Patterns and drivers of habitat utilization in parrotfish (Scaridae)

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Background

Coral reefs are deteriorating extensively across the globe, as 20% of the world's coral reefs have been effectively destroyed, and approximately 24% of the remaining reefs are under imminent risk of collapse. *Coral–algal phase shifts* refers to the phenomenon of coral reefs shifting to unusually low levels of coral cover, associated with persistent states of high algal cover. Such shifts may occur rapidly, triggering a cascading effect which has resulted in the collapse of invertebrate and fish communities. Reef resilience depends on several elements, of which the capacity to resist phase shifts towards an algae dominated state is of greatest concern [1]. Resistance of coral reefs to phase shifts is accredited largely to herbivorous fishes, which feed on algae and play a critical role in preventing algal blooms thereby actively facilitating coral settlement [2].

An outstanding example of such key functional species are parrotfishes (family Scaridae) - large reef-associated herbivores who are ubiquitous components of fish communities on tropical reefs around the world. **Parrotfishes are widely viewed as a key functional group in ecosystem services on coral reefs, by playing a crucial role in facilitating the resilience and recovery of reefs from recurrent and irregular disturbances** [3]. Though parrotfish have become the focus for many reef ecologists and conservationists- studies of distribution at the individual level are limited to coarse spatial scales (>km), short temporal spans (days to weeks), small sample sizes, and specific phases of their life history (e.g., spawning season). As a result, the current body of research provides a limited understanding of long-term space-use patterns in parrotfish; the spatiotemporal extent over which individuals exert their function (i.e., forage); and how biological and environmental conditions affect their utilization patterns.

In my research, I take a multifaceted approach to study habitat utilization by monitoring long-term patterns at fine-grain resolution; examine how said patterns vary in response to environmental disturbances (both endogenous and exogenous stressors); and study the crucial (yet grossly overlooked) aspect of habitat selection during periods of non-activity (i.e., at night). Given the key functional role of parrotfish on coral reefs, it is crucial to better understand how individual space-use patterns vary under adverse scenarios, and how such behavioral adaptations would potentially scale-up to the level of ecosystems they maintain.

Selected research questions include:

(1) **The role of individual variation** (i.e., personality) **in shaping overall distribution patterns**. The degree of behavioral variation within a population could have a wide range of ecological implications – from affecting individual fitness to population resilience. In the context of parrotfish, it provides novel insights on what shapes grazing patterns and the ability of parrotfish to adapt in response to rapid phase shifts [in collaboration with Prof. Moshe Kiflawi of Ben-Gurion University of the Negev; Prof. Glenn Crossin of Dalhousie University, Canada].

(2) **Patterns and preferences in nocturnal habitat selection** (i.e., sleeping sites) – an aspect of animal ecology that is largely understudied and often overlooked [4]. The selection of sleeping sites can have critical consequences for individual fitness, as these sites may provide access to necessary diurnal resources and\or protection from predation or natural elements [4]. However, to date, sleeping behavior and habitat selection among co-occurring species remain undocumented (with the notable exception of primates). My working hypothesis is that interspecific variation in sleeping-site selection by herbivorous reef fishes may elucidate parrotfish considerations for habitat selection, and the degree to which considerations are shaped by fear of predation. On a broader view, variation in nocturnal habitat utilization may indicate a mode of niche differentiation facilitating species-coexistence.

(3) **The effects of chronic stress of behavior and function.** Reef fish are subjected to many stressors that are non-lethal yet long lasting (i.e., chronic stress, such as fishing pressure, recreational activities, various forms of pollution). In fish, as in other vertebrates, the physiological response to environmental stressors is mediated by glucocorticoids (often referred to as *stress hormones*). While adaptive in the short-term, chronically elevated levels of stress hormones can be detrimental to factors such as locomotion, feeding, reproduction, and survival; all of which could have cascading ecological consequences. Despite the potential for direct ecological ramifications, little has been done to examine how chronic stress may scale-up from the level of the individual to the functioning of the associated ecosystem, e.g. through changes in habitat utilization. [in collaboration with Prof. Glenn Crossin of Dalhousie University, Canada; Dr. Iris Meiri - Israel Oceanographic & Limnological Research].

(4) **Effect of extreme events on behavior and resilience of parrotfish**. Recent extreme evens include the massive storm in the Gulf of Eilat during March 2020 which left in its wake considerable devastation throughout the reef (including substantial degradation and destruction of areas utilized by parrotfish up to that point), and the recent COVID-19 shutdowns, which have reduced and at times ceased all human activities on the reef such as vessel traffic and recreational activities. These *real-life experiments* provide a rare opportunity to empirically assess both the impact of landscape degradation and fragmentation, and of human presence and activity on parrotfish at a scale that would otherwise be impossible to achieve [5].

(5) **Other collaborations**:
Prof. Ronen Segev, head of the Inter-Faculty Brain Sciences School, Ben Gurion University of the Negev, Israel – collaborator on multiple projects focusing on *Neural activity in free ranging reef fish*.
The European Aquatic Animal Tracking Network (COST action #18102). As chair of a workgroup for *training and dissemination* - I am responsible for producing training materials and conducting international training schools on tracking methods of aquatic animals.

Methods

My main research tool is a cutting-edge underwater tracking system that can provide high-accuracy positions of free ranging animals (*acoustic telemetry*); and record measurements from within the animals' body such as depth, acceleration, and body tilt (watch short video of tag implantation). I designed and deployed an acoustic array that spans across a large swath of the shallow reef (> 2 km^2 in size). Over the last two years, we have developed powerful analytical tools to process and calculate positions from raw acoustic data collected by the receivers. To date, our algorithm outperforms (in terms of accuracy, processing time) - all existing alternatives, ranging from open-source algorithms [e.g., 6] to (paid) commercial services. To emulate a state of chronic stress of parrotfish while in their natural habitat, we designed and manufactured ethylene-vinyl acetate copolymer implants (EVAc) that release sublethal levels of cortisol in a controlled rate for periods of up to 21 days. Acoustically tagged parrotfish received either a cortisol implant, or a placebo (EVAc without the glucocorticoid component). This will enable me to quantify the effect of chronic stress both within and among individuals- by doing so this will be the first study to record the behavior and movement of any aquatic animal in the wild under sustained chronic stress.

Results

In a paper titled *Highly repetitive and spatially constrained space-use patterns of parrotfishes revealed through long-term acoustic tracking* (submission to *Proc. Royal Soc. B*) – I describe our findings that parrotfish exhibited surprisingly high degrees of sleeping and foraging site fidelity, between which they commuted daily. We also find that parrotfishes forage at remarkably limited areas and at temporally restricted times-of-day (see Figure 1). Remarkably, these patterns did not vary with environmental and biological conditions. Our findings indicate concerning challenges as to the ability of parrotfish to actively change their foraging behavior to counter and potentially reverse phase shifts [7].

Sleeping site selection: Though surveys were all conducted within the same area- site selection and behaviors are found to vary substantially among species. For example, some species utilize highly sheltered micro-habitats that minimize exposure, and regularly create cocoons, while other species consistently sleep in highly exposed sites and do not produce protective cocoons (such as *C. sordidus* and *H. harid*, respectively; [click to see a sample of sleeping sites]). Surprisingly, fish size, life phase, and depth show no effect on site selection or behavior.

Data collection of space-use by parrotfish in response to chronic stress and extreme events (i.e., southern storm, March 2020) is completed. Data analysis and findings are forthcoming.

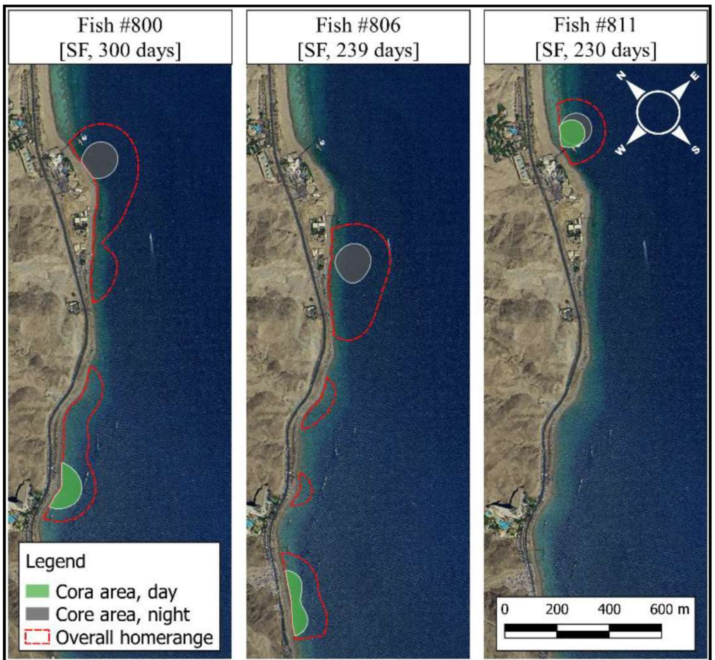

Figure 1. Home-range estimations for three *S. fuscopurpureus* (SF) individuals. Dashed lines (red) delimit the overall home range ($KUD_{95\%}$) calculated over the entire tracking period. Core areas ($KUD_{50\%}$) are shown separately for peak-activity (foraging) during the day and night-time (sleeping site).

Significance

This research has been providing new insights on the spatial and behavioral ecology of parrotfish - a key functional group which plays a crucial role in maintaining and boosting resilience of healthy coral reefs. This work significant not only for gaining a better understanding of the biology and ecology of parrotfish from the individual to the population-level but also enables us to assess and better predict the performance of parrotfish in catastrophic scenarios such rapid phase shifts and other environmental catastrophes.

1. Hughes *et al*. 2010
2. Mumby *et al*. 2006
3. Hughes *et al*. 2014
4. Singhal *et al*. 2007
5. Rutz *et al*. 2020
6. Vergeynst *et al*. 2020
7. Green & Bellwood 2009