appear to accelerate rates of withering syndrome transmission and disease-induced mortality (Ben-Horin et al. 2013). Changes in both salinity and water temperature may compromise physiological functions (Morash and Alter 2015). We highlight two factors that can cause elevated water temperatures: (1) anthropogenic sources of thermal effluent (e.g., thermal discharges from coastal power plant facilities) and (2) long-and short-term climate change (e.g., global climate change and ENSO events). For example, discharge from the Diablo Canyon nuclear power plant and recent ENSO events have produced short-term periods of ocean warming that were associated with increased rates of withering syndrome and mortality in local black abalone populations. Vilchis et al. (2005) found that red abalone held in a lab at elevated water temperatures for a year stopped growing and reproducing and had significantly greater mortality due to withering syndrome. These results suggest that warming ocean temperatures are likely to have negative effects on abalone species that are adapted to cooler water temperatures and/or particularly susceptible to withering syndrome. Continued ocean warming may facilitate the northward progression of withering syndrome and increase the duration of elevated water temperatures, further increasing the vulnerability of black abalone to effects of withering syndrome. Ocean warming may also affect the growth of kelp and other macroalgae that are important food sources for black abalone. Declines in macroalgae due to warming water temperatures have affected red abalone populations along the North-Central California coast (unpublished observation by Ian Taniguchi, CDFW, on 22 August 2016). However, thus far, similar effects have not been observed for black abalone populations along the California coast (pers. comm. with Black Abalone Recovery Team, 22 August 2016).

Most of the other habitat threats occur infrequently; have a narrow geographic scope; or have uncertain, indirect, and/or low effects on black abalone. These threats include coastal development (e.g. shore stabilization projects), recreational access, cable repairs, nearshore military operations, vessel groundings, benthic community shifts (e.g., due to the absence or reduced presence of abalone), sedimentation (e.g., landslides, storm-generated burial), and fluctuations in food quantity and/or quality (naturally or due to factors such as kelp harvest, ocean warming, or non-native species). Some exceptions may exist in that sedimentation, fluctuations in food quantity and/or quality, and sea level rise could produce widespread impacts. However, the effects on black abalone are uncertain and/or low. For example, we currently lack information to evaluate how potential habitat changes resulting from sea level rise might affect the survival and recovery of black abalone. Abalone may be able to adapt to shifts in habitat, because sea level rise is likely to occur over a long period of time. Abalone species are also likely able to alter their foraging strategies to account for changes in their food supply (Kiyomoto et al. 2013). As stated above, declines in macroalgae due to warming water temperatures have been observed to affect subtidal abalone species like red abalone. Changes in food availability or quality could also affect black abalone; however, field researchers have not observed declines in food availability for black abalone in 2015 and 2016, despite warmer water temperatures, and have noted that black abalone can consume diverse food types, allowing them to adapt if the supply of drift macroalgae declines (pers. comm. with Black Abalone Recovery Team, 22 August 2016).

2.2.2 Overutilization for commercial, recreational, scientific, or educational purposes

The recovery team identified low local densities as a threat of greater concern for black abalone. Withering syndrome was the primary factor in the species' decline, but historical harvest of black abalone also contributed. Commercial landings for black abalone peaked in the early to mid-1970s and subsequently declined, prior to the outbreak of withering syndrome (CDFG 2005). By the early 1990s, landings had declined by more than 90%; however, at approximately the same time, mass mortalities due to withering syndrome had begun in many locations, so these declines were not entirely due to fisheries harvest (CDFG 2005). The black abalone fishery in California closed in 1993, but the effects of both the fishery and disease (e.g., reduced local abundance and density of black abalone) remain and continue to affect the species' recovery. In particular, populations in southern California remain at low densities and in some areas the remaining individuals may be too far apart from one another to successfully reproduce. However, as discussed in Section 2.1 (Biological Assessment), evidence of recent recruitment has been observed in a small number of locations in southern California despite these low densities. To guide our decision-making regarding recovery actions and where to focus recovery efforts, we need a better understanding of the species' population dynamics to evaluate the viability of low-density populations. Important information needs include (1) the abundance and spatial scale of thresholds required for successful spawning and recruitment, and (2) the most appropriate way to characterize these thresholds (e.g., number/m^2, number/crevice, nearest neighbor distance, etc.).

Illegal harvest of black abalone continues to pose a threat to the species' recovery. We have documentation of 13 black abalone poaching cases between 2007 and 2012, involving a total of 387 black abalone (unpublished data by Ian Taniguchi, CDFW, 13 July 2015). We likely do not have a complete record of black abalone poaching cases for this time period. Continued high demand for abalone on the black market provides a strong incentive for poaching. To better understand the level of poaching that is occurring and assess the impacts to black abalone, we need to improve data collection and collaboration with enforcement. We also need to improve coordination among Federal, State, and local enforcement to maximize and target efforts (given the limited number of enforcement personnel and the large area that needs to be covered) and to ensure that cases are prosecuted with the maximum penalties. Additional actions, such as increased penalties for poaching, may be needed to deter illegal harvest.

Mexico has not yet prohibited fisheries harvest of black abalone, although a fishing moratorium for black abalone has been proposed for August – December 2016 in Baja California. Improved communication and coordination is needed to understand abalone harvest regulations in Baja California and to assess harvest impacts on wild black abalone populations.

2.2.3 Disease and Predation

The recovery team identified withering syndrome as a primary threat to black abalone survival and recovery, as well as the threat of other pathogens and invasive species that are known to affect abalone species worldwide. Withering syndrome caused mass mortalities and near extirpation of populations throughout southern California and the disease continues to spread to populations in Monterey County and to the north. As discussed above, elevated water temperatures may increase the rate at which the disease spreads northward. Also, because increased black abalone abundance may facilitate disease transmission, recovery of populations may allow a resurgence of the disease in areas that have already been impacted. Populations of black abalone (in the wild and in captivity) may serve as sources of *Candidatus* Xenohaliotis californiensis. For example, DNA from *Candidatus* Xenohaliotis californiensis was found in the effluent of a shore-based farm in Santa Barbara (Lafferty et al. 2013). However, studies are underway to evaluate the biological implications of this effluent (e.g., does the presence of DNA from *Candidatus* Xenohaliotis californiensis indicate live bacteria that can infect animals?). Two factors may ameliorate the future impacts of the disease on black abalone populations: the discovery of a bacteriophage that infects and reduces the pathogenicity of *Candidatus* Xenohaliotis californiensis (Friedman and Crosson 2012, Friedman et al. 2014) and the potential for genetic resistance to withering syndrome. Recovery of black abalone will require continued research on the disease and monitoring of impacts on wild populations.

Other abalone diseases have emerged over the past several decades and include herpes virus, ganglioneuritis (and the related amyotrophia), vibriosis, and shell deformities (sabellidosis). To date, no outbreaks have been observed in wild black abalone populations and there is no evidence indicating that these diseases have been a major source of mortality in the recent past or currently for the species. However, black abalone are potentially susceptible to these diseases. Multiple sources and pathways exist for pathogens or invasive species to be introduced into wild populations, including aquaculture facilities and the movement of abalone (e.g., import, transfer) for aquaculture, research, and food/hobby markets (identified below under the Section 2.2.4, Inadequacy of existing regulatory mechanisms). Great care is needed to closely monitor and manage these sources and pathways, to protect wild populations from potentially devastating pathogens and invasive species.

A number of species prey on abalone, including other gastropods, octopuses, lobsters, sea stars, fishes, birds, and sea otters (Ault 1985, Estes and VanBlaricom 1985, Shepherd and Breen 1992). We will need to consider the presence and potential effects of these predators on black abalone survival when considering enhancement efforts such as translocation, aggregation, and outplanting. For example, enhancement efforts may need to focus on large juveniles or adults that are better able to withstand predation pressure. In addition, when feasible, we may consider temporarily moving predators from the local area where enhancement activities occur (e.g., moving sea stars out of the site).

Numerous entities have expressed concern regarding the potential threat that sea otters, which are also protected under the ESA, pose to black abalone recovery. The level of risk to black abalone recovery depends on many factors including: 1) abundance levels of sea otters and black abalone within areas of co-occurrence; 2) black abalone micro-distribution within rocky reefs (i.e., deep within crevice refuges or in more vulnerable, exposed areas); 3) predation rates; and 4) population recovery rates for both species. Current research indicates a positive association between sea otters and black abalone at San Nicolas Island (VanBlaricom 2015, unpublished data) and in areas that have not been affected by withering syndrome along the central California mainland coast (Raimondi et al. 2015). The relationship between the two species is not completely understood and may change as populations of sea otters and black abalone increase. The recovery team agreed that sea otter predation poses a low to moderate threat to the species' recovery, but that the level of predation on black abalone is uncertain, given that black abalone are intertidal and sea otters exhibit different predation strategies, specializing on certain prey items. Recovery efforts for black abalone should be closely coordinated with recovery efforts for sea otters.

2.2.4 The Inadequacy of Existing Regulatory Mechanisms

Two threats of greater concern and associated with inadequate regulatory mechanisms are illegal harvest and the potential introduction of pathogens and invasive species. Despite prohibitions on black abalone harvest in California since 1993, illegal harvest of black abalone continues to occur. From 1993 – 2012, most documented poaching cases occurred in San Luis Obispo County and Monterey County. Thus, poaching presents a potentially serious risk to populations unaffected by disease and located in areas with public access along the central coast of California. Poaching could also increase as black abalone populations recover, counteracting the benefits of natural recovery or enhancement efforts. Regulatory measures have been established, but continued efforts to enforce the regulations, monitor and document poaching cases, and deter poaching (e.g., via increased penalties, outreach, and education) are needed.

The introduction of pathogens or invasive species could pose a high risk to black abalone recovery, given the devastating effects these diseases have had on abalone in other parts of the world. Strict regulations are needed to ensure adequate monitoring whenever animals are moved (e.g., imports, transporting between facilities) for aquaculture, research, and/or food/hobby markets, to protect wild populations from pathogens and invasive species. In California, state regulations require regular abalone health monitoring at aquaculture facilities, control the importation/exportation of abalone between facilities, and restrict out-planting abalone from facilities that have not met certification standards. Some improvements to existing regulations are needed to further protect the species. For example, although a permit is required to import non-native abalone species into California, a permit is not needed to import native abalone species, even if the source of those abalone is outside of the U.S. This presents a potential risk because live abalone imported into the State could carry pathogens. Information was not available regarding the amount of native abalone species that are imported into the U.S. from other countries each year.

2.2.5 Other Natural or Manmade Factors Affecting the Species' Continued Existence

The recovery team identified two threats of greater concern within this category: (1) spills and spill response activities and (2) ocean acidification. In Section 2.2.1 above, we discussed the potential effects of spills and spill response activities on the quality and quantity of black abalone habitat. Here, we consider the potential effects of spills and spill response activities on individual black abalone, focusing on oil spills. We have very little information on how different types of oil affect black abalone, although there is evidence that black abalone were killed in past oil spills in California and Baja California (e.g., Torch oil spill, Tampico Maru spill). The impact of future spills on the species' status and recovery depends on several factors, including the type and amount of material spilled, the location, local environmental conditions, and the status of impacted populations. We cannot predict when and where spills will occur, but we can minimize the effects to black abalone by providing guidance on appropriate spill response activities, as well as providing guidance on post-monitoring efforts to learn from each spill and inform future response efforts. To develop this guidance, we need information on abalone habitat and presence throughout the coast; the effects of different types of oil on abalone habitat and different life stages of abalone (e.g., survival, physiology, reproduction); and methods to clean oiled abalone.

Ocean acidification is an emerging threat that could reduce larval survival and shell growth and increase shell abnormalities (Crim et al. 2011), as well as reduce the quality of larval settlement habitat by affecting the growth of crustose coralline algae. Our understanding of the potential effects to black abalone is highly uncertain, due to variability in local conditions throughout the coast, natural variation in ocean pH, species adaptability, and uncertainty in projections of future carbon dioxide emissions. Studies indicate that species exposed to varying carbon dioxide levels may be acclimatized to ocean acidification, with species-specific variation in the responses. North Pacific waters, including the California Current Ecosystem, experience fluctuations in pH, including relatively low seawater pH values due to a variety of natural oceanographic processes (Feely et al. 2004, Feely et al. 2008, Feely et al. 2009, Hauri et al. 2009). This exposure to low pH may make black abalone better able to adapt to the effects of ocean acidification if, for example, ocean acidification increases the duration or areal extent of acidified water. However, we do not know how black abalone may respond to further decreases in pH levels or to other effects of ocean acidification.

Other natural or manmade factors that could affect black abalone recovery include other environmental pollutants and toxins and the potential for larval entrainment at coastal facilities. We know of three cases where environmental pollutants and toxins directly affected the health and survival of black abalone. First, on the Palos Verdes Peninsula in the late 1950s and early 1960s, black abalone growth and reproduction declined due to poor water quality, resulting from the combined effects of a significant El Niño event and large-volume domestic sewage discharge by Los Angeles County (Leighton 1959, Cox 1962, Young 1964, Miller and Lawrenz-Miller 1993). Second, Martin et al. (1977) documented black abalone mortalities in Diablo Cove in the 1970s, resulting from the local power plant’s release of effluent containing toxic levels of copper. Third, the grounding of the S/V Blue Mist at Piedras Blancas, and subsequent release of ballast shrapnel, led to the loss of at least one abalone, and possibly more. Overall, environmental pollutants and toxins likely pose a low risk to recovery, given the limited temporal and geographic scope of these cases. Likewise, larval entrainment poses a low risk to recovery, given the low number of intakes (e.g., at power plants, desalination plants) along the coast and the small area affected (likely limited to the area directly around the intake).

2.3 Conservation Assessment

The objective of a conservation assessment is to identify the steps that have been or are being taken to address the species’ conservation needs. By considering the existing conservation actions and comparing them with threats identified in the previous section, the types of recovery actions that still need to occur should become clear. NMFS believes the following recent and ongoing protective efforts contribute to the conservation of black abalone: prohibitions on harvest to protect the species from further decline; regulations on aquaculture and abalone trade to minimize the potential spread of pathogens and invasive species; habitat protections within National Marine Sanctuaries and designated critical habitat; and past and ongoing research and monitoring efforts to evaluate the species' status and inform recovery efforts.

Commercial and recreational harvest of black abalone has been prohibited in California since 1993. Passage of the Thompson bill (AB 663) in 1997 created a moratorium on taking, possessing, or landing abalone for commercial or recreational purposes in ocean waters south of San Francisco, including all offshore islands. Poaching remains a problem, but CDFW has prioritized enforcement against abalone poaching. Current penalties for poaching include a fine between $15,000 and $40,000, possible imprisonment for up to one year, and forfeiture of any licenses, equipment, and vehicles used in the poaching incident. Given the high demand for abalone on the black market, however, increased penalties may be needed to effectively reduce poaching.

As discussed in Section 2.2.4 above, California closely monitors state aquaculture facilities and strictly regulates the transfer of abalone (e.g., imports, transporting between facilities) for aquaculture, research, and/or food/hobby markets. The regulations help minimize the potential for transmitting pathogens and/or invasives between facilities and to wild populations.

Three of NOAA's National Marine Sanctuaries in California contain intertidal habitat suitable for black abalone: the Channel Islands, Monterey Bay, and Gulf of the Farallones National Marine Sanctuaries. The sanctuaries strictly regulate discharges into its waters and require permits for allowable development activities or other activities that directly disturb the seabed within the sanctuary. These regulations protect water quality and physical features of black abalone habitat within the sanctuaries. Portions of the sanctuaries have also been designated as state marine reserves and marine conservation areas, providing additional levels of enforcement to protect black abalone from poaching.

There has been and continues to be great interest in black abalone conservation among researchers and managers throughout California. This is important because research and monitoring will play a critical role in implementing and tracking the recovery of black abalone. Our understanding of the species' status has been and will be based largely on the data provided by long-term monitoring to track population trends and the progression of WS along the coast. Much of these data are available because of the Multi-Agency Rocky Intertidal Network (MARINe), a partnership of agencies, universities, and private groups that not only conducts intertidal surveys, but provides this information to the public. Through MARINe, survey efforts are coordinated and data are collated to provide a picture of trends throughout the species' range. This monitoring has been expanded to include new sites (e.g., Golden Gate National Recreation Area, Point Reyes National Seashore Area, and the Farallon Islands) as well as revisiting areas that have not been surveyed since 1995 (Año Nuevo Island; Tissot, 1995).

At the same time, continued disease research is providing critical information on the effects of withering syndrome with and without the bacteriophage, the distribution of *Candidatus* Xenohaliotis californiensis and the bacteriophage throughout the coast, and the role of *Candidatus* Xenohaliotis californiensis effluent (from abalone facilities) in disease transmission. Research into critical questions regarding reproduction and recruitment dynamics (e.g., how fertilization success changes as distance between individuals increase) will directly inform our evaluation of population viability and enhancement efforts. Finally, there are ongoing efforts to develop captive breeding methods for black abalone, to support a better understanding of the species' reproduction and early life stages, as well as to support future laboratory research and outplanting efforts. Further research efforts are needed to address critical data gaps, as described in Section 3.3 below. These research and monitoring efforts are or will need to be authorized under ESA section 10 permits, or use other abalone species as surrogates.

2.4 Recovery Status Summary

Overall, black abalone have experienced severe declines in a large portion of their range, due primarily to the disease called withering syndrome. Recovery of black abalone will require protection of the healthy populations north of Monterey County, restoration of populations in southern California, and monitoring to assess the status of populations in Baja California. The northward progression of withering syndrome along the coast poses an imminent threat to the remaining healthy populations; however, the discovery of a bacteriophage that reduces the disease's pathogenicity could ameliorate the disease's effects. Populations in southern California continue to persist at low densities and the species' biology (broadcast spawning, limited larval dispersal) may limit or slow natural recovery, although recruitment is occurring and a few local populations are increasing in numbers. In addition to withering syndrome, threats of particular concern include poaching, spills (primarily oil spills) and their associated response activities, ocean warming and ocean acidification, and the potential introduction of other pathogens known to affect abalone. The effects of these threats on black abalone are highly uncertain, given the unpredictability of their occurrence (spills, introductions of pathogens) and the lack of information on species-specific effects. Research and monitoring will be critical to better understand these effects and to inform management decisions, recovery planning, and recovery efforts.

3. Preliminary Recovery Strategy

The preliminary recovery strategy describes initial decisions that have been made about how to recover the species. First, we describe the Priority Number that has been assigned to black abalone to rank the species' priority for recovery plan development and implementation. Next, we developed a Recovery Vision Statement to clearly define the overall goal of recovery. We then developed priority tasks which, if implemented, would improve the species' potential for recovery. Finally, we put together a preliminary action plan for NMFS. This preliminary action plan outlines potential coordination efforts between divisions within NMFS and with other entities involved in black abalone management and recovery. This is a starting point from which the full recovery strategy for the species will be developed.

3.1. Recovery Priority Number

The recovery priority numbers range from 1 (high) to 12 (low) and are based on magnitude of threat, recovery potential, and conflict with development projects or other economic activity (55 FR 24296). The recovery priority number for the black abalone is 3. We believe the species' risk of extinction is high, based on observed declines in abundance throughout more than half of the species' range and the continued threat of disease, poaching, and elevated sea-surface temperatures (linked to expansion and increased transmission rates of withering syndrome) due to short- and long-term climate change. We rated the species' recovery potential as moderate given the uncertainty of whether a successful captive breeding program can be used to supplement and/or create viable wild populations, and whether disease resistance among the extant population exists and can spread. Recovery will include increasing monitoring and enforcement and limiting anthropogenic impacts in areas where black abalone currently occur and/or will be reestablished. Conflicts may arise between the recovery of black abalone and economic interests if restrictions are needed to minimize or avoid effects on rocky intertidal habitats and coastal water quality. Abalone harvest is prohibited throughout southern California, but there is continued pressure to allow harvest of non-ESA-listed abalone at offshore island areas, which could put the species at greater risk of illegal take.

3.2. Recovery Vision Statement

Healthy, self-sustained populations of black abalone exist throughout their range in the wild and threats to the species have been sufficiently abated, such that the species no longer requires protection under the Endangered Species Act.

3.3. Priority Tasks to Facilitate Recovery

Priority tasks that facilitate the recovery of black abalone must address threats to wild populations and support efforts, both ongoing and planned, addressing the species' conservation needs. Priority tasks can be organized into three general categories: reactive, proactive, and tool-oriented. Reactive tasks are those focused on proximal (and/or acute) threats and conservation issues that require a response to reduce the imminent loss of black abalone. Proactive tasks address distal (and/or chronic) threats and conservation issues and are needed to bolster the long-term recovery of black abalone. Tool-oriented tasks focus on innovations, methods, and techniques that support the effectiveness and efficiency of both reactive and proactive tasks. All of the threats and conservation needs related to black abalone have components of all three categories.

The list of priority tasks that would improve the species' potential for recovery include, but are not limited to the following:

Reactive priority tasks:

- Spills and spill response activities during an incident: Assess impacted area for presence of black abalone and critical habitat. Prevent oiling in unaffected areas. Consider moving unaffected abalone to nearby safe areas in suitable habitat or bringing them into captivity.
- Poaching: Improve coordination among federal, state, and local enforcement groups and their attorneys to maximize enforcement effort, implement outreach and education, track poaching incidents (e.g., improvements to CDFW database), and evaluate methods to further deter poaching (e.g., increased penalties).
- Other Federal and non-Federal actions: Consult on Federal actions through the ESA Section 7 consultation process to ensure that federal activities do not adversely affect black abalone and their critical habitat. Federal actions are not only those carried out by Federal agencies but also actions funded or permitted by Federal agencies. Coordination on ESA Section 10 permits is also needed for non-Federal actions that affect black abalone or black abalone habitat. Specific actions highlighted by the recovery team include:
    - Projects involving sand transport and sedimentation effects: Consider potential effects on black abalone and their habitat (upcoast and downcoast or upland) and include monitoring of black abalone habitat adjacent to the project site; consider the spatial scale and severity of the impacts and the value of the habitats affected.
    - Vessel groundings: Consider secondary effects from materials released (e.g., ballast)
    - Coastal facilities with intakes/discharge in marine waters: Work with entities to evaluate potential effects on black abalone; where feasible, locate intake/discharge in deeper, sandy habitats, away from abalone habitat.

Proactive priority tasks:

- Introductions of pathogens and invasive species: Review existing regulations to identify and minimize potential pathways for introduction; conduct targeted outreach and education; continue health inspections at abalone facilities; and continue to document, collect, and analyze moribund individuals
- Develop GIS maps of black abalone habitat and black abalone presence (known and predicted) to identify areas important for black abalone and to guide assessment of threats and management decision-making. Data from the long-term monitoring programs can be used to develop these maps.

- Evaluate the feasibility and effectiveness of potential enhancement actions: Habitat restoration; local aggregation; translocation; and captive propagation and outplanting. These actions address the threat of low density, the main demographic threat to the species.
    - Pilot studies have been proposed to enhance recruitment via habitat restoration (e.g., remove encrusting organisms that have moved in following the decline of black abalone) and translocation of juveniles (via recruitment modules) (UC Santa Cruz).
    - Studies have been proposed to develop captive propagation methods for black abalone (NMFS Southwest Fisheries Science Center)
    - Pilot studies have been proposed or are underway that involve other abalone species as surrogates to evaluate the efficacy of local aggregation, translocation, and outplanting as recovery tools.
- Identify partners and develop monitoring of black abalone populations in Baja California, to better understand and track the status throughout the range

Tool-oriented priority tasks: Research tools and monitoring needs include:

- Spills and spill response activities prior to an incident: Develop best practices manual for black abalone to guide spill response and clean-up efforts as well as post-monitoring plans. This manual should include a protocol for deciding when to pre-emptively collect abalone. While the manual is in development, general guidance should be provided to inform decision-making should a spill occur.
- Long-term monitoring: Continue monitoring demographic trends in wild populations throughout the range, to evaluate the species' status, track the progress of disease along the coast, and identify areas where populations are experiencing greater stress (related to disease, elevated water temperatures, ocean acidification, etc.).
- Habitat evaluations: Monitor the quality of rocky intertidal habitat throughout the species' range
- Status/biology: Address uncertainties in species status/biology, such as reproduction and recruitment dynamics (e.g., spawning seasons, variation in fertilization success with distance between individuals, critical adult density needed to support reproduction and recruitment) and how abalone health and recruitment relate to oceanographic conditions.
- Population dynamics and connectivity: Conduct genetic and/or larval dispersal studies to evaluate population dynamics and connectivity throughout the coast.
- Disease studies: Continue studies on withering syndrome and the bacteriophage. Important research topics include: how the bacteriophage affects the thermal tolerance of abalone infected with *Candidatus* Xenohaliotis californiensis; the viability of *Candidatus* Xenohaliotis californiensis and the bacteriophage in sea water; the biological impacts of *Candidatus* Xenohaliotis californiensis effluent; development of qPCR methods to detect the bacteriophage; and the transmission dynamics of the bacteriophage. Also, evaluate the genetic basis for disease resistance, the geographic distribution of disease resistance, and the feasibility of developing phage therapy techniques (e.g., introducing the bacteriophage to wild

populations).

- Enhancement studies: Evaluate the effectiveness of habitat restoration to enhance recruitment potential for wild and outplanted populations. Develop reliable methods for determining the sex of individuals (e.g., genetic marker).
- Captive propagation methods: Develop captive propagation methods for black abalone, for research and enhancement efforts. Captive propagation methods have been and are being developed for other abalone species, and will inform development of methods for black abalone.
- Oil spill and response studies: Evaluate the effects of different types of oil on abalone habitat and on different life stages of abalone (e.g., survival, physiology, reproduction; smothering)
- Ocean acidification studies: Evaluate the effects of low pH on different life stages of black abalone. Until captive propagation methods are developed, studies may need to be conducted on other intertidal abalone species (e.g., green abalone, red abalone). Ocean acidification studies on red abalone are already underway at the University of California, Davis – Bodega Marine Laboratory.

3.4. Preliminary Recovery Action Plan

While the recovery plan is being developed, we provide this preliminary action plan to guide decisions that may affect the recovery of black abalone. This preliminary action plan focuses on measures that may be implemented by NMFS and identifies the major steps that could lead to full recovery, the needs that must be addressed immediately, and the options to conserve for later planning decisions. We will link and coordinate ESA programs to recovery planning and focus on developing stronger, more collaborative partnerships with other entities whose decisions affect black abalone recovery.

Major steps for recovery:

- Continue to monitor the status of populations throughout the species' range and track the progress of withering syndrome along the coast. NMFS' role involves supporting ongoing, long-term monitoring of black abalone populations through funding, coordination on ESA permitting needs, and participation in surveys, as well as establishing partnerships to obtain data and support monitoring in Baja California.

- Protect healthy populations from withering syndrome and other pathogens/invasive species, and minimize disease impacts (e.g. using genetic therapy to increase wild resistance to disease). NMFS's role involves supporting ongoing disease research and coordinating with CDFW on regulations to minimize pathways for introduction and spread of pathogens and invasive species.

- Increase the abundance and density of local populations affected by disease (e.g., south of Monterey County). Current low densities may not be enough to support reproduction and recruitment at rates to achieve natural recovery. Enhancement may be required and could include habitat restoration, local aggregation, translocation, and/or captive propagation and outplanting. NMFS' role involves coordinating with partners on pilot studies and ESA permitting needs.

- Coordinate with those within NMFS that are implementing ESA Section 6 (Coordination with States), Section 7 (Consultation on Federal Actions), and Section 10 (Scientific Research and Enhancement Permits; Incidental Take Permits for non-Federal entities) and with other internal and external partners to evaluate and address potential threats to recovery, including poaching, spills and spill response activities, other pathogens/invasive species, ocean acidification, and sea otter predation (USFWS).

Needs to address immediately:

- Develop GIS maps of black abalone habitat and black abalone presence (known and predicted) to identify areas important for black abalone and to guide assessment of threats and management decision-making.

- Baja California: Identify contacts and establish partnerships to obtain data and establish monitoring of populations in Baja California.

- Enhancement: Support pilot studies to evaluate and develop methods for habitat restoration; local aggregation; translocation; captive propagation and outplanting.

- Minimize potential for introductions of pathogens and invasive species: Work with CDFW to review existing regulations and identify ways to minimize potential pathways for introduction; continue health inspections at abalone facilities and provide public education and outreach about disease threats.

- Plan for spill response: Develop general guidance to inform decision-making should a spill occur while more comprehensive guidance is being developed.

- Poaching: Coordinate with CDFW to improve the statewide database and to evaluate methods to further deter poaching (e.g., increased penalties).

Options to conserve for later planning decisions:

- Enhancement activities: Based on results from pilot studies and long-term monitoring, we can evaluate the role of the different enhancement options for recovering black abalone (habitat restoration, local aggregation, translocation, captive propagation, and outplanting).

- Research needs: We identified several research needs to evaluate and address threats to species' recovery (e.g., research on disease, larval dispersal and distribution, oil impacts, ocean acidification). Further planning will involve prioritizing these needs, linking them to threats, identifying specific questions and partners to conduct the work, and coordinating with those partners. This planning should consider which needs are prerequisites to addressing other needs (e.g., captive propagation methods need to be developed before larval studies can be conducted), which are most urgent, and which constitute key information needs.

- Coordination with USFWS on sea otter recovery in California. The USFWS and NMFS agreed to share recovery information and coordinate recovery actions to best facilitate the recovery of both sea otters and abalone (e.g. share planning and implementation meetings and cooperate in working groups) ("Memorandum of Understanding," 2013).

4. Pre-Planning Decisions

4.1. Product

Draft and Final Recovery Plan for black abalone

4.2. Scope of Recovery Effort

Species _X_ Recovery Unit __ Multi-Species __ Ecosystem __

4.3. Recovery Plan Preparation

NMFS has appointed a 13-member recovery team, consisting of biologists with expertise in marine invertebrate and rocky intertidal biology/ecology, as well as conservation biology and policy. The NMFS WCR PRD will lead preparation of a draft recovery plan for black abalone, using the most recent Recovery Planning Guidance from September 2007. Primary authorship of the Recovery Plan will be the responsibility of NMFS staff. Outreach by NMFS to state, federal and private partners will be central to the recovery effort. We will identify and coordinate with external partners, as well as internal partners (e.g., the National Ocean Service, Restoration Center, Science Centers, Office of Law Enforcement) to develop and implement recovery for the species.

4.4. Administrative Record

The administrative record will be housed in the NMFS WCR PRD Long Beach Office.

4.5. Schedule and Responsibility for Recovery Plan

Completed:

September 2011
- NMFS technical recovery team established

October 2011
- Kick-off meeting with recovery team
- Draft Terms of Reference for the recovery team

July 2013 – February 2014
- Conducted several recovery team meetings, including one in-person meeting
- Conducted and finalized the threats assessment

July 2015
- Conducted in-person recovery team meeting
- Reviewed the threats assessment and confirmed that overall ratings have not changed
- Discussed and drafted recovery actions to address threats
- Initiated development of recovery goal and objectives

To Be Completed:

July 2015 – December 2016
- Finalize recovery outline
- Meet with recovery team to develop recovery objectives and criteria
- Develop draft recovery plan

January – March 2017
- Issue draft recovery plan and publish Federal Register Notice
- Initiate public review and comment
- Initiate independent peer review

Summer 2017 - 2018
- Revise draft recovery plan and finalize

Summer 2018
- Post final plan on website
- Outreach to initiate recovery plan implementation for priority actions

4.6. Outreach and Stakeholder Participation

While NMFS is responsible for adopting recovery plans, the plans will have a greater likelihood of success if they are developed in partnership with entities that have the responsibility and authority to implement recovery actions. These entities include federal, state, and local agencies; academic institutions; regional planning organizations; special interest groups; non-governmental organizations; and members of the public. To facilitate communication with these various stakeholders, we will develop a webpage that provides technical information about black abalone life history, status, threats, and recovery needs, as well as updates on the recovery planning process. We also plan to communicate with stakeholders and the public through outreach events, workshops, and presentations in various forums. As needed, we may host public meetings and workshops to further engage stakeholders and the interested public in recovery planning and implementation.

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