January 27, 2023

MEMORANDUM FOR: Brian Nelson, Chair
Monterey Bay National Marine Sanctuary Advisory Council

Lisa Wooninck, PhD, Superintendent
Monterey Bay National Marine Sanctuary

FROM: Steven Haddock, PhD, Acting Chair
Monterey Bay National Marine Sanctuary Research Activity Panel

SUBJECT: Response to request from MBNMS AC on iconic kelp

Kelp (*Macrocystis pyrifera* and *Nereocystis luetkeana*) form an iconic habitat in Monterey Bay National Marine Sanctuary (MBNMS). Kelp canopies have declined drastically in Northern California and there has also been a noticeable decline within MBNMS, where kelp supports valuable economic and cultural resources. The Research Activity Panel (RAP) has discussed the issue at several meetings and received additional insight from internationally recognized kelp experts. On December 9, 2022, the MBNMS Advisory Council (AC) approved a motion requesting the RAP, "evaluate in MBNMS suggested/proposed options for science to inform monitoring, recovery, and restoration of kelp forests." Below, please find a series of RAP-endorsed related science projects that need to be addressed; though numbered, the items are not prioritized. Potential MBNMS contributions to these efforts include: staff support (subject matter experts; field operations); use of MBNMS research vessels; facilitating coordination with other kelp interest groups; and supporting funding efforts to address the research.

1) <u>Monitoring the natural recovery of giant kelp forests</u>
Monitoring the natural recovery of kelp forests is necessary to identify the environmental and ecological conditions that are conducive to forest recovery. The objective is to monitor and compare kelp forests that exhibit early phases of recovery with those that do not, to identify those conditions that facilitate recovery. The information would inform when and where restoration efforts might be most successful, as well as what can be done to expedite recovery (e.g., urchin removal, kelp outplanting). This type of information is also necessary for accurate MBNMS Condition Reports. Methods to address this topic could include modifications to ongoing PISCO/MPA diver surveys, additional surveys, and aerial drone canopy surveys.

2) <u>Determining sea urchin behavior in kelp forests of various conditions</u>
By determining the size distribution, movement, relative abundance of exposed and concealed urchins, and associated levels of live and drift algal cover, this project

would inform conditions needed to facilitate kelp forest recovery (e.g., altering sea urchin behavior or reducing their numbers). It is also possible that kelp and urchins interact differently in deep reefs, at the limits of standard SCUBA diving depths, providing some sort of kelp refuge. Methods to address this topic could include academic and community scientist diver surveys, and use of the recently developed autonomous camera system BOSS (Benthic Observation Survey System).

3) Determining the role of sea otters in persistent boundaries of healthy kelp forests
Sea otters feed preferentially on sea urchins that have healthy gonads, and these may be associated with access to drift algae at the boundaries of healthy kelp forests. By assessing biomass of urchins (concealed and exposed) and frequency of otters in healthy kelp forests, there will be an improved understanding of whether otters actively protect forest boundaries or whether intervention with urchin removal is necessary to protect and expand remnant forests. The Monterey Bay Aquarium has initiated this project with UC Santa Cruz.

4) Determining the effects of urchin density on urchin condition and kelp recruitment and survival
This study would assess the effect of the separate and combined densities of both red and purple urchins on kelp settlement and post-settlement survival. Red and purple urchin densities would be manipulated in cages while associated kelp recruitment and gonad conditions would be measured. Related experiments could be done by creating urchin clearings of different sizes at different frequencies to determine thresholds for kelp recovery. This project not only informs efforts to facilitate recovery, but also evaluates the effect of purple urchin numbers on the marketability of red urchins (for *uni*) in northern California.

5) Evaluating the areal extent of kelp spore dispersal "shadow"
The objective of this study would be to determine what dispersal patterns can be expected from kelp. Methods to address this question could include measuring recruitment on settling plates at different distances from naturally persisting kelp or placed spore sources (e.g., bags of sporophylls or translocated kelp) of giant and/or bull kelp. Knowledge of the distance of spore dispersal will inform where restoration efforts can leverage natural spore dispersal or require outplanting.

6) Evaluating the required frequency of urchin removal to maintain or expand forests
For protecting remaining forests or restoring kelp through expansion of those forests, it is important to understand: the relationship between the width of an urchin removal border and frequency of urchin removal to maintain reduced urchin densities; how that relationship differs with the rugosity of the reef; how the relationship varies with the density of urchins in the adjacent barrens; how the density of other herbivores (e.g., gastropods, herbivorous crabs) alter the effect of urchin removals on the maintenance of forest boundaries; what the recruitment rate of kelp plants is relative

to urchin density; what the overall effort (number of visits and number of divers) per unit length of a removal area is required to maintain urchin removals; and what the costs (e.g., divers, time, vessels) are associated with the overall effort. Carefully designed experiments could be addressed through a professional and community scientist collaboration. These questions are already being addressed, in part, at "Tanker Reef" by CDFW, MBNMS and community scientists.

7) Evaluating the effects of environmental conditions on the foraging rate of purple sea urchins and kelp production

Mesocosms (large outdoor tanks at marine labs) can be used to determine relationships between water chemistry and temperature on urchin feeding and kelp growth. If grazing rate increases with water temperature, it may explain the outbreak of urchins associated with the marine heatwave. If grazing rates decline with cold temperatures, it might suggest recovery will coincide with cold water events/locations (upwelling) and years; these would also be favorable conditions for restoration projects. This project has been initiated by a UC Santa Cruz PhD student.

8) Evaluating the effects of water temperature, density and starvation on disease in the purple sea urchin

Recovery of kelp may be determined by a decrease in density of sea urchins, and sea urchin densities in southern California have declined with disease outbreaks. Knowing what conditions are conducive for disease outbreaks would allow for predictions of whether outbreaks will naturally control urchin numbers. This study would involve laboratory experiments where temperature, urchin body condition and urchin density are manipulated to assess the infection rate and mortality from black spot disease.

9) Developing an understanding of the economic and social values of healthy kelp forests

Kelp forests have value for a number of human uses like: providing critical habitat for dozens or hundreds of key species; recreational diving opportunities; food for abalone aquaculture; habitat that supports commercial and recreational fisheries; decreasing coastal erosion; scenic value, including bird and sea otter watching; and cultural activities, including for indigenous groups. An academic study on the social/cultural and monetary value of MBNMS kelp forests would inform the need to protect and restore this iconic habitat.

10) Taking advantage of remote sensing technology

Satellites are able to make large scale assessments of changing kelp cover, and lower altitude drones can provide higher resolution imagery. LIDAR from planes can be used to distinguish between the canopies of different species of kelp and to assess the health of plants. Monterey Bay Aquarium Research Institute (MBARI) is developing a drone program with long-range capabilities and CSU Monterey Bay already has a

short-range drone program (partly funded by NOAA). Datasets generated by these surveys could be integrated with other data sharing products being developed by the Central and Northern California Ocean Observing System (CeNCOOS).

11) Developing a visual, conceptual model of MBNMS kelp forests
This model would include: environmental causes for growth and decline; anthropogenic causes for growth and decline; biological interactions impacting kelp abundance; and effects of different restoration methods. A visual (graphic) model would highlight how science questions around kelp are interrelated and the role of different restoration methods. The model would also have heuristic value in interpreting this complex system to decision makers.

12) Assessing the potential of solutions from aquaculture
Conservation aquaculture has been used in marine systems to outplant impacted species for restoration (e.g., white abalone); to select for individuals that are resistant to problematic pressures (e.g., heat resistant populations); to grow and release predators that reduce problematic species (e.g., sea stars that eat urchins); and to enhance the commercial value of harvested species (e.g., feed collected urchins until they are valuable for human consumption). While not necessarily in the purview of MBNMS, NOAA has been promoting aquaculture as a necessary component to addressing the increasing need of seafood for human consumption.

13) Developing a historical perspective
Using tools of historical ecology (e.g., old photographs, media interviews) it would be valuable to develop retrospective knowledge on variability in MBNMS kelp canopy cover through time. This would help provide targets for kelp restoration, could determine if kelp has decreased and recovered before (to what levels and over what time periods), and therefore provide guidelines on the urgency of MBNMS resource management actions.