2009 NMFS West Coast Workshop on Abalone Species of Concern

1 September 2009

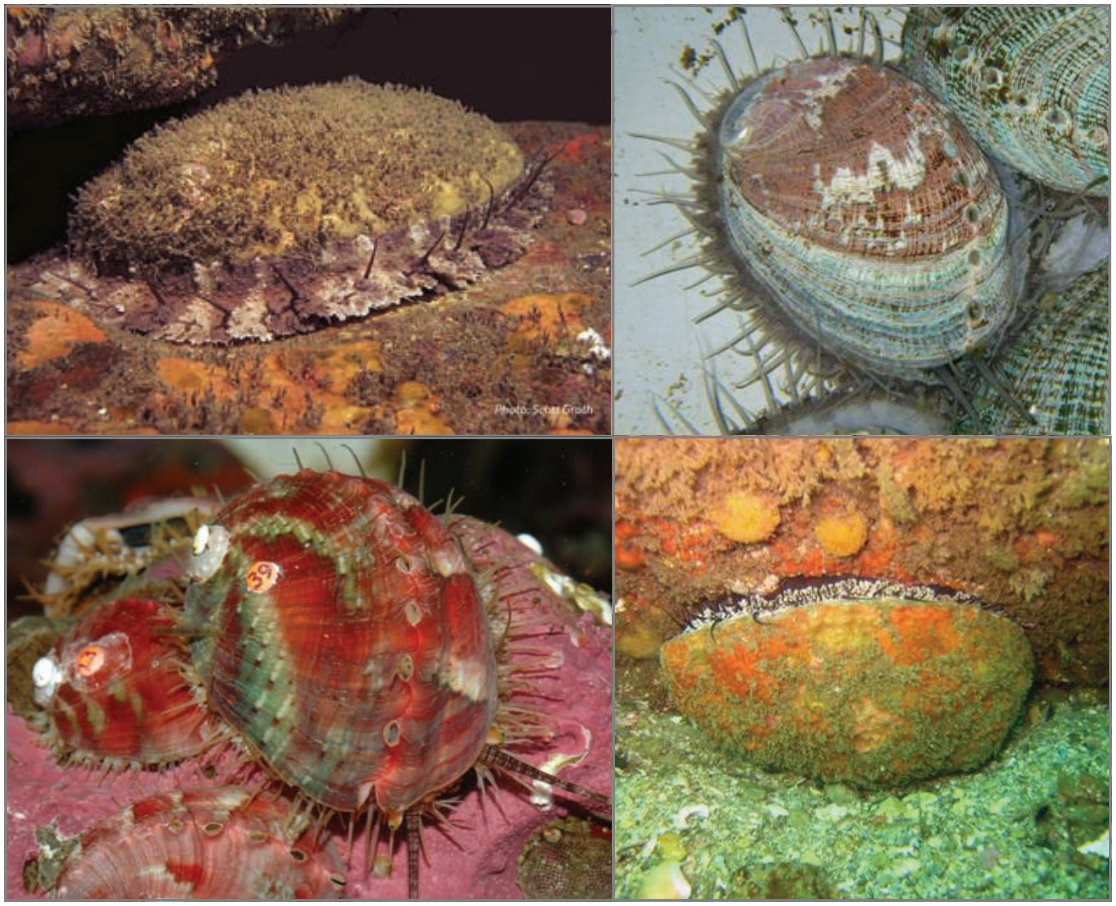

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Photo credits: Flat abalone (top left; Scott Groth, Oregon Department of Fish and Wildlife); green abalone (top right; Brent Scheiwe, Redondo SeaLab); pinto abalone (bottom left; Josh Bouma, Washington Department of Fish and Wildlife); pink abalone (bottom right; Ian Taniguchi, California Department of Fish and Game)

SUMMARY

On 1 September 2009, the National Marine Fisheries Service (NMFS) Northwest Region (NWR) and Southwest Region (SWR) Protected Resources Divisions held a joint Species of Concern (SOC) workshop for abalone on the U.S. West Coast. The NMFS SOC Program was established to draw attention to and focus proactive conservation efforts on species for which there is some concern or uncertainty regarding status and threats. Species of concern are not listed under the Federal Endangered Species Act (ESA) and do not receive protection under the ESA.

The workshop focused on the three abalone species of concern: green abalone (*Haliotis fulgens*), pink abalone (*H. corrugata*), and pinto abalone (*H. kamtschatkana*). Flat abalone (*H. walallensis*) were also discussed as a potential species of concern. The purpose of this workshop was to bring together current and potential SOC partners, including researchers and resource managers, in the abalone community to raise awareness of the SOC program, build partnerships, and gather information about the biology, status, threats, and research and conservation needs of these four abalone species. The workshop also provided a forum for participants to discuss and identify research and conservation actions to address threats to the species.

Green abalone, pink abalone, pinto abalone, and flat abalone have been subject to common threats such as overfishing and disease that have resulted in population declines and reduced local densities. The species also share common research and conservation needs, including the need for a better understanding of basic life history characteristics and increased public awareness and education about abalone. High priority actions for all four species include:

- Optimization of culture methods and restoration actions (i.e., outplanting and enhancement techniques);
- Understanding the role of reproductively isolated abalone (i.e., is it better to transplant isolated individuals to aggregation areas or leave them where they are?);
- Population monitoring to identify high density areas;
- Long-term monitoring and tagging studies; and
- Combating poaching through education and enforcement.

The purpose of this summary is to inform NMFS and our SOC partners regarding the research and conservation needs and priorities for these abalone species of concern, to aid in focusing our efforts for these species over the coming years. NMFS will continue to work with the SOC partners through regular communication and coordination to discuss and address the research and conservation needs identified by the workshop participants.

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Meeting Date and Location

The workshop was held on Tuesday, 1 September 2009, at the Northwest Fisheries Science Center Auditorium in Seattle, Washington.

Workshop Participants

Brian Allen – Puget Sound Restoration Fund, Washington

Allen Andrews – NMFS Pacific Islands Fisheries Science Center, Hawaii (previously with the Moss Landing Marine Laboratories, California)

Josh Bouma – Washington Department of Fish and Wildlife

John Butler – NMFS Southwest Fisheries Science Center, California

Joth Davis – Baywater, Inc., Washington

Carolyn Friedman – University of Washington School of Aquatic and Fishery Sciences

Scott Groth – Oregon Department of Fish and Wildlife, Marine Resources Program

Rick Gustafson – Northwest Fisheries Science Center, Washington

Bob Kiel – Seattle Aquarium, Washington

Dwayne Meadows – NMFS Headquarters

Eric Murray – NMFS Northwest Region, Oregon

Melissa Neuman – NMFS Southwest Region, California

Betsy Peabody – Puget Sound Restoration Fund, Washington

Laura Rogers-Bennett – University of California Davis

Don Rothaus – Washington Department of Fish and Wildlife

Mike Schaadt – Cabrillo Aquarium, California

Brent Scheiwe – Redondo SEA Lab, California

Bob Sizemore – Washington Department of Fish and Wildlife

Kristi Straus – University of Washington School of Aquatic and Fishery Sciences

Ian Taniguchi – California Department of Fish and Game

Brent Vadopalas – University of Washington School of Aquatic and Fishery Sciences

Susan Wang – NMFS Southwest Region, California

Jordan Watson – Puget Sound Restoration Fund, Washington

Background and Introduction

Eric Murray, NMFS Northwest Region (NWR) and Susan Wang, NMFS Southwest Region (SWR)

This workshop was developed in response to interest expressed by participants at the 2008 Cooperative Conservation Workshop held by the NMFS Headquarters (HQ) Office. Support for this workshop was provided by the NMFS 2009 Species of Concern (SOC) internal funding program.

Purpose and goals for the day were to:

- Learn about the SOC program, including funding opportunities and the process for how species are added or removed from the SOC list.
- Bring together experts in the abalone community to build partnerships.
- Gather information about the biology, status, threats, and current research and conservation efforts for each species.
- Identify and prioritize research needs and conservation actions for each species.

This workshop focused on four abalone species, three of which are currently on the SOC list and one that is being considered for addition to the list:

Current SOC:

- Green abalone (*Haliotis fulgens*)
- Pink abalone (*H. corrugata*)
- Pinto abalone (*H. kamtschatkana*)

Potential addition to SOC list:

- Flat abalone (*H. walallensis*)

National Species of Concern Proactive Conservation Program Overview

Presentation by Dwayne Meadows, NMFS HQ, Office of Protected Resources, National SOC Program Coordinator

Program Origins and Purpose: The SOC program was created for species that NMFS wants to focus conservation attention on. It is not the "candidate" species list or a queue for Endangered Species Act (ESA) listing. The purposes of the SOC program include:

- Identifying species potentially at risk
- Increasing public awareness
- Identifying data deficiencies and uncertainties in status and threats
- Stimulating research efforts
- Fostering voluntary conservation efforts
- Taking proactive conservation actions

Species of Concern List: There are currently 39 species on the SOC list. Species may be identified for inclusion on the SOC list based on concerns regarding their status (demography, threats), or when ESA-listing for a species is determined to be "not warranted" but concerns remain. Species on the SOC list are eligible for funding under the SOC program. Each year the SOC program funds on-the-ground conservation or planning projects through an external grant program and an internal grant program.

External grant program: A competitive program for state, local, or tribal entities with management authority over the species. Partnering with other entities is allowed and interstate partnerships are encouraged. Awards can range from one to five years. Multi-year proposals that are awarded do not need to compete each year. The call for proposals is announced in the *Federal Register* in the December omnibus grants notice. The total funds available vary by year, but have averaged about $700,000 per year in the past few years. There is no match requirement.

Internal grant program: A competitive program for NOAA staff. Partnering with non-NOAA entities is allowed. Awards are for one year. The call for proposals is usually announced in February or March, after the external program is announced. The total funds available vary by year, but have averaged about $300,000 per year in the past few years, with a limit of $35,000 per proposal.

Outcomes and Future Plans: NMFS has developed many partnerships through the SOC grant programs and continues to raise awareness of the species among potential partners and the public through stakeholder workshops and outreach products. Many informative documents are available at the SOC web site (www.nmfs.noaa.gov/pr/species/concern/), including species fact sheets, status reports, a programmatic flyer, and the SOC strategic plan. In the future, NMFS plans to expand the SOC program by adding new species to the list (about 50 were identified for consideration at the 2008 Cooperative Conservation Workshop). NMFS also plans to evaluate the performance of the grant programs on a regular basis by reviewing the annual reports, and to increase technical assistance and training for partner states and territories.

Process for Adding/Removing Species from the Species of Concern List

Presentation by Eric Murray, NMFS NWR SOC Representative

Eligibility: All species for which NMFS has potential management authority are eligible to be species of concern (i.e., marine and diadromous species). Species are identified by the public, NMFS Science Centers, Fishery Management Councils, State agencies, Tribes, and other groups, or through the ESA listing process (i.e., where listing is "not warranted" but concerns remain).

Process for adding a species to the SOC list: A species may be added to the SOC list based on available information on the status, threats, and concerns regarding the species.

(1) The NMFS Regional Office develops a draft species fact sheet for review by the NMFS Science Center, HQ PRD, and other experts.

(2) The Regional Administrator sends the final draft fact sheet and request to add the species to NMFS HQ for review.

(3) The Director of Protected Resources makes the final review and decision.

(4) Once approved, the final fact sheet is posted on the web site and the public informed of the addition to the SOC list.

Process for removing a species from the SOC list: A species may be removed from the SOC list if the species' status improves or the threats and concerns have been mitigated. A species may also be removed if it is listed as threatened or endangered under the ESA.

(1) The NMFS Regional Office prepares a draft status report for review by the NMFS Science Center and NMFS HQ PRD.

(2) The Regional Administrator transmits the final status report to NMFS HQ.

(3) The Director of Protected Resources makes the final review and decision.

NMFS informs the public of additions or removals from the SOC list via the web site and/or a notice published in the *Federal Register*. The SOC list is reviewed annually to determine if updates to the fact sheets or the SOC list (additions/removals) are needed.

Review of the Species

Workshop participants presented information on the life history, biology, status, threats, and research and conservation needs of each abalone species. Following the presentations, participants discussed the threats to the species and the research and conservation needs of each species in detail. The presentations and discussions are summarized below. The threats are summarized in Table 1.

Pinto Abalone (*Haliotis kamtschatkana kamtschatkana*)

Presentation: Pinto Abalone (*Haliotis kamtschatkana kamtschatkana*) status and restoration summary, by D. P. Rothaus, J. Bouma, B. Vadopalas, K. M. Straus, B. Stevick, J. P. Davis, B. Peabody, P. Zohovetz, P. Dinnel, and C.S. Friedman. Presented by Carolyn Friedman (University of Washington).
(Photo of pinto abalone at right by Josh Bouma)

Summary of Species Information

Distribution: Sitka, AK, to Point Conception. Pinto abalone are the northernmost abalone species in the eastern Pacific Ocean and the only known abalone species found in inland waters of Washington state.

Oregon: Naturally very rare in Oregon. No directed surveys for the species have ever occurred, but shells have been found. The first confirmed live pinto abalone in Oregon was found at Orford Reef the week of 7 December 2009 by an urchin diver (pers. comm. with Scott Groth, Oregon Department of Fish and Wildlife (ODFW), via phone call with Susan Wang, NMFS, on 14 December 2009).

Genetics: The two subspecies, pinto (*H. k. kamtschatkana*) and threaded (*H. k. assimilis*) abalone, are not genetically distinguishable. Divergent pintos have been found at one site on the San Juan Islands.

Status: From the 1990s to 2000s, size frequencies of monitored populations in Washington suggest little or no recruitment.

Research and conservation actions in Washington state include: Genetic and disease (Withering Syndrome) assessments; captive rearing optimization; tolerance and behavior experiments; adult aggregation; larval seeding; experimental outplanting (captive-bred abalone shown below; photo by J. Bouma).

Pilot outplanting studies: Disease screening is conducted and breeding methods are done with genetics in mind. Lone abalone are collected as wild broodstock for breeding and placed back in the wild in aggregations.

- The majority of mortalities probably occurred early in the experiment.
- Average growth in shell length among survivors was 19.7 mm. The abalone that died showed little growth.
- Abalone at larger outplant sizes had high survival rates: 20% at 25 mm, 50% at 34 mm; and 75% at 41 mm.

Rearing methods: In experiments with conventional vs. habitat-enriched tanks, no differences in survivorship were observed but abalone reared in enriched tanks showed more habitat changes. The effect on survival in the wild needs to be determined.

Research, monitoring, and conservation efforts underway

- Fisheries: Closed in Canada since 1990 and in the U.S. since 1994, except for the Alaska recreational fishery. No fishery has ever existed for pinto abalone in Oregon.
- Monitoring: Washington Department of Fish and Wildlife (WDFW) began a monitoring program in 1992. The future status of the program is uncertain.
- Ongoing research efforts in Washington state: Broodstock collection, development of captive rearing methods, genetic diversity studies, and disease screenings and assessments to determine susceptibility to disease.
- Ongoing public outreach throughout Washington using posters and stickers.

Research and conservation efforts needed

- Greater public awareness and education for pinto abalone and all abalone species.
- Studies to address the lack of basic life history information.

Developing/expanding population monitoring program

Locations to monitor and potential partners, including areas throughout California to monitor threaded abalone (*H. kamtschatkana assimilis*, a subspecies of pinto abalone):

Alaska Coast: Alaska Department of Fish and Game, NMFS Auk Bay Lab (POC: Scott Walker, Doug Woodby)

Strait of Georgia: Canada's Department of Fisheries and Oceans (DFO) – see status report for SARA listing in 2009.

Strait of Juan de Fuca: WDFW and Washington Coast partners

San Juan Archipelago, including established survey sites since 1979 and 1992: WDFW and Washington Coast partners

Washington outplanting sites: WDFW and Washington Coast partners

Washington Coast: Jamestown S'Klallam Tribe, Makah Tribe (POC: Yongwen Gao), Northwest Indian Fisheries Commission (POC: David Fyfe), Olympic Coast National Marine Sanctuary (POC: Carol Berthal), Puget Sound Restoration Fund, REEF (POC: Jana Nichols), SeaDoc Society, Tulalip Tribe, University of Washington, WDFW (POC: Bob Sizemore), Western Washington University.

Oregon Coast: ODFW

Northern California (Sonoma, Mendocino, and Monterey counties): California Department of Fish and Game (CDFG), Stanford Lab

Southern California to Mexico: CICESE (Ensenada) and other potential partners identified for green abalone and pink abalone (see list below in the next section).

Green Abalone (*Haliotis fulgens*) and Pink Abalone (*H. corrugata*)

Presentations:

Green abalone (*Haliotis fulgens*), by Brent Scheiwe (Redondo SEA Lab)

Pink and green abalone: Status, threats, current conservation efforts, by Ian Taniguchi (CDFG)

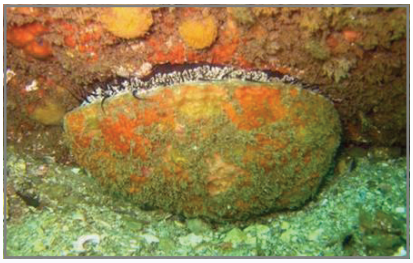
(Photo at left of green abalone by Ian Taniguchi, CDFG)

Summary of species information:

Geographic range: Pt. Conception, California, to Baja California. There is evidence of a few individual abalone on the Palos Verdes Peninsula. Natural populations are extremely low, especially at mainland sites.

Depth range: Green abalone – intertidal to 18 meters depth.

Pink abalone – 6 to 36 meters depth.



Pink abalone (photo by Ian Taniguchi)

Commercial fisheries: Began in the early 1940s; closed in 1995. Pink, green, and red abalone were the primary commercial species harvested.

Causes of decline: Sea otter population expansion into Southern California, increased harvest (expansion of fishing and technology), Withering Syndrome disease.

Threats to recovery: Withering Syndrome, poaching, environmental factors (e.g., El Niño, climate change; warmer waters exacerbate Withering Syndrome and impact food availability), predation (e.g., by sea otters).

Conservation efforts:

- CDFG's Abalone Recovery and Management Plan (ARMP) for all California abalone. Recovery goals: Reverse abalone population declines, establish self-sustaining populations throughout the historic range, and achieve population levels to sustain a fishery in at least three-fourths of the historic range.
- CDFG's aggregation/translocation/tagging studies at Santa Catalina Island and San Clemente Island.
- CDFG developing/supporting existing culture programs (for adult/larval outplanting studies). Conducting genetic and disease research and establishing marine protected areas (MPAs).
- Redondo SEA Lab green abalone project: Currently holding 36 broodstock and over 1,500 juvenile/subadults. Conducting rearing and broodstock conditioning experiments and preparing for outplanting trials.

Research, monitoring, and conservation efforts underway

- Fisheries: Closed in 1995. Abalone moratorium adopted in 1997 in California.
- Implementation of California's ARMP. How often is monitoring conducted to evaluate the achievement of recovery criteria?
- Ongoing development of aggregation, translocation, and outplanting methods.
- Ongoing genetics and disease research.
- Establishment of MPAs throughout California.

Research and conservation efforts needed

- Development of captive propagation methods for population enhancement.
- Efforts to minimize the threat of disease.
- Studies to address the lack of basic life history information.

Developing/expanding population monitoring

Locations to monitor green abalone and pink abalone populations in California and potential partners:

Mainland Areas: Cortez Bank, Dana Point, Orange County (e.g., Laguna Beach and other locations), Palos Verdes, Point Loma

- Potential Partners: Aquarium of the Pacific divers, Monterey Bay National Marine Sanctuary divers, Scripps kelp forest monitoring program (POC: Paul Dayton), SONGS monitoring program (existing transect monitoring), The National Phenology Network (POC: Dwayne Meadows), other volunteer divers (e.g., Baykeepers)

Channel Islands: Anacapa, San Clemente, San Miguel, San Nicolas, Santa Barbara, Santa Catalina, Santa Cruz, and Santa Rosa Islands

- Potential Partners: Aquariums (volunteer diver programs), Catalina Conservancy volunteer divers, Channel Islands National Park (includes Anacapa, San Miguel, Santa Cruz, and Santa Rosa islands), Marine Life Protection Act (MLPA) process partners, National Marine Sanctuaries, PISCO, Reef Check.

Green abalone settlement tanks and juvenile rearing tanks (photos by Brent Scheiwe).

Flat Abalone (*Haliotis walallensis*)

Flat abalone (photo by Scott Groth, ODFW)

Presentations:

Flat Abalone, *H. walallensis*, and the species of concern designation, by Laura Rogers-Bennett (UC Davis)

Abalone in Oregon, by Scott Groth (ODFW)

Summary of species information

Narrow distribution: Northern California to Washington. Occurs throughout Oregon, with largest concentrations on the South coast. Only one record of a flat abalone found in southern Washington.

Depth range: Most common at 20 to 70 feet in areas within vegetated rock. Occasionally found intertidally.

Habitat: Cryptic, significantly greater numbers in MPAs with red sea urchins than in MPAs with no sea urchins.

Commercial fishery in Oregon: Conducted from 2001 to 2008, with one permit and an annual limit of 3,000 pounds. Closed in January 2009.

Population size estimates:

- California: An estimated 75% decrease from 71,404 abalone in 1971 to 16,544 abalone in 1999 to 2001, based on habitat model.
- Oregon: Fishery landings from 2001 to 2008 equaled 21,796 pounds, for an estimated 24,218 abalone fished (assuming 0.9 pounds per abalone and no new recruits to the fishery).

ODFW's key concerns:

- Current management tools proved ineffective to prevent stock collapse
- Underfunded, lack of fishery independent data
- Very limited biological information for flat abalone
- CPUE/size decline
- Declines in density and recruitment from fishery dependent surveys

Lessons from fishery:

- Avoid commercial abalone fisheries
- Start with a small number of fishers and poundage
- Include spatial management from the start
- Enforceability and monitoring of adherence to fishery regulations must be very high

Research, monitoring, and conservation efforts underway

- Fisheries: Closed in California in 1995 and in Oregon in 2009.
- Continued monitoring efforts. Evidence of recruitment has been found despite declines.

Research and conservation efforts needed

- Critical information needs: Geographic range, population genetics, population status for 2009, ongoing recruitment monitoring, Allee effects (nearest neighbor distance), size at first reproduction.
- Studies are needed to address the lack of basic life history information, especially age, growth, and longevity studies.
- Establishment of a tissue library across the species' range.
- Data can be gained through historical records: Collections, presence surveys, notes from urchin surveys, intertidal surveys. Work with the recreational fleet, academics, and other agencies on specific goals.

Developing/expanding population monitoring

Locations to monitor flat abalone populations and potential partners:

Oregon Coast to Monterey Bay, CA (more specific locations?)

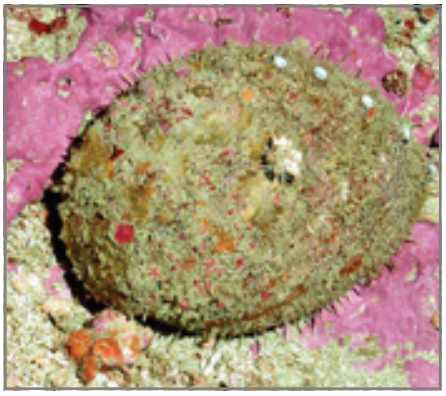
- Potential Partners: CDFG, ODFW, Oregon Coast Aquarium, PISCO

Table 1. Summary of threats identified for flat, green, pink, and pinto abalone. Potential sources of the threats are listed.

THREAT	SOURCES	FLAT	GREEN	PINK	PINTO
Allee effects that continue to threaten the species	Historic overfishing, disease, poaching, other factors that have led to population declines	X	X	X	X
Disease	Bacteria (e.g., Withering Syndrome), invasive species, Labyrinthuloides haliotidis, disease transfer between hatchery and wild populations		X	X	X
Habitat modification due to absence of abalone and other bioengineering invertebrates (e.g., red abalone – provide spine canopy, maintenance of algal community)	Abalone/urchin fishery, disease, historic overfishing, poaching, other factors that have led to declines in the population.	X			X
Habituation in hatcheries	Research/restoration, aquaculture activities				X
Low densities and current distribution pattern	Historic overfishing (and current overfishing for flat abalone)	X	X	X	X
Ocean acidification (affects shells, fertilization, development)	Global warming	X	X	X	X
Ocean warming	Greenhouse gases, warm water effluent from facilities such as power plants (localized warm water temperatures)	X	X	X	X
Poaching	Inadequate enforcement, funding, and education	X	X	X	X
Pollution	Sewage outflow, agricultural/urban runoff, heavy metals, environmental estrogens, other organics (PCBs, PAHs), military (jet fuel, etc), increased natural gas production along the coast	X	X	X	X
Predation	Sea otters, Pycnopodia helianthodes, other fish and invertebrates, invasive species		X	X	X
Reduced quantity or quality of food resources	Kelp decline, invasive species, intra-specific and/or inter-specific competition				X
Sedimentation, increased turbidity	Upland forest practices, shoreline development	X	X	X	X

Presentations on ESA-listed Abalone Species and Lessons Learned

White Abalone (*Haliotis sorenseni*)



White abalone (photo by John Butler, NMFS

Presentations:

Bomb radiocarbon dating of white abalone (*H. sorenseni*): Investigations of age, growth, and lifespan, by A. H. Andrews, R. Leaf, L. Rogers-Bennett, H. Hawk, G. Cailliet, K. Coale, and T. Brown. Presented by Allen Andrews (NMFS PIFSC)

White abalone (*H. sorenseni*): Biology and current status, by Mike Schaadt (Cabrillo Marine Aquarium)

Summary of species information

Federal status: Endangered (66 FR 29046, May 29, 2001)

Distribution: Pt. Conception to Mexico, mostly in deep water off Channel Islands at depths of 4.5 m or deeper. Most abundant at 24.5 to 30.5 meters.

Average shell length: 13 to 20 cm (maximum 25 cm).

Maximum estimated age: 30 to 40 years. Bomb radiocarbon dating techniques were used to age white abalone shells with known collection dates and found that white abalone can have highly variable growth and a long lifespan.

Predators: Seastars, crabs, and octopus feed on the young. Sea otters, octopus, and humans feed on adults.

Parasites: Sabellid worm *Terebrasabella heterouncinata* (invasive from South Africa). Also, parasitic snails, worms, and boring clams can inhabit the shell.

Diseases: Withering syndrome.

Reasons for decline: Commercial and recreational harvest. Populations became reproductively extinct in the 1990's (i.e., the few animals left were too far apart to reproduce).

Recovery actions:

- Captive breeding program by the Channel Islands Marine Resource Institute in Ventura (POC: Tom McCormick). In 2008, the stocks were moved to the Bodega Marine Laboratory to continue the program.
- Cabrillo Aquarium: Currently maintains a public display of white abalone. Future plans for the white abalone include spawning, rearing, and gamete cryopreservation experiments.

Black Abalone (*Haliotis cracherodii*)

Presentation:

Demographic signs of small-scale recovery of black abalone (*Haliotis cracherodii* Leach, 1814) on an isolated island off the coast of southern California, USA, by M. Neuman, D. Witting, and G. VanBlaricom. Presented by Melissa Neuman (NMFS)

Black abalone (photo by Cris Elfes, University of Washington)

Summary of species information

Federal status: Endangered (74 FR 1937, January 14, 2009)

Distribution: Point Arena (Mendocino County, CA) to Northern Baja California. Rare north of San Francisco and south of Punta Eugenia.

Depth range: Intertidal to 6 m depth.

Habitat: Coastal and offshore rocky intertidal habitats. Open bedrock, crevices, narrow ledges, and overhangs.

Reasons for decline: Fishing pressure coupled with Withering Syndrome (first appeared at the Channel Islands in 1986) led to mass mortalities throughout southern California. Some populations have declined by 99%. The commercial fishery closed in 1993.

Threats: Withering Syndrome, poaching, pollution, effects of climate change, activities affecting rocky intertidal habitat (e.g., coastal development).

Status: Estimated 95% risk of extinction in the next 30 years, primarily due to Withering Syndrome.

Signs of local recovery: Evidence of recent recruitment at two Channel Island locations. Evidence of potential disease resistance.

Recovery efforts:

- Continuation of long-term population monitoring at the Channel Islands and along the California coast.
- Channel Islands: Tagging studies to examine growth and survival.

DISCUSSION OF RESEARCH NEEDS AND CONSERVATION ACTIONS FOR GREEN, PINK, PINTO, AND FLAT ABALONE

The workshop participants discussed and identified research and conservation needs for the four current and potential abalone species of concern. They then discussed and identified potential next steps to address these needs, as well as issues to consider for the development and/or expansion of population monitoring programs for these species. These discussions are summarized below.

Research and Conservation Needs and Actions:

- Remember our first goal is to *DO NO HARM!*
- *Optimize culture methods* for genetic diversity and survival. Need to understand fundamental culture methods, especially for species where spawning and fertilization success has been difficult to attain. Apply lessons learned from salmon aquaculture.
- *Develop optimal restoration actions* (i.e., outplanting and enhancement techniques), keeping in mind carrying capacity. Monitoring is important.
- Understand the *role of reproductively isolated abalone*. Is it better to transplant isolated individuals to aggregation areas, or leave them where they are?
- Develop *threshold levels/target densities* for restoration. What are the species-specific threshold densities for successful reproduction?
- *Long-term tagging and monitoring* to study abalone movements and aggregations.
- Population monitoring is important, particularly to identify where *high density areas* are or may be.
- Identify and map habitat. *Map potential habitat* and use habitat maps to estimate population levels.
- *Outplanting module*: Bob Kiel (Seattle Aquarium) presented a module he developed for outplanting abalone. He would like to find partners to help test out the module for possible use in abalone aquaculture and recovery.
- *Combat poaching* through education and enforcement (e.g., increase penalties, educate enforcement on the importance of abalone conservation)
- *Public education and outreach* to develop environmental stewardship and knowledge of abalone is important. Good examples: K-12 educational programs, Canada's educational programs.
- *CITES listing* for the SOC abalone? This would be helpful for public outreach/education and enforcement. A CITES listing should consider all abalone species, not just the ESA-listed species (i.e., white abalone and black abalone).
- *Demographic modeling*: Gain a better understanding of population demography.

- Develop *aging methods* for abalone: Other methods for species (O^{18} methods) or testing of bomb carbon dating methods. Increase utility by producing region-specific references. Need shells with known collection dates.
- Understand the *genetic diversity* of the species throughout their ranges
- Make available *molecular species identification markers*
- Understand *disease resistance*, especially in disease endemic zones
- Identify *fisheries interactions* (e.g., urchin harvest and abalone impacts)
- Understand *predator-prey interactions* (e.g., in MPAs).
- Understand *abalone endocrinology*. Make contacts and get students involved in established labs. Gary Cherr (UC Davis) is interested.
- *Sex determination studies* (e.g., when and how sex is determined?). Important given concern over introduction of estrogens into marine waters.

Discussion of next steps to address these actions:

- *Focus on optimizing culturing and outplanting methods for restoration and make sure monitoring is conducted.*
- Continue, and if necessary expand, population monitoring programs.
- Identifying and mapping habitat: Identify and compile the available data. Identify where data are needed. See Gary Greene's maps.
- Aging techniques: For each species, determine if there is an archive of shells with known collection dates. Live collections are the best.
- Identify experts for each of the actions identified above and initiate contact.
- Develop relationships between universities and natural resource agencies and get student involvement on projects, like genetics studies. Agencies can provide samples to the universities for analysis.
- NMFS: Establish regular communication with abalone contacts along the coast, including the workshop participants and other abalone contacts.

Issues to Consider and Discuss Regarding a Monitoring Program

The participants identified several concerns and issues to consider and discuss in follow-up discussions with the group (potentially in smaller groups by species) regarding development and/or expansion of abalone monitoring programs.

Survey methodology: Varies by area and population density.

- The data can still provide useful information as long as the methods and their constraints are understood.
- Options: maintain an established survey methodology, or establish some kind of calibration or adjustments to make the data comparable.
- Consider DFO's survey methodology: Paul Breen's methodology as described in the COSEWIC report (http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_northern_abalone_0809_e.pdf). Recommend reading the report and consider how this methodology might work for the different species/areas.

Abalone recruitment modules (ARMs): Designs vary by species and by life history stage.

Training: Consider what kind of diver training would be needed and how it would be conducted. Much time and effort is needed to develop an abalone search image. Training would be a large investment.

- Would this be a NOAA Program? If so, divers must be NOAA-certified.

Role of NOAA: Participants suggested that NOAA should play a coordinating and supporting role for such a program. For example, coordinating meetings, providing funding (through the SOC funding program or other programs), providing a central location for data management, etc.

Priority of monitoring vs. other research/conservation needs: Participants suggested examining the level of data available for each species and determining whether the focus should be on additional monitoring or on restoration actions.

Next steps: Set up follow-up calls with the group to discuss/prioritize actions. If developing a monitoring program is of high priority, we will work with the group to discuss the concerns/issues identified here and to develop the program. Establish regular communication with the workshop participants and other abalone contacts along the coast.

Post-Workshop Follow-up and Evaluation of Research and Conservation Actions

After the workshop, the workshop participants discussed (via teleconference) and evaluated the list of research and conservation actions to prioritize the actions. Tables 2 through 6 summarize the results of this evaluation. The priority rating for each action (High, Medium, or Low) represents the majority opinion among the workshop participants. Where there was no majority opinion, the priority ratings with the greatest number of votes are listed. The purpose of this evaluation and prioritization was to identify high priority actions for abalone species of concern, to inform and help focus the efforts of NMFS and our partners for these species. The following research and conservation actions were identified as high priority actions for all four abalone species (flat, green, pink, and pinto abalone):

- Optimization of culture methods for genetic diversity and survival. It is important to understand the fundamental culture methods for each species.
- Development of optimal restoration techniques and actions (i.e., outplanting and enhancement techniques) for each species, keeping in mind carrying capacity.
- Understanding the role of reproductively isolated abalone. Should these abalone be collected and transplanted to aggregation areas, or left where they are?
- Continued population monitoring, with expansion to other areas where necessary. In particular, it is important to identify where high density areas are or may be.
- Combating poaching through education and enforcement. Methods for increasing the effectiveness of enforcement include increased penalties for poachers and educating enforcement about the importance of abalone conservation.

NMFS plans to communicate regularly with the workshop participants and other abalone contacts throughout the West coast, to develop strong partnerships and implement effective actions to address the research and conservation needs of these abalone species of concern.

Table 2. Summary of priority ratings for each research and conservation action by abalone species.

Research/Conservation Action	Flat	Green	Pink	Pinto
Optimization of culture methods for genetic diversity and survival. Need to understand the fundamental culture methods.	High	High	High	High
Develop optimal restoration actions (i.e., outplanting and enhancement techniques).	High	High	High	High
Understand the role of reproductively isolated abalone (should they be moved to aggregations?)	High	High	High	High
Population monitoring, including knowing where high density areas are or may be.	High	High	High	High
Combat poaching through education and enforcement (e.g., increasing penalties, educating enforcement about the importance of abalone conservation).	High	High	High	High
Long-term tagging and monitoring: Movements of abalone and aggregations.	High	High	High	Medium
Understand disease resistance, especially in disease endemic zones.	Medium	High	High	Low
Demographic modeling: Develop a better understanding of the population demography.	High/ Medium	Medium	Medium	High
Develop threshold levels: Target densities for restoration (species-specific targets).	Medium	Medium	Medium	High/ Medium
Identify and map habitat. Develop maps of potential habitat to estimate population levels.	Medium	Medium	Medium	Medium
Understand the genetic diversity of the species throughout the range.	Medium	Medium	Medium	Medium
Public education/outreach to develop environmental stewardship and knowledge of abalone.	Medium	Medium	Medium	Medium
Make available molecular species identification markers.	Medium	Medium	Medium	Low
Identify fisheries interactions (urchin harvest and abalone impacts)	Medium	Medium	Medium	Low
Understand predator-prey interactions (e.g., in MPAs)	Medium	Low	Low	Low
Develop aging methods for abalone. Increase utility by producing region-specific references.	Low	Low	Low	Medium/ Low
Understand sex determination (when and how sex is determined)	Low	Low	Medium/ Low	Low
Understand abalone endocrinology	Low	Low	Low	Low

Table 3. Evaluation of research and conservation action priorities for flat abalone. The tally of votes across all reviewers and the priority rating with the majority vote are provided. VH = Very High, H = High, H/M = High/Medium, M = Medium, L = Low.

Research/Conservation Actions	VH	H	H/M	M	L	Total	Priority
Optimization of culture methods for genetic diversity and survival. Need to understand the fundamental culture methods.		4		2	1	7	High
Develop optimal restoration actions (i.e., out-planting and enhancement techniques).		4		3		7	High
Understand the role of reproductively isolated abalone (should they be moved to aggregations?)		4		2		6	High
Population monitoring, including knowing where high density areas are or may be.	1	3		2	1	7	High
Combat poaching through education and enforcement (e.g., increasing penalties, educating enforcement about the importance of abalone conservation).	1	3		1	2	7	High
Long-term tagging and monitoring: Movements of abalone and aggregations.		3		2	2	7	High
Demographic modeling: Develop a better understanding of the population demography.		3		3	1	7	High/ Medium
Understand disease resistance, especially in disease endemic zones.		1	1	4	1	7	Medium
Develop threshold levels: Target densities for restoration (species-specific targets).		2		4	1	7	Medium
Identify and map habitat. Develop maps of potential habitat to estimate population levels.		2		3	2	7	Medium
Understand the genetic diversity of the species throughout the range.		1		5	1	7	Medium
Public education/outreach to develop environmental stewardship and knowledge of abalone.		1		5	1	7	Medium
Make available molecular species identification markers.		1		5	2	8	Medium
Identify fisheries interactions (urchin harvest and abalone impacts)		2		3	2	7	Medium
Understand predator-prey interactions (e.g., in MPAs)				4	3	7	Medium
Develop aging methods for abalone . Increase utility by producing region-specific references.				2	5	7	Low
Understand sex determination (when and how sex is determined)				3	4	7	Low
Understand abalone endocrinology		1		2	4	7	Low

Table 4. Evaluation of research and conservation action priorities for green abalone. The tally of votes across all reviewers and the priority rating with the majority vote are provided. H = High, M = Medium, M/L = Medium/Low, L = Low .

Research/Conservation Actions	H	M	M/L	L	Total	Priority
Optimization of culture methods for genetic diversity and survival. Need to understand the fundamental culture methods.	3	2	1	1	7	High
Develop optimal restoration actions (i.e., out-planting and enhancement techniques)	6			1	7	High
Understand the role of reproductively isolated abalone (should they be moved to aggregations?)	5			1	6	High
Population monitoring, including knowing where high density areas are or may be.	4	1		2	7	High
Combat poaching through education and enforcement (e.g., increasing penalties, educating enforcement about the importance of abalone conservation).	4	3			7	High
Long-term tagging and monitoring: Movements of abalone and aggregations.	3	1		2	6	High
Understand disease resistance, especially in disease endemic zones.	5	2			7	High
Demographic modeling: Develop a better understanding of the population demography.	1	3		2	6	Medium
Develop threshold levels: Target densities for restoration (species-specific targets).	2	4		1	7	Medium
Identify and map habitat. Develop maps of potential habitat to estimate population levels.	1	3		2	6	Medium
Understand the genetic diversity of the species throughout the range.	2	4		1	7	Medium
Public education/outreach to develop environmental stewardship and knowledge of abalone.	1	4		1	6	Medium
Make available molecular species identification markers.	1	3		2	6	Medium
Identify fisheries interactions (urchin harvest and abalone impacts)	1	3		2	6	Medium
Understand predator-prey interactions (e.g., in MPAs)	1	2		3	6	Low
Develop aging methods for abalone. Increase utility by producing region-specific references.		1		5	6	Low
Understand sex determination (when and how sex is determined)	1	2		3	6	Low
Understand abalone endocrinology		2		4	6	Low

Table 5. Evaluation of research and conservation action priorities for pink abalone. The tally of votes across all reviewers and the priority rating with the majority vote are provided. H = High, M = Medium, M/L = Medium/Low, L = Low.

Research/Conservation Actions	H	M	M/L	L	Total	Priority
Optimization of culture methods for genetic diversity and survival. Need to understand the fundamental culture methods.	3	2	1	1	7	High
Develop optimal restoration actions (i.e., out-planting and enhancement techniques)	6	1			7	High
Understand the role of reproductively isolated abalone (should they be moved to aggregations?)	6				6	High
Population monitoring, including knowing where high density areas are or may be.	4	1		2	7	High
Combat poaching through education and enforcement (e.g., increasing penalties, educating enforcement about the importance of abalone conservation).	5	2			7	High
Long-term tagging and monitoring: Movements of abalone and aggregations.	4	1		1	6	High
Understand disease resistance, especially in disease endemic zones.	5	2			7	High
Demographic modeling: Develop a better understanding of the population demography.	1	3		2	6	Medium
Develop threshold levels: Target densities for restoration (species-specific targets).	2	4		1	7	Medium
Identify and map habitat. Develop maps of potential habitat to estimate population levels.	1	3		2	6	Medium
Understand the genetic diversity of the species throughout the range.	2	4		1	7	Medium
Public education/outreach to develop environmental stewardship and knowledge of abalone.	1	4		1	6	Medium
Make available molecular species identification markers.	1	3		2	6	Medium
Identify fisheries interactions (urchin harvest and abalone impacts)	1	3		2	6	Medium
Understand sex determination (when and how sex is determined)		3		3	6	Medium/ Low
Understand predator-prey interactions (e.g., in MPAs)	1	2		3	6	Low
Develop aging methods for abalone. Increase utility by producing region-specific references.		1		5	6	Low
Understand abalone endocrinology		2		4	6	Low

Table 6. Evaluation of research and conservation action priorities for pinto abalone. The tally of votes across all reviewers and the priority rating with the majority vote are provided. VH = Very High, H = High, H/M = High/Medium, M = Medium, L = Low, H/L = High/Low.

Research/Conservation Actions	VH	H	H/M	M	L	H/L	Total	Priority
Optimization of culture methods for genetic diversity and survival. Need to understand the fundamental culture methods.		11		2	1		14	High
Develop optimal restoration actions (i.e., out-planting and enhancement techniques)		10	1	2	1		14	High
Understand the role of reproductively isolated abalone (should they be moved to aggregations?)		9	1	2	2		14	High
Population monitoring, including knowing where high density areas are or may be.	1	6		6	1		14	High
Combat poaching through education and enforcement (e.g., increasing penalties, educating enforcement about the importance of abalone conservation).		12		1	1		14	High
Demographic modeling: Develop a better understanding of the population demography.		6		5	3		14	High
Develop threshold levels: Target densities for restoration (species-specific targets).		6		6	2		14	High/ Medium
Long-term tagging and monitoring: Movements of abalone and aggregations.		5		6	2		14	Medium
Identify and map habitat. Develop maps of potential habitat to estimate population levels.	1	2		7	4		14	Medium
Understand the genetic diversity of the species throughout the range.		4		9	1		14	Medium
Public education/outreach to develop environmental stewardship and knowledge of abalone.		5		6	3		14	Medium
Develop aging methods for abalone. Increase utility by producing region-specific references.				7	7		14	Medium/ Low
Understand disease resistance, especially in disease endemic zones.		3		4	6	1	14	Low
Make available molecular species identification markers.		2		5	6		13	Low
Identify fisheries interactions (urchin harvest and abalone impacts)		2		5	7		14	Low
Understand predator-prey interactions (e.g., in MPAs)		1		5	8		14	Low
Understand sex determination (when and how sex is determined)				5	9		14	Low
Understand abalone endocrinology.		3		5	6		14	Low