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22 November 2017

Re: status of red abalone stock in northern California

Dear Commissioners,

We write to provide you with information that we believe can help inform your management decisions for the Northern California recreational red abalone fishery. We apologize and are disappointed that we cannot present this information to you in person at the public Commission meeting in December. The salient points that we intend to convey in this letter are that:

1) The information conveyed here has been generated by separate academic and citizen science monitoring programs that are independent of CDFW's red abalone monitoring program. The information we present corroborates the information and conclusions conveyed to you by CDFW staff responsible for conducting stock assessments for the red abalone recreational fishery.

2) A series of environmental and biological anomalies (oceanographic conditions and disease, respectively) described below has incrementally caused declines in the density (number of individuals per area of rocky reef) and abundance due to the mortality of all sizes of red abalone across all but the intertidal portion of the abalone's depth range. These anomalies are not associated with recreational take.

3) Abalone abundance in the rocky intertidal has remained within the long-term range of abundance throughout the study period. In sharp contrast, abalone densities in the subtidal depths indicate declines to the lowest numbers observed by the two kelp forest monitoring programs. The resulting subtidal densities in 2016 and 2017 are below the ARMP fishery closure trigger of 0.30 abalone per m^2 (= 18 abalone per $60m^2$).

4) The sequential temporary increases in density from deeper to shallower survey depths are suggestive of movement of individuals from deeper to shallower depths. This also corroborates CDFW's conclusion that abalone are moving from deeper to shallower depths (i.e. from a deep refuge below the recreational fishery to where they are now exposed to recreational take). However, actual movement data would help clarify this, and some of these increases (i.e. in the rocky intertidal) are also associated with the implementation of MPAs.

5) Trends in size structure of abalone in the rocky intertidal reflect the history of fisheries management interventions with declines in larger individuals attributed to fishing. Trends in deeper subtidal depths instead indicate no change in size structure. Lack of change in size structure over time at deeper depths indicate little impact of fishing and that declines in density impact all size classes and are attributable to environmental and ecological impacts (i.e. lack of food and starvation as the primary source of mortality).

Background:
We are the principal investigators of three long-term monitoring programs. Dr. Mark Carr oversees the kelp forest survey program sponsored by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) in the central and north-central coasts of California (http://www.piscoweb.org/kelp-forest-study). Dr. Jan Freiwald directs the state wide kelp forest monitoring studies conducted by Reef Check California (http://reefcheck.org/california/ca-overview). Dr. Peter Raimondi, a principal investigator with PISCO and the Multi-Agency Rocky Intertidal NEtwork (MARINE: https://www.marine.gov/) oversees long-term rocky intertidal community surveys throughout the state of California. In northern California, all three programs were designed to inform the evaluation and adaptive management of the MLPA marine protected areas. The years of sampling and number of sites sampled each year reflect this. Surveys conducted by PISCO are only conducted in 2010 and 2011 associated with the North Central Coast Baseline Characterization, and again in 2016 and 2017 with the onset of the long-term MPA monitoring program on the north-central coast. Reef Check surveys include those same time periods as well as additional intervening years. The surveys are designed to characterize change in kelp forest ecosystems and therefore include information on many more species than abalone as described below. This allows us to better understand what environmental and biological factors (including fishing effects) are influencing observed changes in kelp forests across the regions surveyed.

For broader context and evidence of what factors are likely driving changes in abalone abundance, we first describe recent trends in key species in kelp forest communities on the north central coast that we believe explain observed abalone mortality events and declines in density. In 2013, a West Coast-wide sea star wasting disease led to near local extinction of sea stars by 2014, including the sunflower star (*Pycnopodia helianthoides*), a voracious predator of sea urchins (Figure 1). In the absence of its predator, numbers of exposed purple sea urchins began to increase (Figures 1 and 2). Anomalously warm water temperatures referred to as the “blob” occurred in 2014, followed by a brief El Nino event between 2014 and 2015. These oceanographic events were associated with low nutrient availability and reduced production of kelps that provide food for both sea urchins and abalone (Figures 1 and 2). This lack of food further increased the number of exposed sea urchins that deforested reefs of algae and created “urchin barrens” characterized by pavements of encrusting pink coralline algae (Figure 2). These same trends were observed by Reef Check surveys to the North Coast region of California. Thus, abalone on the north central coast experienced unprecedented declines in the availability of their food, drift bull kelp (*Nereocystis*) and the northern sea palm (*Pterygophora*).

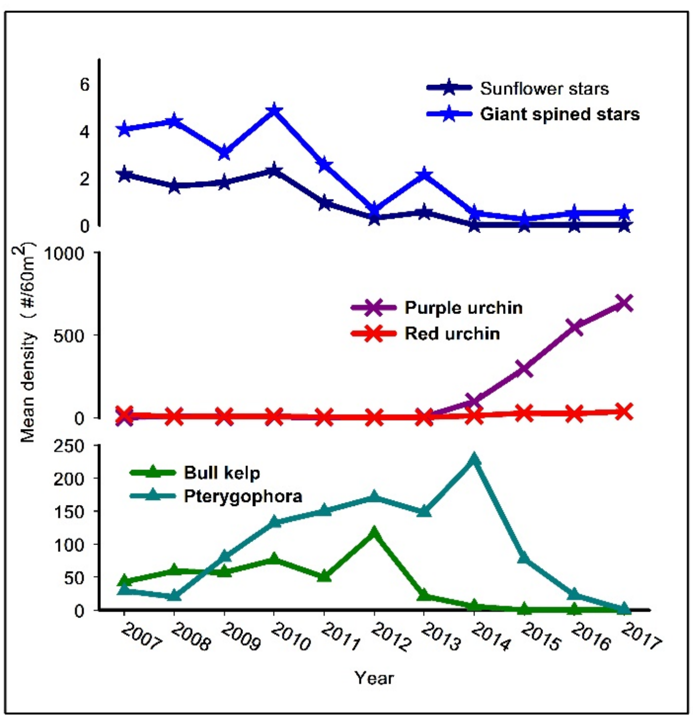

Figure 1. Trends in sea stars, sea urchins and kelps in North Central California kelp forests characterized by the Reef Check California kelp forest monitoring program. Sea stars declined markedly since the sea star wasting disease of 2013 with concomitant increases in the purple sea urchin and declines in kelps.

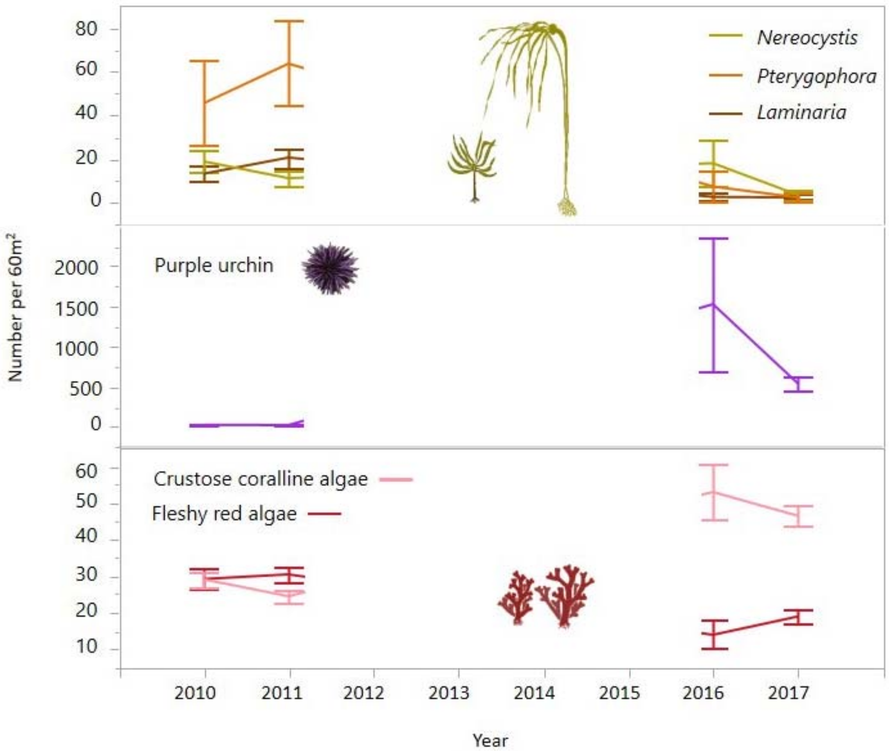

Figure 2. Trends in kelps, sea urchins and understory algae in North Central California kelp forests characterized by the PICSO kelp forest monitoring program. Surveys were conducted only in 2010 and 2011, and again in 2016 and 2017. Kelps and foliose red algae have declined markedly between the two sampling periods, while densities of exposed purple sea urchins and cover of encrusting coralline algae have increased.

Trends in red abalone abundance differ across the species depth range (Figure 3). Abalone abundance in the rock intertidal has remained within a consistent range throughout the study period. In contrast, densities of abalone at intermediate subtidal depths (0-8m and 8-16m) have declined to all time low levels. Both PISCO and Reef Check density estimates for 2016 and 2017 are below the ARMP fishery closure trigger (0.3 per m^2 equates to 18 per $60m^2$). Densities are very low in the 16-22m depth bin, indicating that the vast majority of the stock resides above 16m depth. The decline between 2010 and 2011 reflet the Hamrful algal bloom event that caused mass mortalities at many sites across the study region. Another notable trend is the sequential decline in density at deeper depths with subsequent increase at shallower depths (2014, 2015, 2016), suggesting that individuals are moving from deeper to shallower depths. Although the peak in numbers in 2016 in the rocky intertidal also suggest this, it may be confounded by other factors (e.g., MPAs).

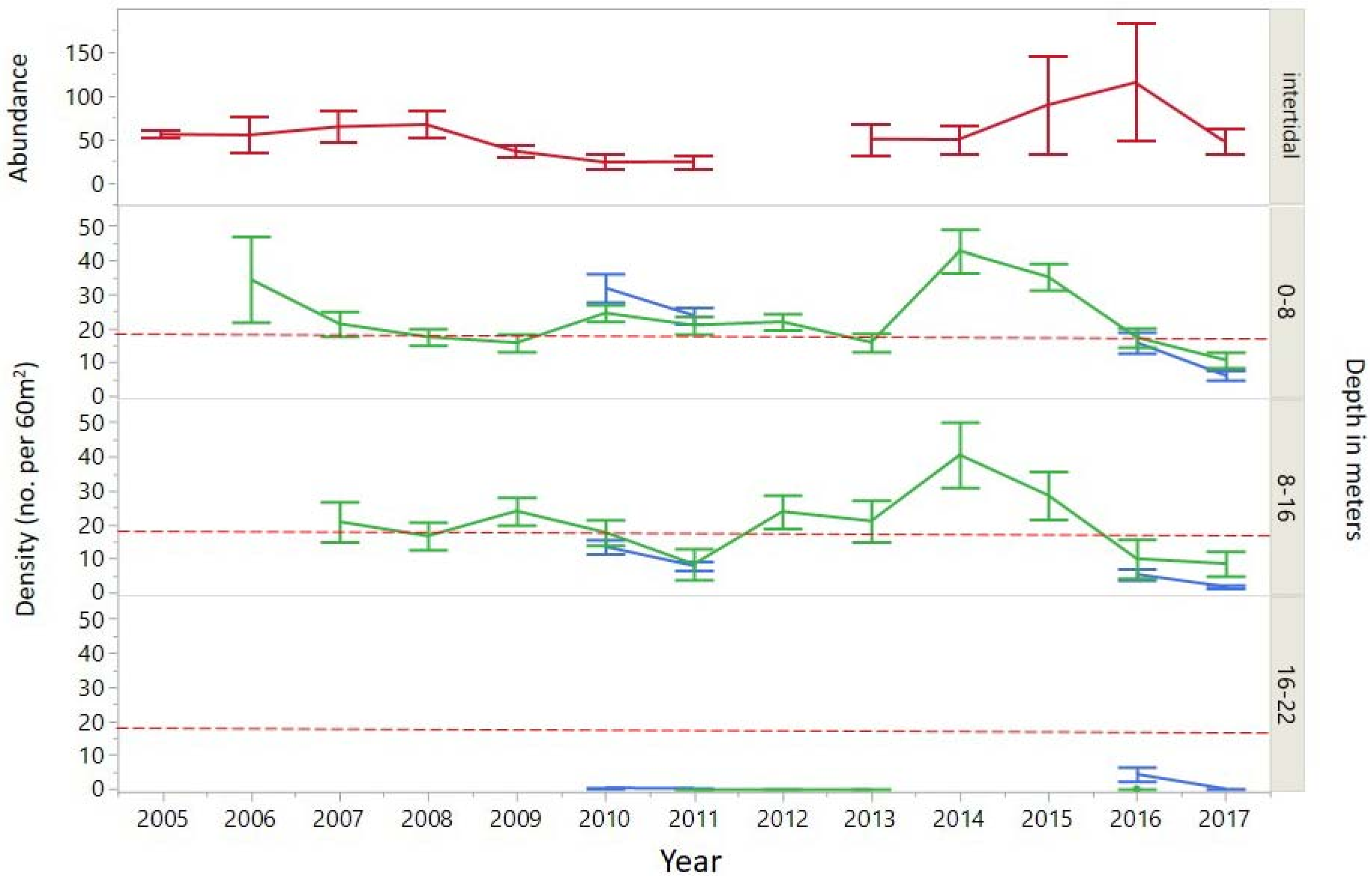

Figure 3. Trends in abundance (rocky intertidal) and density (deeper depths) of red abalone in North Central California. Trends in the rocky intertidal are depicted in the upper panel. Trends at increasing depth bins are depicted in lower panels. Note the lack of abalone at the deepest depth bin, indicating that the vast majority of the stock is restricted to depths less than 16 meters. The dashed red line indicates the ARMP fishery closure trigger.

Trends in the size structure of red abalone also vary across the species' depth range (Figure 4). Size structure in the rocky intertidal reflects changes in levels of protection from fishing over the study period (Figure 4, upper panel). In 2005, abalone were protected from fishing on private lands and individuals above the legal size limit were abundant. Upon opening those sites to fishing, the number of individuals larger than the size limit declined dramatically. With establishment of the MLPA MPAs in 2010, numbers of individuals at and above legal size limit has increased through time. In the two deeper subtidal depths, there has been no change in the size structure over time, including legal-sized abalone. This suggests that the declines in abalone density at these deeper depths depicted in Figure 3 apply to all size classes. This implies that the declines in abalone density at these deeper depths are not attributable to fishing, but instead are the result of environmental conditions and ecological interactions that impact all sizes of abalone.

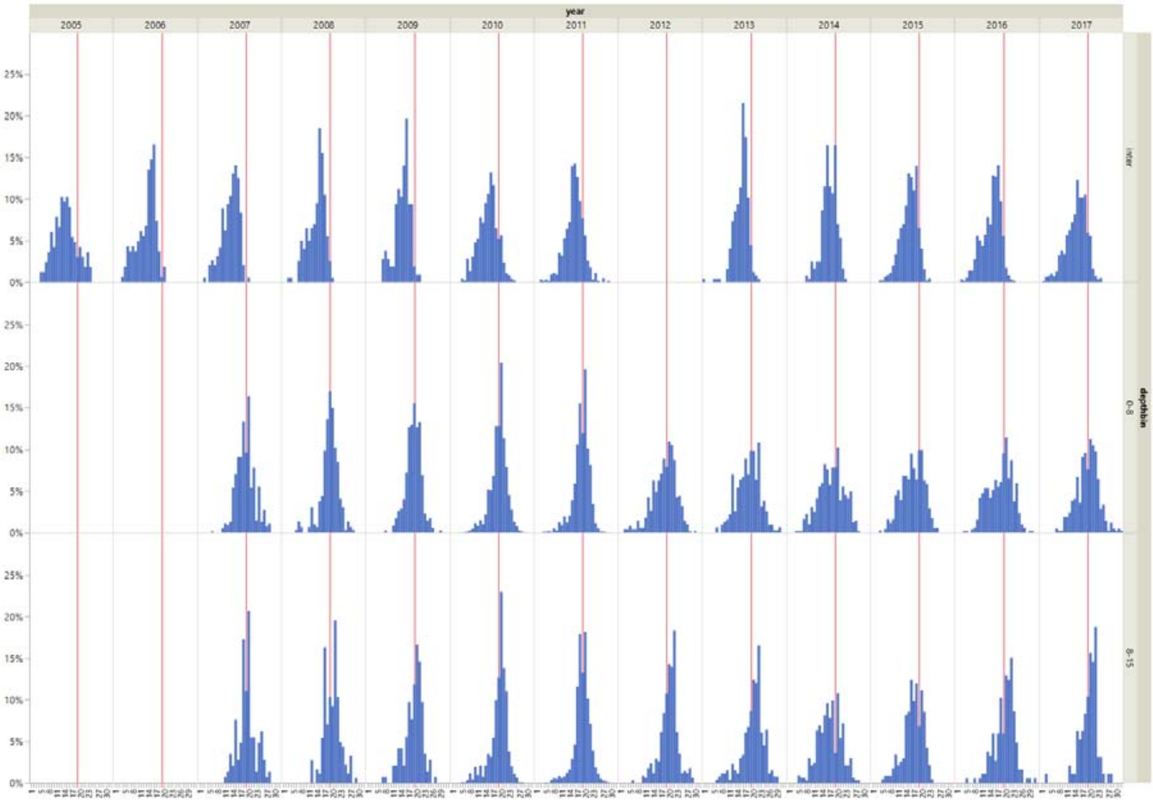

Figure 4. Trends in the size structure of red abalone in North Central California over time in each of three depth bins: intertidal, 0-8m, and 8-15m. There are insufficient numbers of abalone below 15m depth to plot size structure. The vertical red lines are the legal size limit.

Conclusions:

The results presented here corroborate CDFW's evidence of dramatic declines in abalone density at depths below the rocky intertidal zone. Our estimates indicate that abalone at subtidal depths within and below that accessible by the fishery are below the ARMP fishery closure threshold. These results also demonstrate the combined value of both population density and size structure across the entire depth range of a stock for interpreting the overall status of a stock. The results presented here are the combined product of long-term MPA monitoring programs and demonstrate the broader value of these integrated monitoring programs for informing nearshore fisheries management. Again, we apologize for not being able to present and discuss this information with you and others at the upcoming Commission meeting, but we are eager to discuss them with you before or after the meeting at your convenience.

Sincerely,

Mark H. Carr
Principle Investigator, PISCO

Jan Freiwald
Director, Reef Check California

Pete Raimondi
Principle Investigator, PISCO