The role large marine herbivores play in coral reef resiliency and recovery in Palmyra Atoll

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Introduction

Coral reefs are essential marine ecosystems that harbor a high amount of biological diversity. However, due to destructive anthropogenic factors such as overfishing coral reef health around the world has declined. Reefs that were once dominated by corals are being replaced by algal turfs and macroalgae. Marine herbivores are important contributors to reef health consuming algae and opening space for coral recruitment. In this study, we investigate the role marine herbivores, in particular large herbivorous fishes (>50 cm total length) play in coral recruitment and reef recovery.

We conducted this study at the Palmyra Atoll National Wildlife Refuge, located in the Central Pacific, approximately 1600km south of Hawaii (Fig. 1). Palmyra's intact, pristine fish community provides a unique opportunity to study the role large herbivores play in coral recruitment. In 1991 a long line fishing vessel was grounded on Palmyra's shallow reef terrace and subsequently started an outbreak of the corallimorph, *Rhodactis howesii*. The outbreak smothered the majority of corals in the wreck's vicinity and were found in density as high as 288 individuals/m^2. In 2013, the US Fish and Wildlife Service removed the wreck and by 2017 corallimorph percent cover was below 10%. As the outbreak subsided, bare calcium carbonate substrate was exposed and the reef began to recover with the onset of coral recruitment.

Fig. 1: Palmyra Atoll is located south of Hawaii.

Methods

To investigate the role large herbivores play in coral reef recovery, the Caselle lab set up herbivore exclusion cages at Palmyra's recovering reef in 2018.

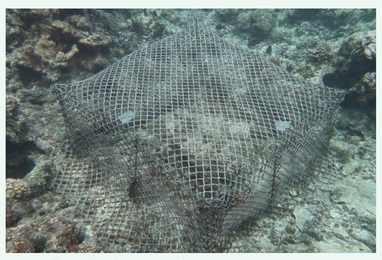

Fig. 2: 1x1 exclusion cage set up

The experiment consists of 3 treatments: 1x1, 2x2, top only and a control. Every treatment includes 2 settlement tile sandwiches which are collected, dried, and coral recruits counted annually.

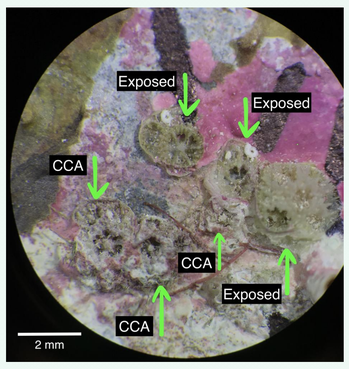

Fig. 3: Six coral recruits under the microscope.

Results

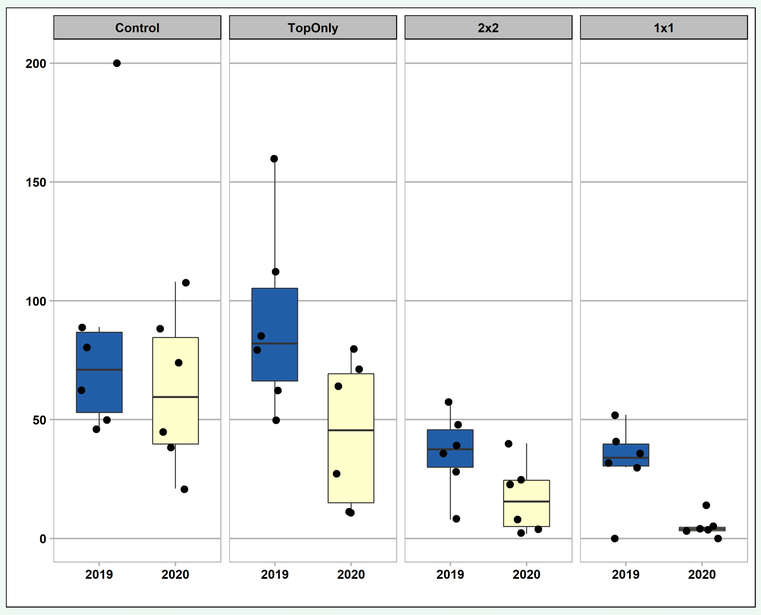

Fig 4. Box plots showing the distribution of coral recruits found on settlement tiles inside herbivore exclusion cages. Blue boxes represent data from tiles deployed from 2018 - 2019, while light yellow boxes represent data from 2019 – 2020. Each panel represent a different herbivore exclusion treatment or control. The control treatment is open to feeding all herbivores. The Top Only treatment excludes largest herbivores (>50cm total lengby th). The 2x2 panel represents the intermediate exclusion treatment and the 1x1 panel depicts the smallest exclusion treatment. The low and upper portions of the box plots represent the 1st and 3rd quartile of the data.

- In both our 2018-19 and 2019-21 sample years, we observed a consistent number of coral recruits in the control.
- As the cage treatments get smaller and the large herbivores have less access, we observed a decrease in coral settlement rates. This general pattern remains consistent with both the 2018-19 and 2019-20 data.
- The lowest values observed were in the 1x1 treatment from 2020.

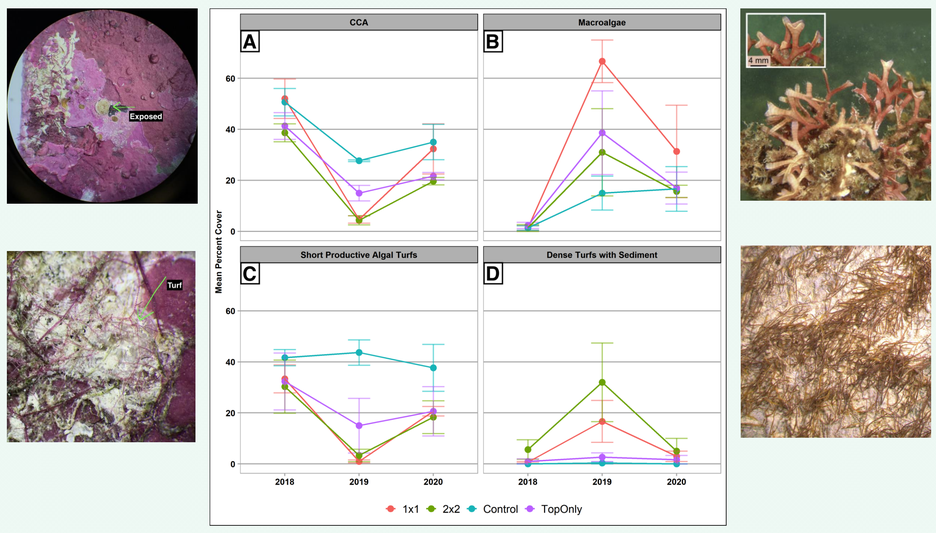

Fig 5. Line graph showing the percent cover data of the four most common cover types observed within the experimental treatments depicting the ambient conditions settling corals were experiencing. Upper left corner box, A, shows data of crustose coralline algae (CCA). Upper right corner box ,B, shows data of macroalgae. Lower left corner, C, shows data of short productive algal turfs. Lower right corner, D, shows data of dense turf with sediment. Red lines represent our 1x1 treatment, green lines represent our 2x2 treatment, blue lines represent our control and purple lines represent our top only treatment.

- In the blue lines, we can see the control consistently having higher levels of CCA and short productive algal turf.
- In the green and red lines which represent our 1x1 and 2x2 treatments, CCA and short productive algal turf are rare while macroalgae and dense algal turf with sediment become the dominant benthic cover types.
- The purple line, which represents our top only treatment, shows an intermediate cover of CCA, macroalgae and short productive algal turf. However, it has a low cover of dense algal turf.

Discussion

- We observed lower recruitment rates during 2020 which could be related to the cage environment becoming less hospitable to coral recruits 2 years after its installment.
- CCA and other corals are positive settlement cues. While macroalgae and dense turf with sediment are negative settlement cues. This may indicate why we observe a higher number of coral recruits in 2018-19 where CCA was abundant and macroalgae as well as dense algal turf were rare. We also observed a lower number of coral recruits in 2019-20 where CCA percent cover decreased and macroalgae increased.
- Short productive algal turf can turn into dense turf in the absence of herbivory. A surprising result was the low dense turf with sediment in 2020 possibly due to wave disturbance removing the thick turf mats. (Fig. 5 D)

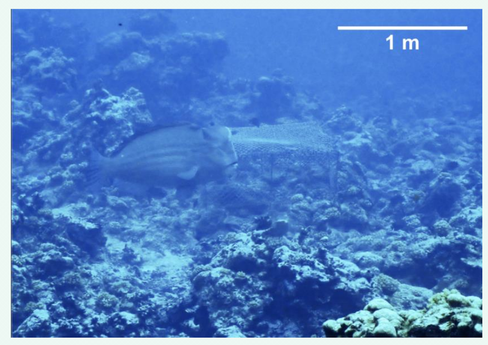

Fig. 6: Bumphead parrotfish next to exclusion cage

- We did not find a strong effect on coral settlement when only large herbivores were excluded.
- We found evidence that large herbivores prevent the establishment of macroalgae, which may impact coral growth and survival.
- In our smallest treatments, macroalgae and dese algal turf were found in high densities which negatively affects coral settlement.

Fig. 7: Close up photo of 2x2 treatment

Next Steps

- Analyze fish variation rates from cage footage as possible explanatory variables for variation in coral settlement.
- Analyze *in situ* cage and tile pictures.
- Continue collecting 2021 data from Palmyra.

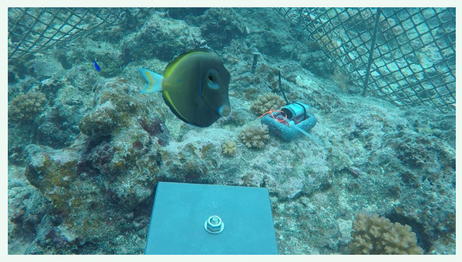

Fig. 8: Frame from 2x2 treatment cage footage

Acknowledgements

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