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| FIRST NAME | M.I. | LAST NAME OR ENTITY NAME (If qualified entity) | PERMANENT ID NUMBER<br><b>SC-</b> |
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**FOR DEPARTMENT OF FISH AND WILDLIFE USE ONLY**

\_\_\_\_\_ PAGES OF ATTACHMENTS NOTED IN THIS PERMIT SHALL REMAIN WITH THIS PERMIT AT ALL TIMES. CONDITIONS, AUTHORIZATIONS, AND APPROVALS ARE AS FOLLOWS:

ISSUED BY/DATE

**Project 3- Urchin Removal Experiment- Project Conditions and Reporting Requirements:**

*This project is approved as per the 'Urchin Removal Experiment' description. This project will be reviewed annually to determine if project continuance will be granted. The mandatory reporting requirements are designed to judge the project based on its desired experimental goals and to ensure the project is not negatively impacting the Marine Protected Area. The Department reserves the right to amend or cancel this permit, and hence the project itself, at any time.*

1. Permission to conduct experiment inside Pacific Grove Marine Gardens State Marine Conservation Area is given.
2. The Project Manager shall submit a report outlined below within 60 days after the completion of each year, which begins at the issuance of this permit. The reports must be sent to each of the following Department staff: Robert Win, Marine Region: robert.win@wildlife.ca.gov
3. Failure to submit the required reports within the given time frame may result in a revocation of urchin removal experiment permission.
4. The report of the urchin removal activities must include these components:
  - A) Experimental goals
  - B) Time-line of the experimental goals including project start and completion date for each experimental site
  - C) Description of removal, control, and reference sites
    - i. General site descriptions (removal and control sites)
    - ii. GPS coordinates
    - iii. Area in hectares
    - iv. Purple urchin density treatment at removal sites
  - D) Pre-removal monitoring at removal and control sites following guidelines outlined below in (E).
  - E) Annual monitoring of all removal and control sites, for the term of this SCP including:
    - i. Monitoring time line
    - ii. Quantity of purple urchins crushed and/or collected for GSI studies per site
    - iii. Species richness
    - iv. Density (individuals/100 m<sup>2</sup>) of:
      - a. Kelp and related under-story algal species
      - b. Red and purple urchins
    - v. Size frequency of red and purple urchins, specifically to identify new recruits
    - vi. Density and biomass of common fish species
    - vii. Gonadosomatic indices of red urchins (*Mesocentrotus franciscanus*) and purple urchins (*Strongylocentrotus purpuratus*) pre and post removal, per treatment.
  - F) Analysis of ecosystem response to the purple urchin removal activities, including species that are key indicators of a healthy and persistent kelp forest ecosystem.
  - G) Evaluation of removal activities and success or failures in restoring kelp forests at different urchin densities.
  - H) Geo-referenced images before and after restoration activities

**APPROVED**  
 By Robert Win at 8:45 am, Aug 13, 2018

DEPARTMENT REVIEWER(S) SIGNATURE  
 1.

2.



Please see urchin removal experiment conditions in Section 6 above.

APPROVED  
By Robert Win at 8:40 am, Aug 13, 2018



## Urchin Removal Experiment

### Permit justification

#### Purpose

The Reef Check California (RCCA) program, established in 2005 by the Reef Check Foundation, monitors California’s shallow rocky reefs and kelp forest ecosystems. RCCA educates, trains, and engages SCUBA divers as citizen scientists in the collection of scientific data to help inform California’s marine management. For over a decade, RCCA has mobilized and trained over 1500 volunteer scuba divers to monitor the health of California’s ocean ecosystem, creating one of the largest ecological datasets of California’s nearshore reefs. This has made Reef Check a key partner in the state’s Marine Protected Area (MPA) program. RCCA has been part of all MPA baseline monitoring programs and is currently collaborating with the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) at UCSC and UCSB on the kelp forest and shallow rocky reef long-term MPA monitoring funded by the Ocean Protection Council. Reef Check has a long-standing Memorandum of Understanding with the California Department of Fish and Wildlife that recognizes the validity of RCCA’s data collection and educational approaches and the value of its data for marine resource management. The requested permit is for a collaborative project between Reef Check and the PISCO program at UCSC (PI Dr. Mark Carr). The proposed collaboration capitalizes on RCCA’s existing citizen science monitoring network and the long-term PISCO kelp forest research expertise. This collaboration will insure sound scientific approaches to the proposed study as well as sufficient volunteer engagement for the long-term under direct oversight from RCCA staff.

Over the last several years, large areas of kelp forest along the Monterey Peninsula and in Carmel Bay have turned into sea urchin “barrens” (Figure1). These barrens are characterized by the absence of kelps and fleshy algae and a very high abundance of purple sea urchins (*Strongylocentrotus purpuratus*). The high population density of urchins prevents kelp recruitment as any algal growth is immediately grazed upon by urchins. The goal of the proposed research project is to identify a threshold population density of purple sea urchins at which giant kelp forests (*Macrocystis pyrifera*) in central California re-establish in areas that currently exist as urchin barrens. In order to investigate the threshold density at which kelp forests will begin to re-establish we will work with Reef Check California’s (RCCA) trained citizen scientist volunteer divers to clear isolated patch reefs to different levels of urchin densities below the current “barren” density. Experimental density manipulations will be replicated at 16 plots (i.e. patch reefs) along the Monterey Peninsula.

Urchin removals have been used in southern California in efforts to return urchin barrens to a kelp forest state and studies indicate that there are threshold densities at which kelp forests return



(Claisse et al. 2013). Studies from other kelp forest ecosystems outside of California have observed thresholds (abrupt “phase shifts”) at which urchin barrens return to the kelp forest state. These phase shifts occur at urchin densities well below the densities that supported kelp prior to its shift to the barren state (Ling et al. 2009, Filbee-Dexter and Scheibling 2014). These differences in urchin densities at which the system shifts from forest to barrens and back to forest is referred to as hysteresis. Hysteresis is caused by, often unidentified, ecological feedback mechanisms and therefore it is unlikely that results from other regions (e.g., southern California with different urchin predators and kelp growth rates, or northern California with different predators and different kelp species) would be applicable to central coast kelp forests. We aim to identify the threshold density at which central coast reefs shift back from barrens to kelp forests.

### **Methods/Techniques**

#### *Experimental approach*

Purple urchin densities will be manipulated to four levels of density and each density level will be replicated on four small, isolate experimental reefs. Four additional reefs will be monitored at natural densities (barren state) as controls. Density levels will be 50%, 30%, 20% and 10% of the average existing density across the barrens sites surveyed by RCCA and PISCO in 2017. Variation in actual urchin densities achieved around each of the four targeted percentages will likely result in a more continuous gradient in urchin densities across the 16 reefs. This will allow us to use a general linear model approach to identify at what density level kelp re-establishes (i.e. an inflection in the dependent variable) across the manipulated urchin densities (independent variable). In order to conduct the density manipulations and maintain densities at or near the target density we would work on isolated patch reefs surrounded by sand. Isolate patches will make it easier to maintain target densities as migration of urchins from outside the patch will be reduced by their reluctance to move over sand. These reefs are identified in the attached map (Figure 2). Organizational meetings and community surveys will be initiated upon receipt of the collecting permit. Full implementation of the experiment will be contingent on timing of funding.

#### *Urchin removal*

Purple urchins will be removed by smashing individuals with a hammer, gradually reducing numbers on each reef over a 1-2 week period then densities will be maintained at the target level. Due to the use of volunteer divers the collection of urchins and their removal from the reef and eventual deposit on land is not feasible. Disposal on land would involve specialized equipment and substantial vessel support. This would substantially increase the cost of the project and require intensive equipment and safety training. One concern with destroying urchins in place is that it might cause an artificial spawning of urchins if gonads are released into the water column. In order to prevent this, we will sample urchins from the experimental reefs prior to manipulation and determine their gonad status. Experimental removal will only proceed if gonad status indicates that artificial spawning is very unlikely. Our surveys of urchin gonadal indices in urchin barrens indicate



that most urchins in barrens have very poor indices (low ratio of gonad weight to urchin test size). Additionally, removals at each reef will be conducted gradually over a period of 2-3 weeks, removing a proportion of urchins on each reef over time.

### *Surveys*

Prior to the initial removal of urchins, the patch reefs for experimental removals will be surveyed using RCCA and PISCO methods to establish exact urchin densities and characterize the reef community in detail (fish, invertebrate, algae and UPC surveys). Video transects and photo plots will be done to document the community prior to removal. These can be used in the future to identify species that might not have been captured by the surveys. After urchins are at target densities for one week on the 16 replicate reefs, continued surveys of urchin density, and macroalgal density (kelps) and percent cover (foliose algae, articulate and encrusting coralline algae, sessile invertebrates) will be repeated one week after establishment of target densities and then semi-monthly (every two weeks) for the subsequent two months and monthly thereafter throughout the dive season. As dive conditions become more unpredictable in the winter months surveys will be conducted to the extent possible depending on conditions. Kelp establishment will be evaluated the following spring (May/June) with one of three consequences: (1) the experiment will be terminated if results are conclusive (a threshold urchin density is identified), (2) density manipulations will be maintained if there is evidence that re-establishment is likely to occur in subsequent months, or (3) alternative (lower) urchin density levels will be established and maintained for a second year if there is no evidence of kelp re-establishment.

### **Species and Numbers to be Collected**

Purple urchins (*Strongylocentrotus purpuratus*) will be sacrificed for this experiment. See attached table for the estimates of the numbers of urchins that will be sacrificed (Table 1). A total number of about 3700 will be removed from the experimental reefs. This number is based on purple urchin density estimates from three types of surveys conducted on reefs in the Monterey area in 2017: PISCO, Reef Check, and Joshua Smith's (UCSC PhD student) surveys. PISCO and RCCA surveys estimate purple urchin densities on standardized 60m<sup>2</sup> transects. Joshua Smith's surveys are conducted in 5m radius circular plots.

Once experimental reefs have initially been manipulated to the target densities there will be some additional urchins removed to maintain the experimental densities should urchins migrate onto the experimental reefs. We estimate that these numbers will be low compared to the initial manipulations. **We estimate that no more than 5000 urchins will be removed over the entire project.** It is likely that the actual number will be lower and closer to 4000 urchins.



### Collection locations

The experiment will be conducted on patch reefs surrounded by sand near Lover's Point, Monterey. The study area is located within the Pacific Grove Marine Gardens State Marine Conservation Area. Please see attached map for exact location of experimental reefs (Figure 2). This study is located in the SMCA because there are no locations anywhere in the central coast where kelp forest turned into urchin barrens that are not in a marine protected area (see Figure 1).

Additionally, the need for easy shore access and safe working conditions are satisfied at this location. We considered working on patch reefs just outside of the boundary of the SMCA but these reefs are at depths of around 20m. This would pose too much of a risk of dive related injuries.

### Deposition

Purple urchins will be sacrificed in place and therefore their remains will stay in the environment.

### Literature:

- Claisse, J. T., J. P. Williams, T. Ford, D. J. Pondella, B. Meux, and L. Protopapadakis. 2013. Kelp forest habitat restoration has the potential to increase sea urchin gonad biomass. *Ecosphere* 4:1-19.
- Filbee-Dexter, K. and R. E. Scheibling. 2014. Sea urchin barrens as alternative stable states of collapsed kelp ecosystems. *Marine Ecology Progress Series* 495:1-25.
- Ling, S. D., C. R. Johnson, S. D. Frusher, and K. R. Ridgway. 2009. Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. *Proceedings of the National Academy of Sciences* 106:22341-22345.

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Figures and Tables.

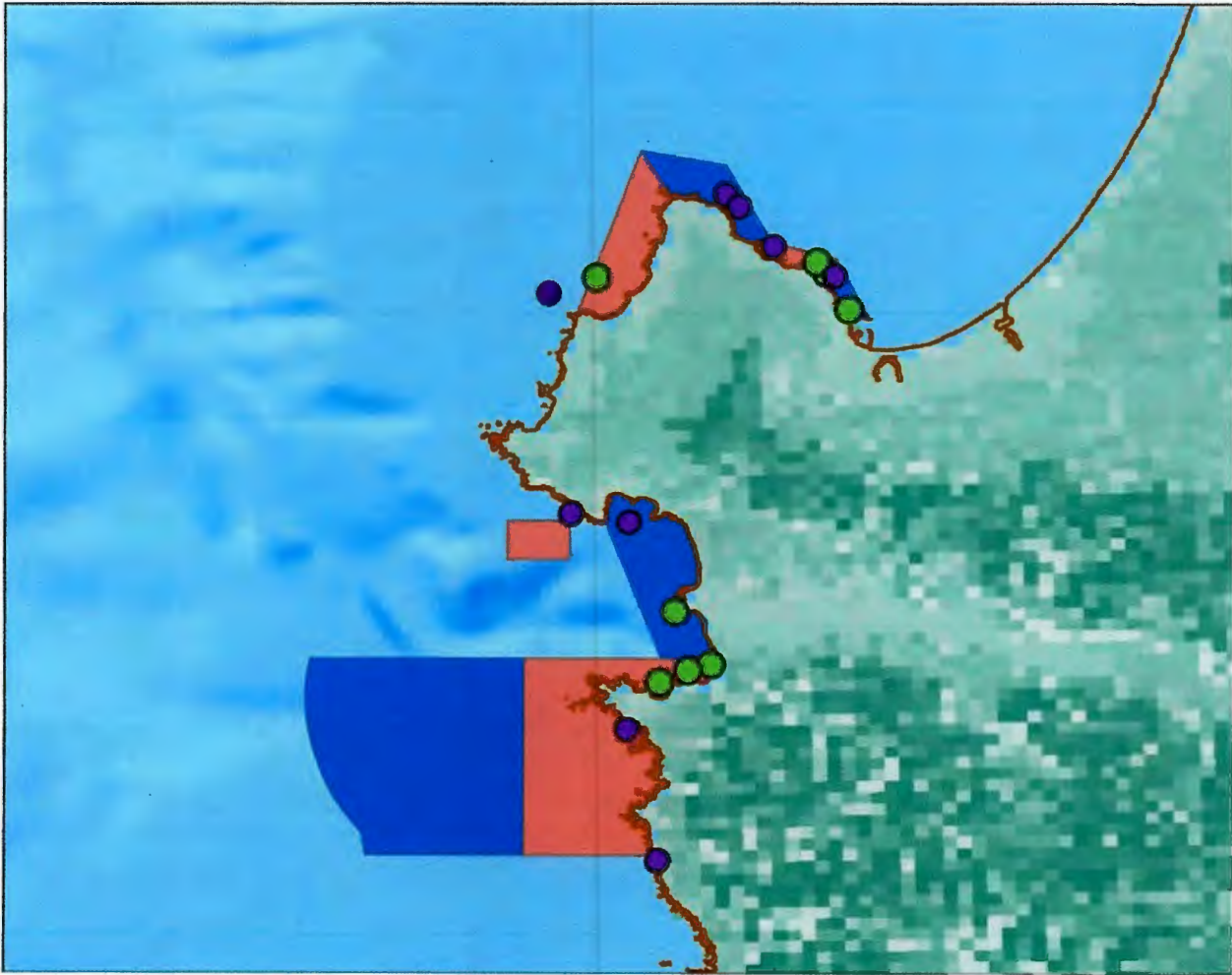


Figure 1. RCCA sites in Monterey and Carmel Bay. Green circles indicate that kelp forest was present at the sites in 2017, purple circles indicate these sites where urchin barrens in 2017.

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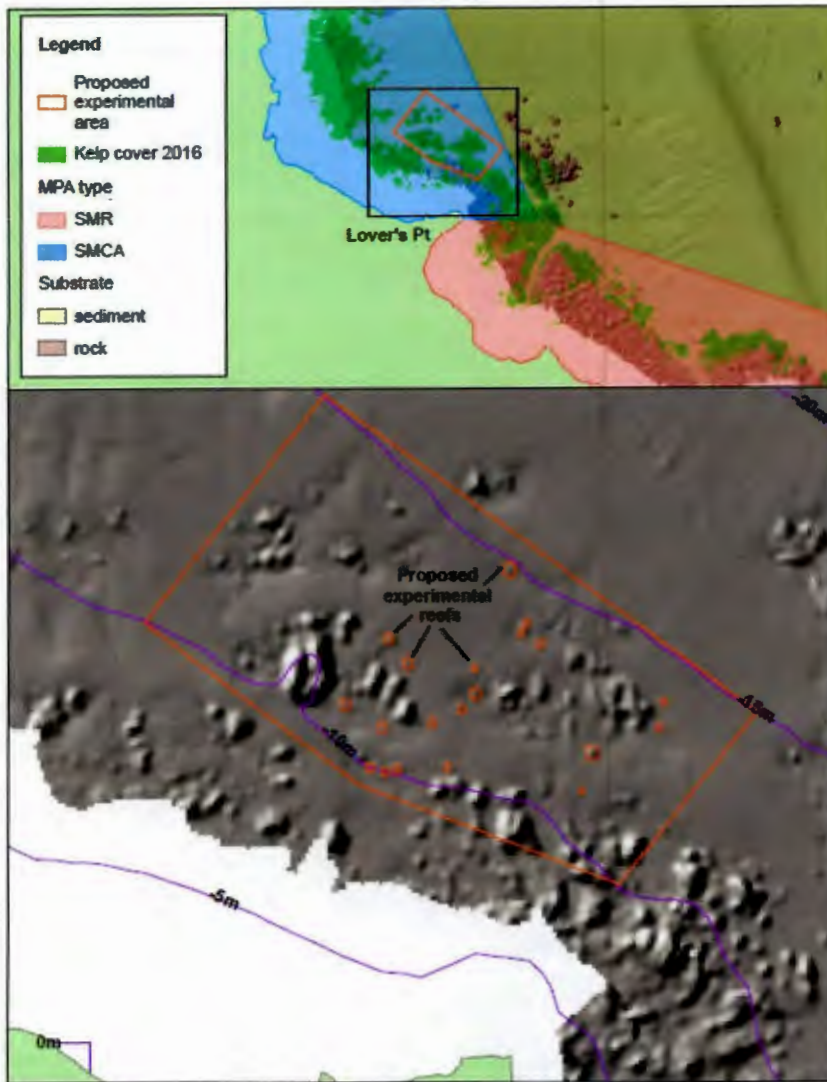


Figure 2. Proposed patch reefs for experimental study new Lovers Point, Monterey.

**Table 1.** Estimate of purple urchin densities on study reefs and the estimated number of urchins expected to be removed.

| Experimental Reef | Reef Area (m <sup>2</sup> ) | Density manipulation level    | Estimate based on average density of 17.89 urchins /m <sup>2</sup> |                         |
|-------------------|-----------------------------|-------------------------------|--|-------------------------|
|                   |                             |                               | Estimated number of urchins on reef                                | Estimated urchin "take" |
| Treatment 1       | 15.70                       | 50%                           | 281  | 140                     |
| Treatment 1       | 14.99                       | 50%                           | 268  | 134                     |
| Treatment 1       | 44.84                       | 50%                           | 802  | 401                     |
| Treatment 1       | 44.84                       | 50%                           | 802  | 401                     |
| Treatment 2       | 24.21                       | 30%                           | 433  | 303                     |
| Treatment 2       | 19.92                       | 30%                           | 356  | 249                     |
| Treatment 2       | 19.84                       | 30%                           | 355  | 248                     |
| Treatment 2       | 16.89                       | 30%                           | 302  | 212                     |
| Treatment 3       | 13.78                       | 20%                           | 247  | 197                     |
| Treatment 3       | 11.30                       | 20%                           | 202  | 162                     |
| Treatment 3       | 18.82                       | 20%                           | 337  | 269                     |
| Treatment 3       | 11.02                       | 20%                           | 197  | 158                     |
| Treatment 4       | 11.30                       | 10%                           | 202  | 182                     |
| Treatment 4       | 11.02                       | 10%                           | 197  | 177                     |
| Treatment 4       | 14.11                       | 10%                           | 252  | 227                     |
| Treatment 4       | 15.05                       | 10%                           | 269  | 242                     |
| Control 1         | 18.11                       | 100%                          | 324  | 0                       |
| Control 2         | 26.73                       | 100%                          | 478  | 0                       |
| Control 3         | 22.05                       | 100%                          | 394  | 0                       |
| Control 4         | 29.21                       | 100%                          | 523  | 0                       |
| <b>Total Area</b> | <b>403.73</b>               | <b>Total Urchins removed:</b> | <b>3704</b>  |                         |

Reef Check purple urchin density estimates at urchin barrens: 10.92 urchins/m<sup>2</sup>

PISCO purple urchin density estimates at urchin barrens: 14.75 urchins/m<sup>2</sup>

Joshua Smith purple urchin density estimates in urchin barrens: 28 urchins/m<sup>2</sup>

**Average urchin density from all three surveys:**

**17.89**

