Spatial-temporal scales of kelp colonization on a large artificial reef: implications for kelp forest restoration

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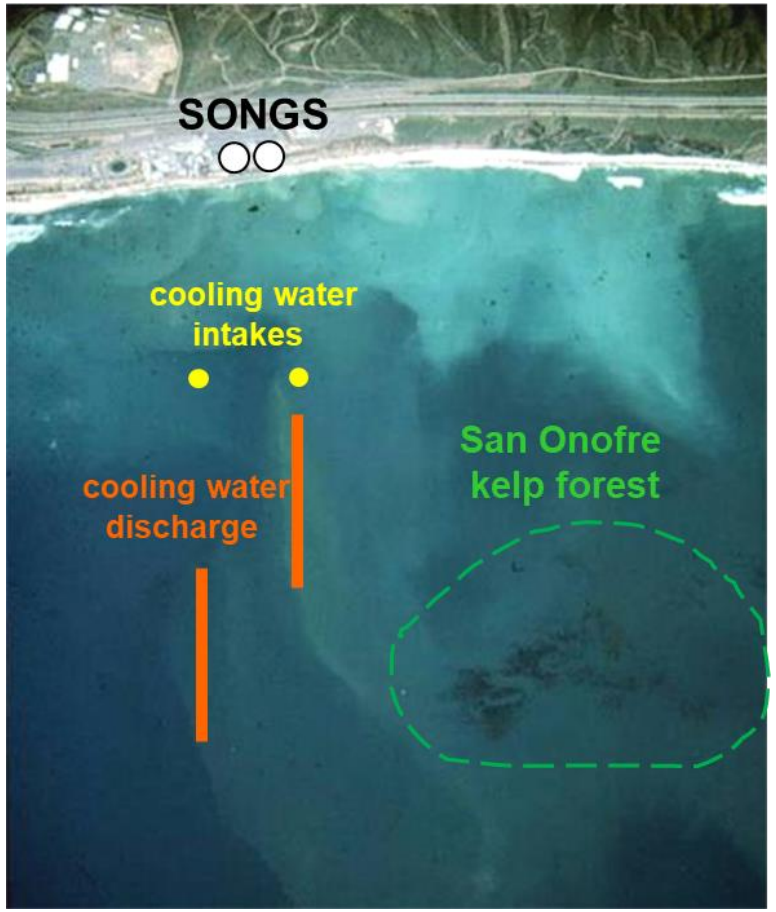
Wheeler North Artificial Reef

Purpose: mitigate the loss of kelp forest habitat caused by the operations of the San Onofre Nuclear Generating Station (SONGS)



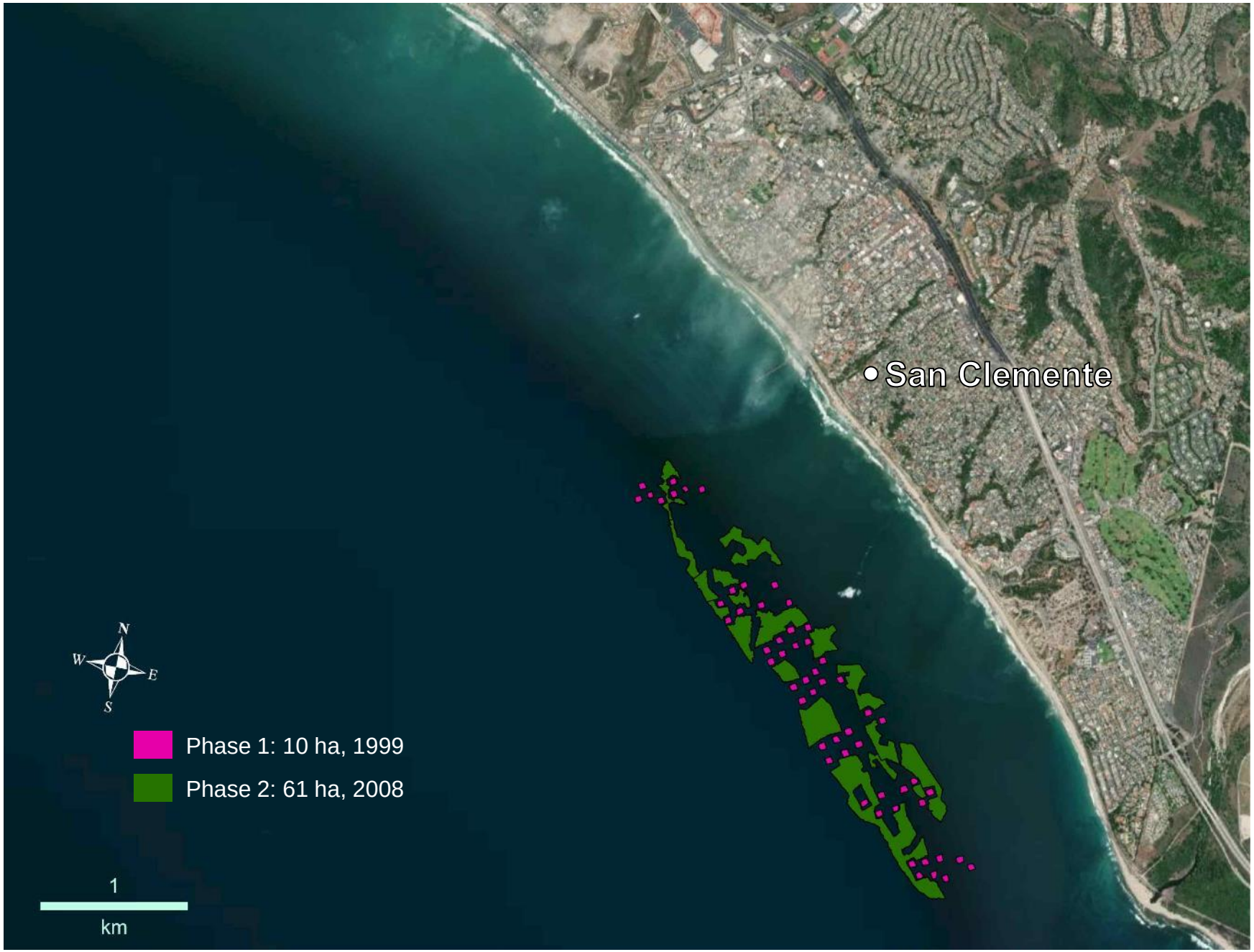
Wheeler North Reef was constructed in three phases

Phase 1

Tested different types of reef material, bottom coverages and the presence of outplanted kelp in a random block design

- Purpose was to inform the design of subsequent phases

Wheeler North Reef was constructed in three phases

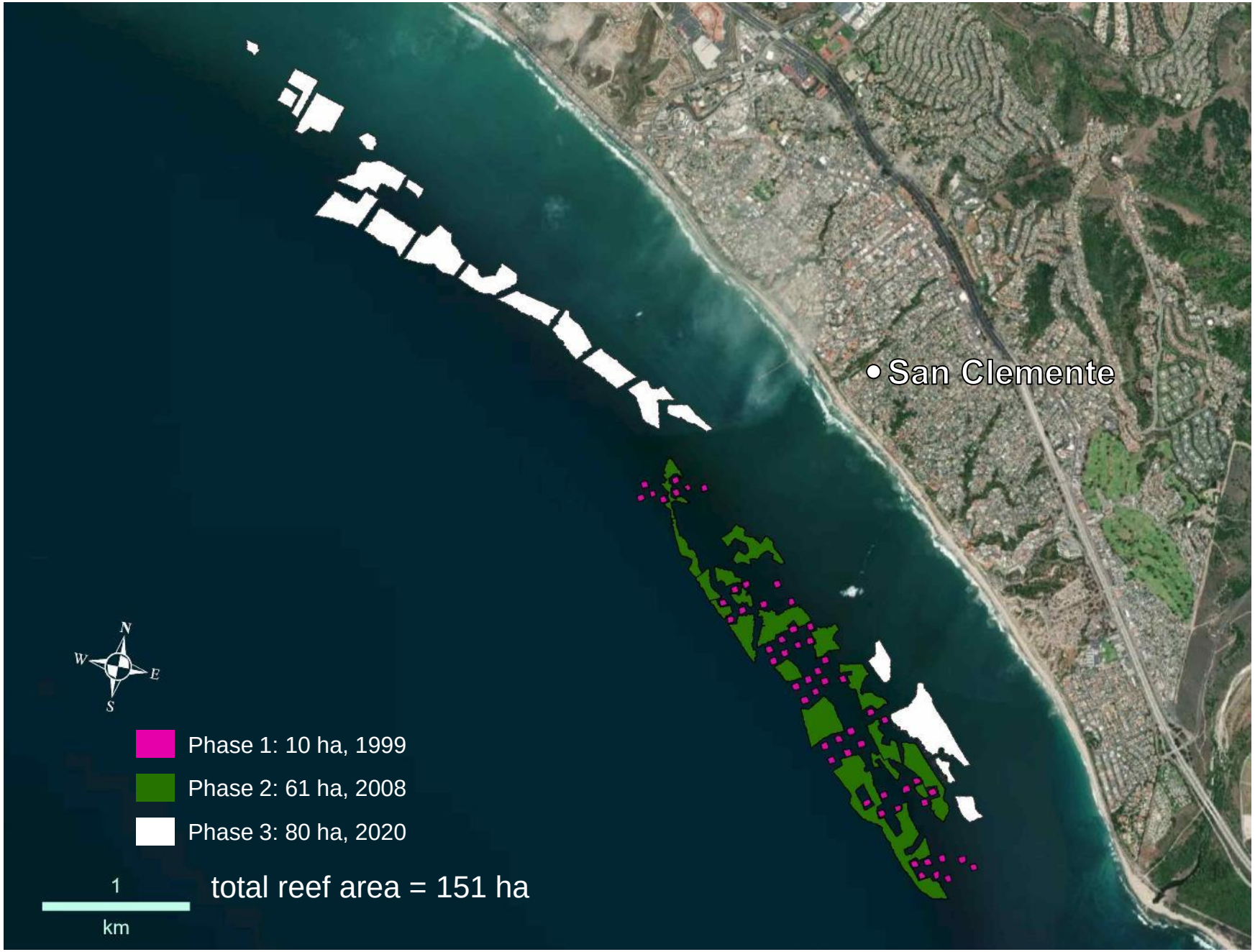


Phase 2

Added 61 ha in 18 irregular shaped polygons of low relief quarry rock to increase the Wheeler North Reef to 71 ha

- Purpose to mitigate losses of kelp forest habitat caused by SONGS

Wheeler North Reef was constructed in three phases



Phase 3

Expanded the Wheeler North Reef to 151 ha by adding 80 ha in 20 irregular shaped polygons of low relief quarry rock

- Purpose to ensure full compensation for losses of kelp forest habitat

Questions

1. How did the spatial patterns of giant kelp recruitment on the three phases of Wheeler North Reef vary in relation to the nearest source population of kelp?

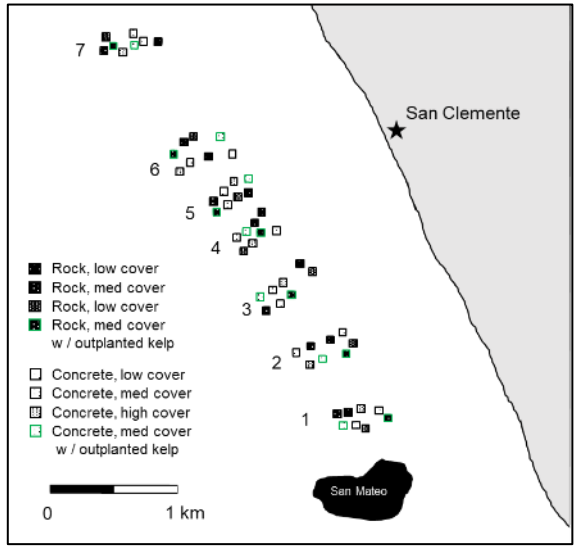
2. How did variation in the density of giant kelp recruits affect spatial patterns in the abundance of larger individuals in subsequent years on the three phases of Wheeler North Reef?

3. Was outplanting laboratory-reared embryos effective and necessary for establishing giant kelp on Wheeler North Reef?

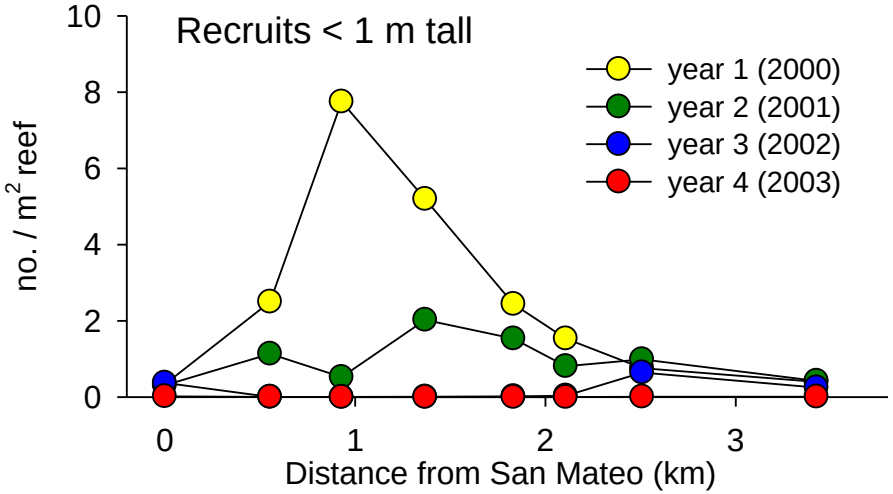
4. Can results from Wheeler North Reef inform efforts to restore kelp on natural reefs where it has declined?

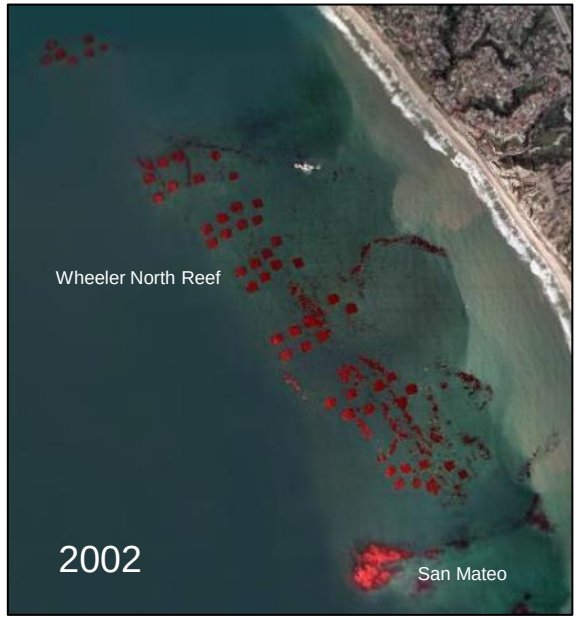
Phase 1 Wheeler North Reef

Giant kelp colonization



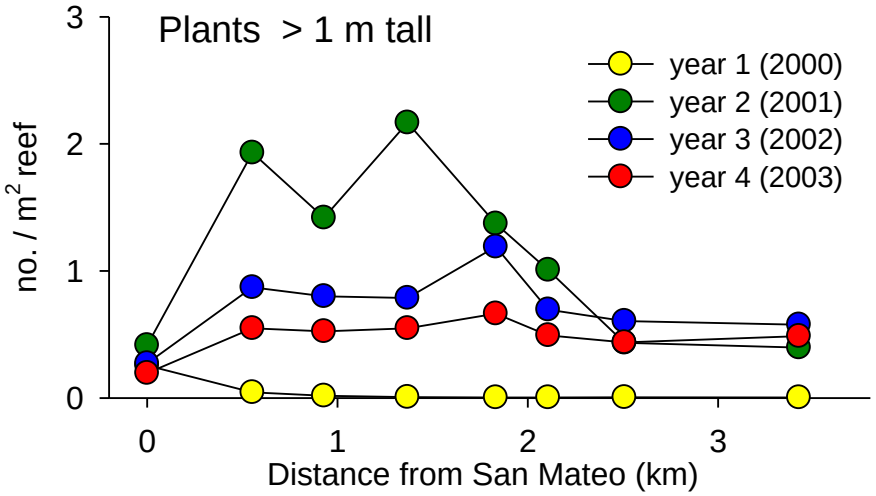
Schematic of Phase 1 Wheeler North Reef and the closest source population of giant kelp at San Mateo Reef





Infrared satellite image of Phase 1 Wheeler North Reef three years after construction

Kelp shown in red



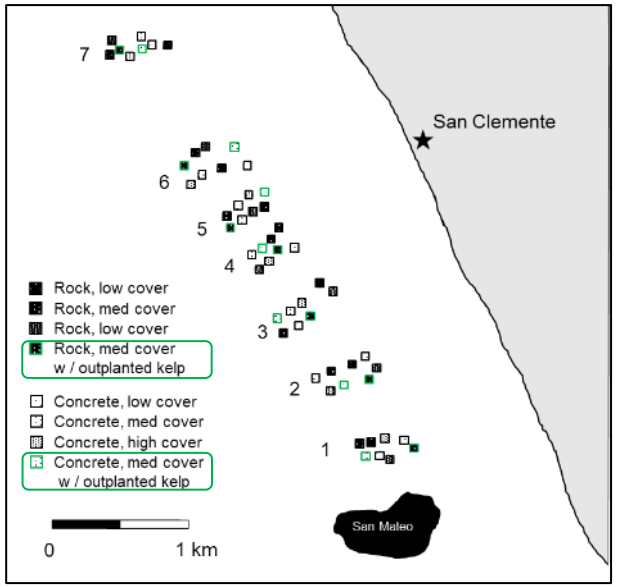
Wheeler North Reef: Phase 1

Outplanting laboratory-reared giant kelp

Outplant unit:
8 cm length of braided line containing many kelp embryos attached to pvc plate bolted to the bottom

Experimental design

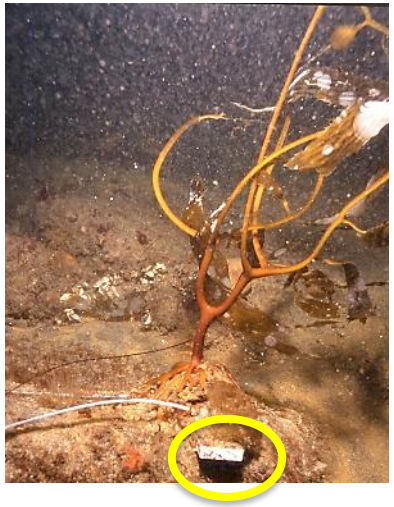
- 60 outplant units/module
- 2 modules per block
- 840 total outplant units



Outplant monitoring
Sampled 1 and 12 months after installation.

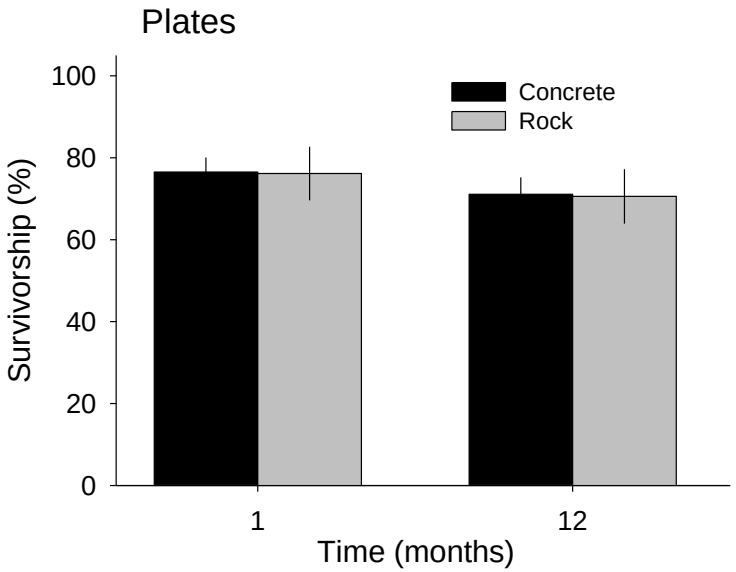
Data collected included:

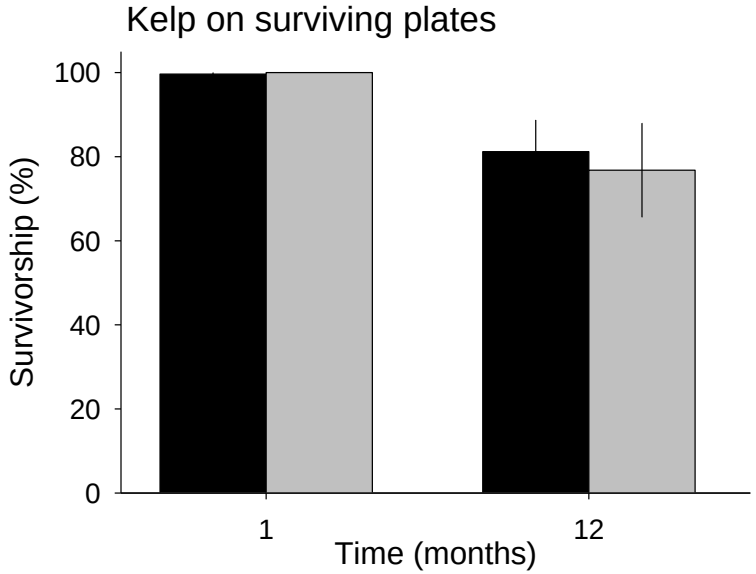
- Survivorship of pvc plates
- Survivorship of kelp on surviving pvc plates
- Size of kelp on surviving pvc plates



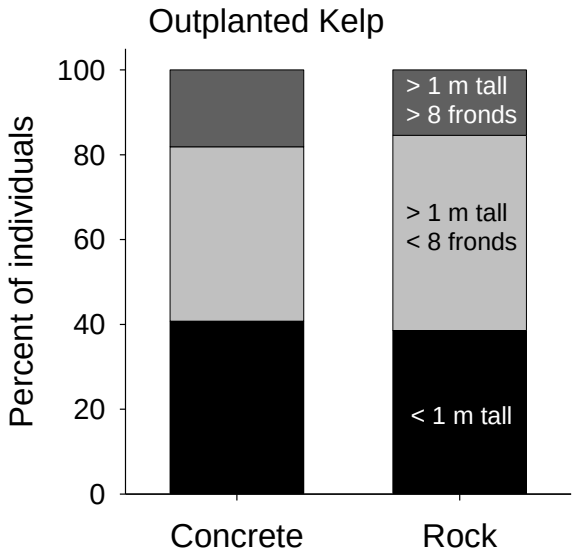
Wheeler North Reef: Phase 1

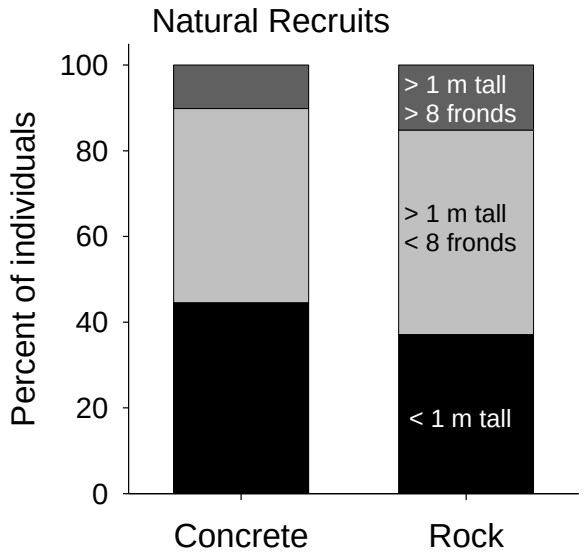
Outplanted laboratory-reared giant kelp

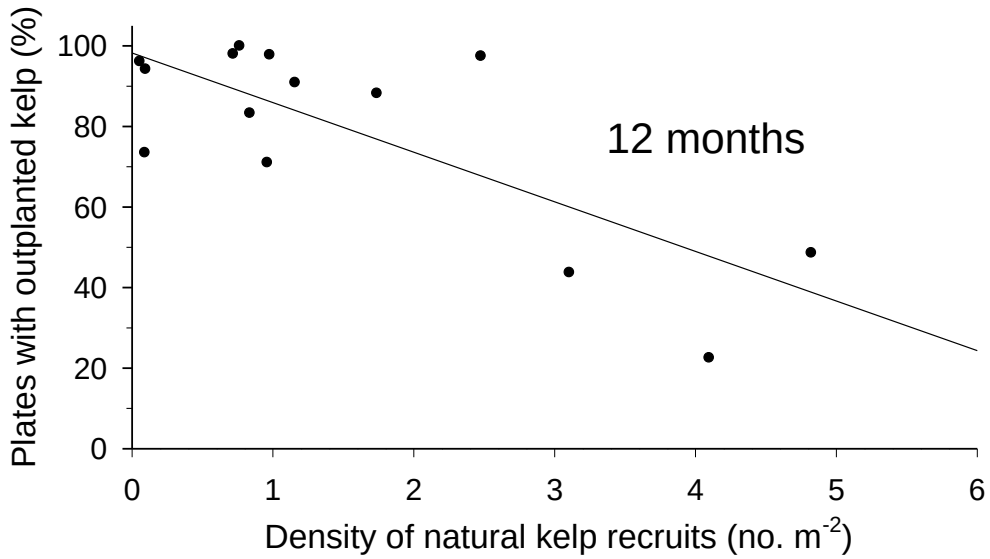




***Outplanting kelp was largely successful, however, it was unnecessary as outplanted kelp was* overwhelmed by natural recruitment**

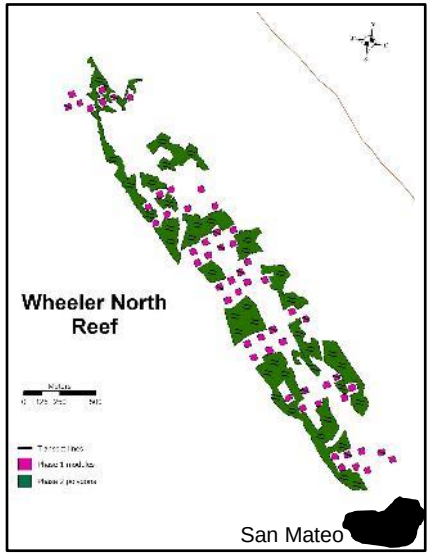






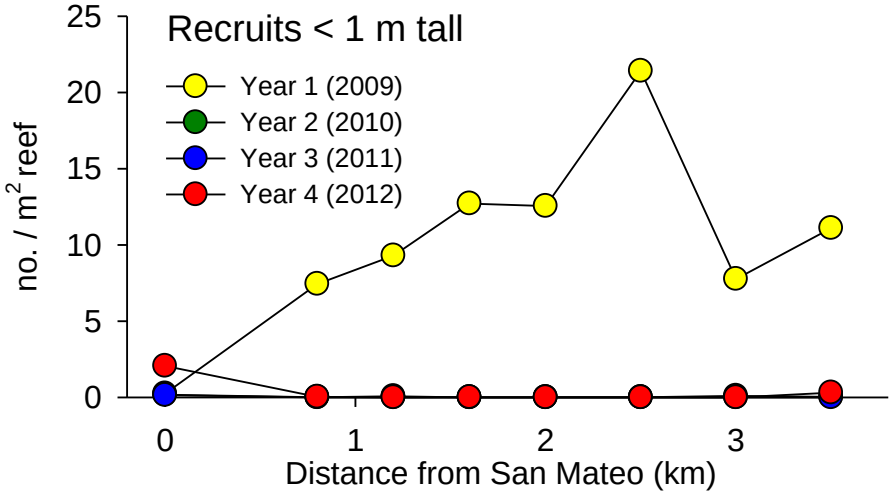
Phase 2 Wheeler North Reef

Giant kelp colonization



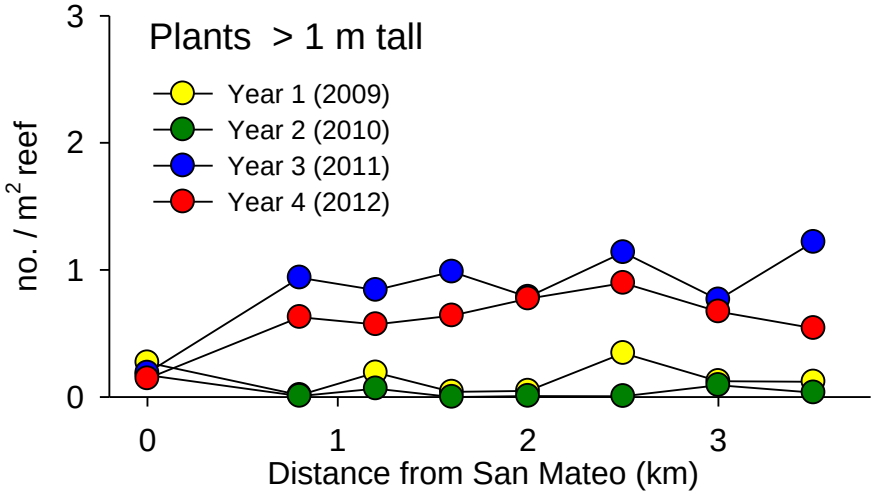
Schematic of Phase 2 Wheeler North Reef in relation to the Phase 1 reef and the natural source population of giant kelp at San Mateo Reef

Black lines in the polygons indicate sampling locations



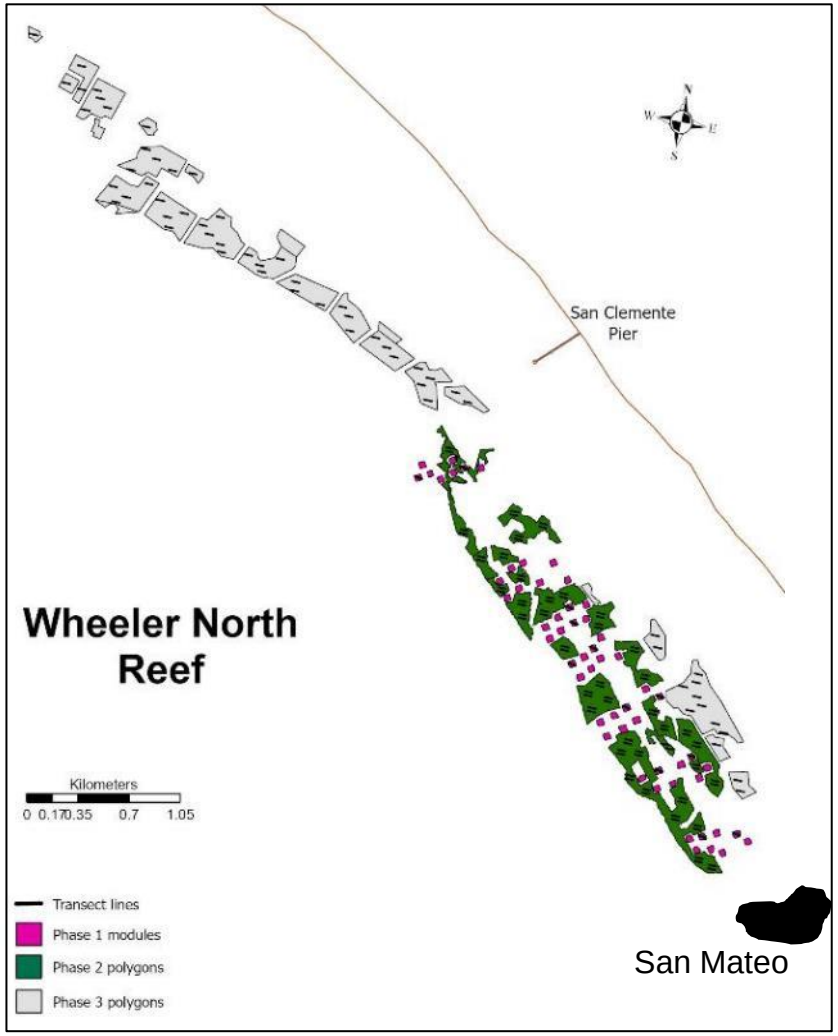
Infrared satellite image of Phase 2 Wheeler North Reef three years after construction

Kelp shown in red



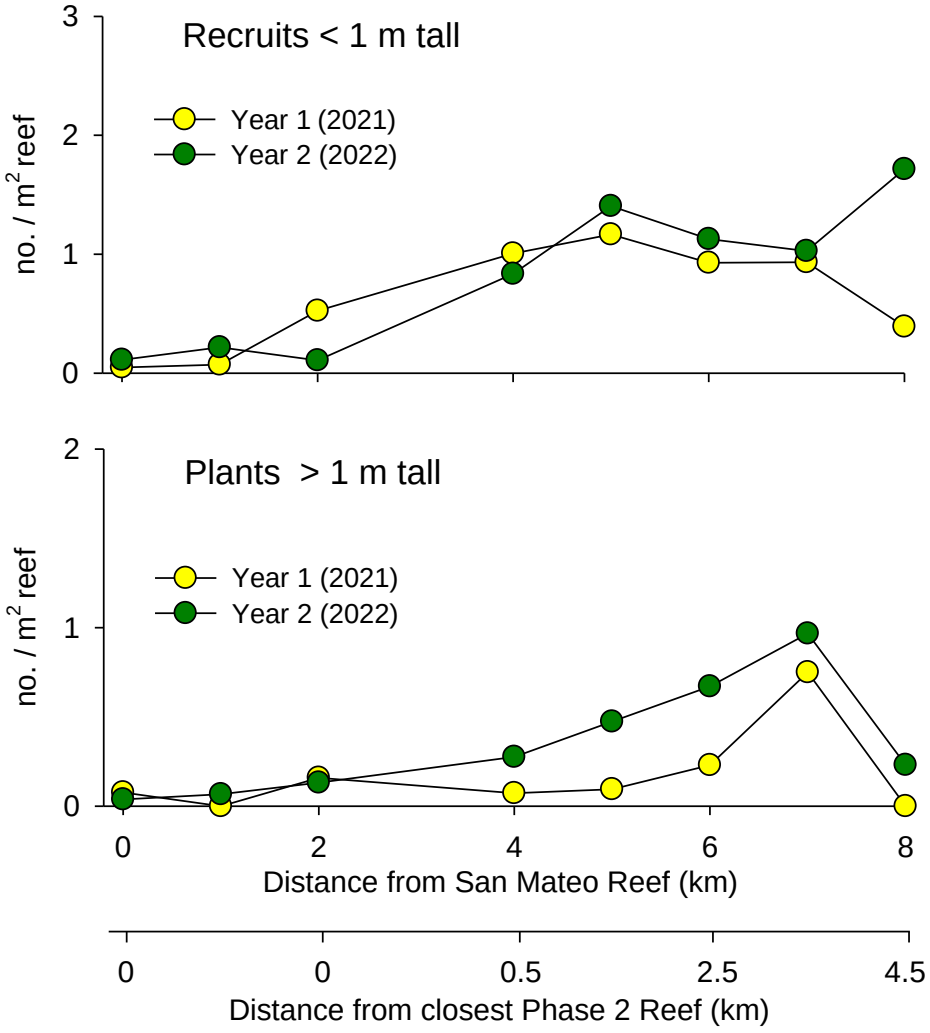
Phase 3 Wheeler North Reef

Giant kelp colonization



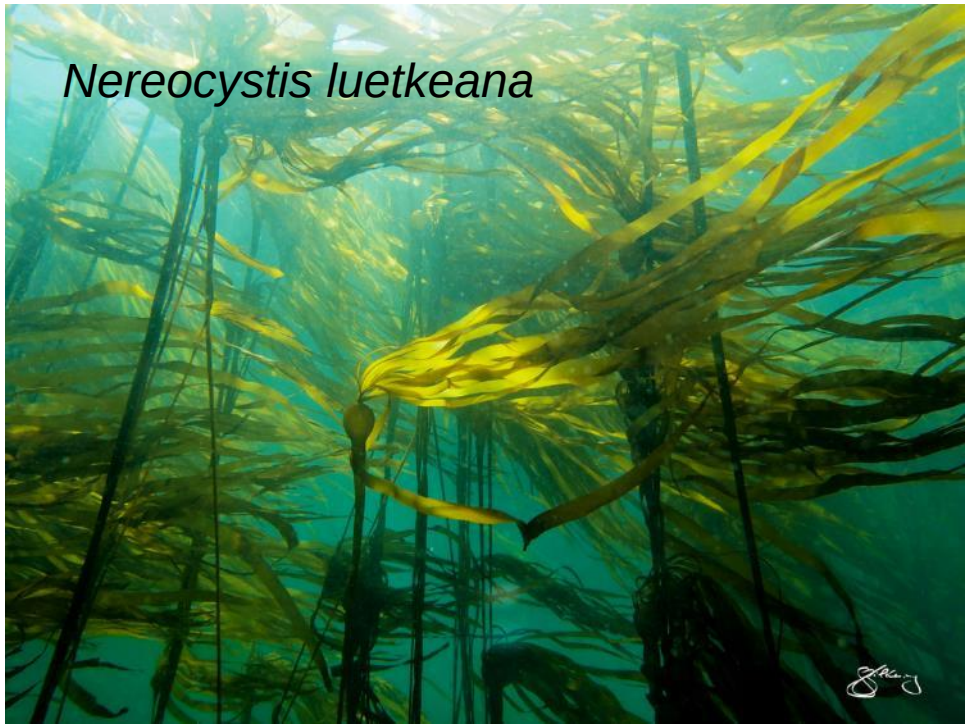
Schematic of Phase 3 Wheeler North Reef in relation to the Phase 1 and 2 reefs and the natural source population of giant kelp at San Mateo Reef.

Black lines in the polygons indicate sampling locations



Colonization by *Macrocystis* over distances of at least several km is the *norm*

The dispersal potential and spatial scales of colonization of *Macrocystis* are not unique among kelps or to floating kelps



Recolonization of bull kelp occurred at km-scale distances in northern California following widespread kelp loss

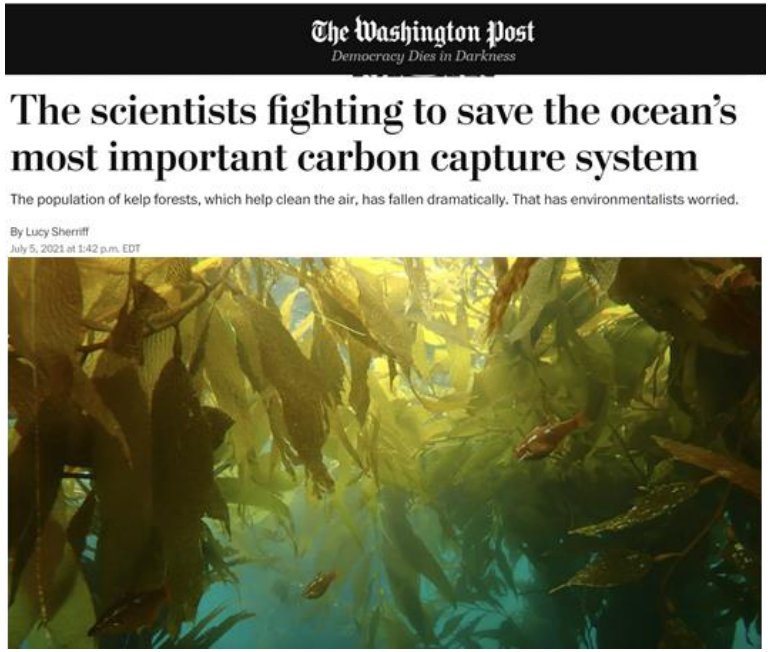
Kate Cavanaugh, The effect of refugia connectivity on northern California kelp recovery (session 5)

In situ measurements of gametophyte recruitment show spore dispersal to at least 4 km *(Reed et al. 1988 Ecol Monogr)*

Estimates of genetic connectivity using microsatellites indicate *Pterygophora* and *Macrocystis* have similar dispersal capabilities despite differences in their rafting ability *(Hargarten et al. 2020 J. Phycol)*

Growing concerns about global kelp forest decline

Growing interests in global kelp forest restoration



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Leveraging the blue economy to transform marine forest restoration

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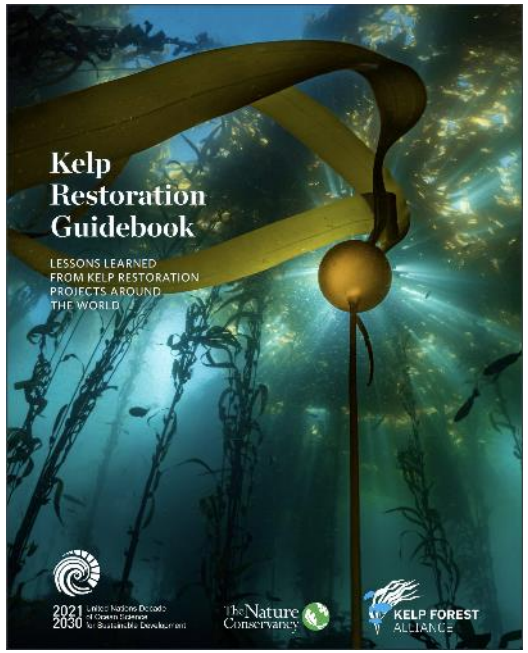
Global kelp forest restoration: past lessons, present status, and future directions

Reforesting California's kelp forests, one pebble at a time

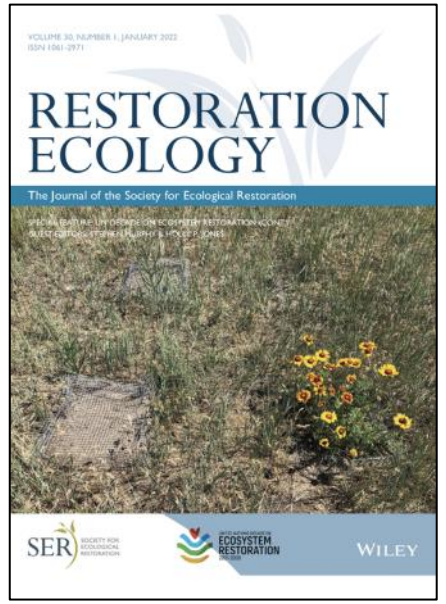


Ecological restoration is most likely to succeed if informed by the science of restoration ecology

The science of restoration ecology involves:

1. Clearly defined restoration goals and targets
2. Identifying the cause(s) of degradation and developing effective restoration methods *prior to* attempting restoration

- ***Policy makers typically determine # 1 in response to the socio-economic concerns of stake holders***
- ***Science and restoration ecologists have a critically important role in #2, which is essential for ensuring that restoration goals and targets are met***



Wheeler North Reef: Implications for kelp forest restoration

1. Restoration goals and targets were clearly defined by the responsible regulatory agency
   - *Build an artificial reef large enough to support 61 ha of moderate to high density giant kelp forest and associated community*
2. Experiments and extensive monitoring were used to determine how reef design affects patterns of kelp colonization and the need to augment kelp abundance via outplanting
   - *Results show kelp can colonize rapidly over relatively large distances (i.e., km)*
     - ***Efforts to seed or plant kelp because it is technically feasible may be misplaced if dispersal and recruitment are not limiting kelp recovery***

Thanks to the SONGS mitigation monitoring team

For more information go to: http://marinemitigation.msi.ucsb.edu/