Development of a method for the quantitative assessment of fish grazing pressure in temperate reefs

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Introduction

Kelps and other macroalgae are critical habitat-forming species in temperate reefs, creating underwater forests that support high biodiversity, contribute to carbon fixation, and provide vital ecological services. However, these ecosystems are increasingly threatened by global warming and other climate-driven changes, leading to their widespread decline. One of the key drivers for kelp loss is overgrazing by tropical fish, which rapidly expand their ranges polewards as sea temperatures rise. Although many studies have investigated the interactions between macroalgae and herbivorous fish, the methodologies applied vary significantly, making it challenging to obtain comparable quantitative data across different sites. Particularly, there is no standardized method to assess herbivory rates by fish, which is one of the main indexes showing the interactions between fish and macroalgae. Here, I review the methods for measuring fish grazing rates, highlighting their strengths and weaknesses, and propose a method to quantify fish grazing pressure in temperate reefs.

Method

Summarize existing methods

To identify and compare existing methods to assess fish grazing pressure, relevant studies published in the last 15 years were reviewed. Publications were collected papers from the Web of Science, using the following search terms: TS=(herbivor* fish* grazing*) AND TS=(pressure* OR rate*) AND TS=(marine* OR ocean*). All the articles were analyzed to understand each method of rating fish herbivory.

A longline-like assay of fish grazing pressure

We developed a simple and cost-effective method inspired by longline fishing techniques. One assay consists of macroalgae baits and a long line tied to a vertical line with a float and anchor. Floats are attached at each end of the long line to prevent an assay from being loose. Assays can be deployed and retrieved from a boat, excluding the need for diving. For broader accessibility, the method primarily uses widely available dried macrophytes, as bait, such as Laminaria. *Saccharina japonica* cutting into rectangles and *Undaria pinnatifida* were chosen for the bait of our assay due to their ease of preparation. Experiments on fish food selection using one of the range-extending tropical fish species *Calotomus japonicus* were also conducted to find suitable bait conditions. As a case study, the proposed method was applied in Shimoda (Japan) to investigate the grazing pressure by range-extending tropical fish and its contribution to the decline of the local kelp population.

Result and Discussion

A total of 89 papers were reviewed of which 35 did not assess herbivory. Four main types of experiments were highlighted: algae deployment (17), quadrat (11), exclusion (17), and Underwater Visual Census (13). Their strengths and weaknesses are shown in Table 1. Each method has its unique advantages, however, they require certain amounts of underwater work (all), long deployment period (exclusion), and often taxonomical knowledge and literature availability on species grazing rates (Underwater Visual Census).

The proposed method has a simple design and does not require underwater procedures. Given that longline fishing is globally used, the simplicity and similarity enable local fishermen to incorporate the survey in management strategies, which allows for obtaining broader data across multiple sites. While algae deploying experiments are usually not used in kelp forests due to the low visibility of the assays affecting fish grazing rates, our method can tackle this issue with changeable bait depth.

Either bitemark presence or percentage of bait loss can be used for the quantitative assessment of herbivory. Although assessing bitemark presence allows for easier data collection, it can quickly reach the maximum value when the herbivory rate is high. Determining the score of each bait according to the percentage eaten can solve this. Even though the case study showed certain numbers of fish bitemarks, there is room for improvement, especially in the bait used. *S. japonica* is robust and it is easy to recognize bitemarks, however, it may not be the preferred bait of targeted fishes based on our case study and fish feeding selection experiments. While *U. pinnatifida* can be more palatable than *S. japonica*, its fragility makes rating more difficult. Combining *S. japonica* with glutamic acid, which is known to attract fish, can be a better option for bait. The shape of the bait may also influence herbivory rates, requiring adjustments to balance between ease of evaluating and impact on fish behavior. Baits located closer (0.5m) to the ground showed a higher bitemark count compared to bait 3m above ground. Further optimization of bait height for ecosystems such as kelp forest should be investigated too. However, 0.5m above ground or above canopy could allow a standardized assessment of fish herbivory in diverse ecosystems.

While certain challenges remain, this study provides a framework for collecting generalized data on fish grazing pressure that can be compared across locations and time periods. Such standardized datasets are crucial for advancing our understanding of ecosystem functions and informing effective ecological conservation and restoration strategies. The proposed method offers a valuable tool for protecting macroalgae-dominated ecosystems that are at risk of disappearing.

Table 1. General comparison of methods for rating fish herbivory

Experiment type	Strength	Weakness
Algae deployment	Direct measurement	Require underwater procedures Limited applicable ecosystem
Quadrat	Repeatability Detailed data on fish activity	Require underwater procedures Impact of non-fish herbivores Indirect measurement
Exclusion	Natural algal community direct measurement	Require underwater procedures Effects of cages on fish behavior
Underwater Visual Census	Data availability by species	Require underwater procedures Indirect measurement
Longline-like assay	Simple, standardized Direct measurement Applicable to diverse ecosystem	Non-natural bait No info on fish species