Overgrazing by warm water fishes drives the loss of kelp forest in a temperate reef

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Introduction

The ocean is experiencing significant warming due to anthropogenic climate change, and it is expected to continue. Ocean warming is driving the ongoing destruction of underwater kelp forests and the exposure of reefs in many parts of the world including in Japan. This phenomenon of kelp loss has been referred to as "isoyake". Kelps are important foundation species and form one of the most productive ecosystems that provides numerous ecosystem services and supports a large biodiversity. One of the potential causes of kelp loss may be the expansion of tropical herbivorous fish species into high latitudes. There are several types of herbivorous fishes, "Browser" that feed on adult kelp, and "Grazer" that prevent the establishment of macroalgae by removing recruits and detritus from the ground. However, the interaction between tropical herbivorous fish and macroalgae in temperate regions, including Japan's coastal waters, is still not well understood. The purpose of this study was to evaluate the direct effects of herbivorous fishes on kelp forests in Shimoda, Izu Peninsula, where kelp loss has been progressing in recent years.

Materials and Methods

Monthly monitoring surveys by scuba diving were conducted in three areas that represent barren (no kelp), transient (ongoing kelp loss), and kelp forest (abundant kelp) sites, in the waters around Shimoda, Shizuoka, Japan. Two types of surveys were conducted in the morning from June 2021 to January 2022.

1. Underwater Visual Census (UVC)

20 x 5 m belt transects were randomly set up at a constant depth, and the abundance of all fish species was recorded. Fish species were identified using FishBase. The presence/absence of kelp thalli was checked for each transect. The difference in the fish community among sites, months, and the presence of kelp, was visualized using nMDS and the significance was assessed using PERMANOVA.

2. Observation of feeding on macroalgae using video cameras

Underwater video cameras were randomly placed at intervals of 5 m or more for 60 min to observe the feeding by herbivorous fishes on macroalgae. The rate of feeding by herbivorous fishes on macroalgae was expressed as the number of bites per species per hour. From the beginning of the survey at the barren site and from November 2021 at the other two sites, kelp loss had already progressed, and kelp was rare or absent, so individuals of *Ecklonia* sp. and/or *Eisenia* sp. collected at another site were strapped onto three sandbags (two individuals per bag), which were then randomly placed. Three cameras were used to record the feeding on the introduced or natural kelp and three cameras were used to record the feed on reef macroalgae.

Results

1. Underwater Visual Census (UVC)

At the barren site, no kelp was found during the whole survey period. At the transient site, kelp was absent in some transects from September, and from November no kelp was recorded. At the kelp forest site, kelp disappeared in some transects from November, and only stipes remained from December.

Visualization of fish community structure by nMDS (Figure 1) and PERMANOVA analysis showed a significant interaction of sites and months on the fish community structure ($p < 0.001$) and no effect of the presence of kelp ($p > 0.05$). The fish community structure at the transient and the kelp forest sites showed similar seasonal variation and community structure. The barren site showed a constant community composition that differed from the two other sites, especially during the warmer months, and included numerous (sub-)tropical species. Sub-tropical herbivorous fishes were present at all sites and months.
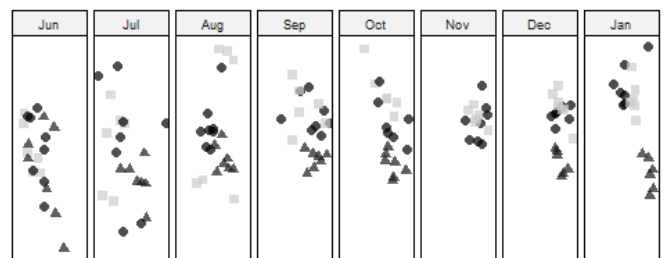

Figure 1: nMDS plot per month of the fish community at the transient (●), kelp forest (■), and barren (▲). Data is missing for the barren site in November 2021.

2. Observation of feeding on macroalgae using video cameras

The species that showed the highest feeding rates on kelp was *Calotomus japonicus*, followed by *Siganus fuscescens* and *Prionurus scalprum*. Feeding rates were generally high at the barren site and increased from April to November at the transient and kelp forest sites. Feeding rates were generally low during the cold months of the year (December and January).

Discussion

Kelp was still abundant at the barren site in 2016 and had completely disappeared by the time of this survey. The fish community at this site differed from that at the other two sites, suggesting that a different, tropicalized, community is already established. During the survey period, all kelp disappeared from the transient site, which was concomitant to a high feeding pressure, suggesting that herbivory by (sub-)tropical fishes is driving kelp loss in waters around Shimoda. Although some kelp remains at the kelp forest site, its abundance decreased and as the fish community and feeding pressure are similar to those at the transient site, there is a high probability that local extinction of kelp will also occur in the coming years at this site.