



Effects of currents, prey abundance, and additional factors on plankton predation by coral-reef fishes

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Background

Coral reefs flourish in oligotrophic, nutrient-poor seas. The source of nutrients required to support the reef's high productivity have puzzled researchers since the middle of the last century¹. Recent studies have resolved this enigmatic question, showing the key role of plankton consumption by reef inhabitants as the main pathway of nutrient import to the reef community. Zooplankton predation by the diverse, ubiquitous guild of fishes found in the reef is thought to be a major component of that pathway². However, the rates of their predation have never been measured in situ and is therefore included as a major chapter in my research. Likewise, the attributes of strikes by those fishes, once a drifting prey has been detected, are poorly understood. An additional un-answered question is the extent to which foraging by those fishes is sensitive to ocean warming.

Most of the zooplanktivorous fishes in coral reefs are site-attached, forming social groups and foraging across stationary areas around shelters such as branching corals and rocky substrates^{3,4}.

My PhD research focuses on the key mechanisms underlying predator-prey relationships between those fishes and their drifting prey, from the level of strike movements by the individual under controlled conditions in a laboratory flume, through the quantification predation rates by whole groups in the reef.

Research Questions and Methods

1. What are the effects of flow speeds on zooplankton strikes by coral-reef, site-attached fishes?

Corollaries: (a) Are cognitive decisions involved in strike planning? (b) Is there an inter-specific difference in the information processing time (IPT) prior to the onset of strikes?

Using 3D video cameras and advanced digitization programs, I recorded the foraging movements of four site-attached fishes (a total of 22 fish) in a flume. In my experiments I examined the effects of flow speed on the main strike attributes and their inter-species differences, as well as the role of cognitive decisions in performing those strikes. In addition, my experimental design allowed, for the first time, the calculations of the time it takes the fish to plan its strikes, from the moment of prey identification to the onset of a strike (IPT).

2. Can ocean warming affect the key attributes of prey strikes in those fishes?

This chapter, carried out in a temperature-controlled flume, examined this question using two levels of temperature (present, elevated), in combination with 3 levels of flow speed, replicated for two species, 5 individuals per species.

3. What are the rates of in-situ zooplankton predation by coral-reef fishes?

Corollaries: (a) What are the effects of flow speed, prey density, and water temperature on predation rates? (b) Is the fish predation selective for certain prey size and/or taxa?

A novel, state-of-the-art, underwater microscope, called “SPC” (Scripps Plankton Camera⁵) was used to measure non-intrusively, for the first time, predation rates by the aforementioned planktivorous fishes in the coral reef. The calibrated SPC allows the quantification of the density of zooplankton in the size range of 200 to 2000 μm . Taxonomic sorting of the images recorded by SPC required the development of machine-learning procedures, completed as part of this chapter. Each experiment consisted of the deployment of 2 SPCs, one up- and the other down-current of a group of foraging fish (Fig. 1). The decline in zooplankton concentration down-current of the group, together with independent, video-base determination of the number of fish in the target group, allowed me to calculate per-capita predation rates under a wide range of current speeds (measured with a current profiler) and prey densities (Fig. 1).



Figure 1: The experimental design. (A) - Two SPCs were placed around a group of *Chromis viridis*, one up- and the other down-current of a fish group. Two cabled, orthogonal video underwater cameras (only one seen in the photo) continuously recorded the position of the fish and their activity (foraging or not). A current profiler was placed near the fish group. (B) – An example of the same setup used for a typical, large group of *Pseudanthias squamipinnis*. (C) Examples of images of different zooplankton taxa captured by the SPCs.

Results

The effects of flow speed and the prey’s drifting path of the strike attributes were similar for the 4 species I studied, with the distance and angle (relative to flow) of the strikes significantly decreasing with increasing flow speed. The reactive distance (the distance between the fish and prey at moment of strike initiation) decreased when the flow speed exceeded 10 cm/s but remained constant above this flow speed (Fig. 2). That trend indicated a threshold above which a change in striking strategy occurred. Surprisingly, striking speeds remained nearly constant under different flow speeds but were significantly faster at wider strike angles (Fig. 3). The latter two trends, together with a (relative) postponement of the strike onset under stronger currents (Fig. 2) and faster strikes when the prey approaches in wider angles (Fig. 3), indicated the involvement of planning when foraging, that is, cognitive decisions⁶. The IPT duration calculated under different flow conditions indicated that those decisions are made within 200-400 msec from the moment a prey is detected, within the range reported for birds and monkeys^{7,8}.

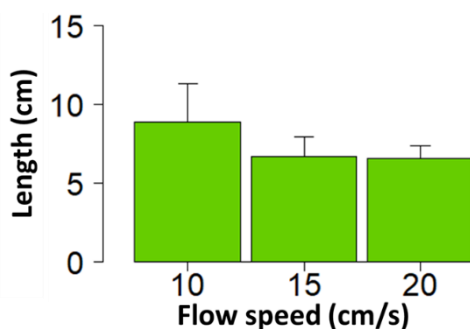


Figure 2: Reactive distance via flow speed. Mean (\pm SD) of the reactive distance for cases in which the prey drifted almost directly ($\leq 45^\circ$) toward the fish. The results of *C. viridis* shown here represent the shared trend by the 4 species.

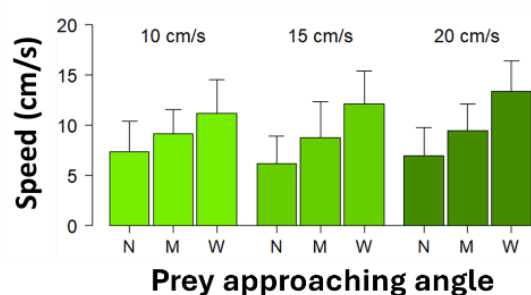


Figure 3: Striking speed relative to Earth vs. prey approaching angle and flow speed. Shown are the means (\pm SD) of the speed of strikes in Earth coordinates performed under different flow speeds (between bar triplicates), in the three different categories of prey approaching angle relative to flow direction: N: angle $< 10^\circ$, M: $10^\circ \leq \text{angle} < 20^\circ$, and W: angle $\geq 20^\circ$ (within bar triplicates). The results of *C. viridis* shown here represent the shared trend by the 4 species.

The effect of warming markedly differed between the 2 examined species, despite their close similarity in size and life-histories. The striking speed in both species increased under warmer water; however, at elevated temperature, *Chromis viridis* increased its strike distance, its foraging volume (Fig. 4), and the area within which the drifting prey was captured. Conversely, in *Dascyllus marginatus* those parameters decreased or were unaffected by warming. Hence, warming is expected to enhance feeding in *C. viridis* while the opposite is expected for *D. marginatus*.

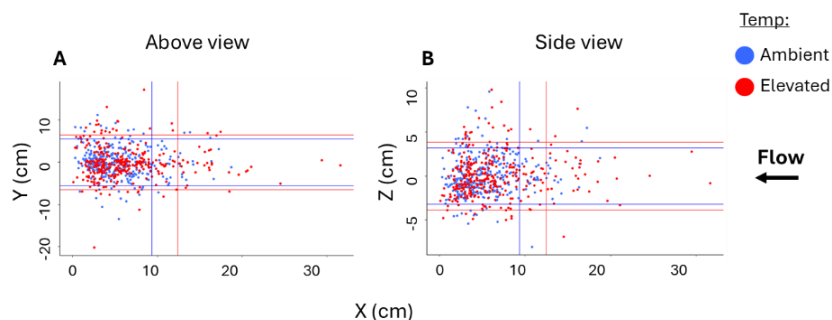


Figure 4: The influence of water temperature on reactive distance. Shown are the reactive distances in the X, Y, and Z directions under ambient (blue dots and lines) and elevated (red) temperatures as viewed from above (A) and from the side (B). The starting point of each strike was defined as located at point 0,0,0. Dots indicate the prey position at the time the strike was initiated. Lines indicate the 0.9 percentile of the distances in each of the X, Y, and Z directions. Flow direction is from right to left. The axes are parallel to the flow direction (X), perpendicular left or right (Y), and vertical (Z).

SPC measurements were carried out at the coral reef off the IUI during 1.3 yrs, targeting 3 species of fish. Preliminary results (Fig. 5) indicated predation rates in the range of 1 to 2 prey/s. Predation rates by *C. viridis* were significantly lower than those of *Pseudoanthias squamipinnis*, and those by *D. marginatus* (more to be analyzed) not different from the other two species. The Chesson Index indicated a strong selectivity by *P. squamipinnis* to appendicularia and by *C. viridis* to veligers. Remarkably, my in-situ measurements with SPC clearly corroborated the conclusion from my flume experiment with *C. viridis*, indicating higher predation rates in warmer waters (Fig. 6).

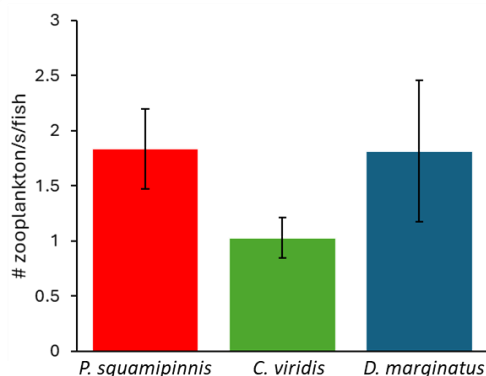


Figure 5: Mean (±SE) in-situ, per-capita feeding rates.

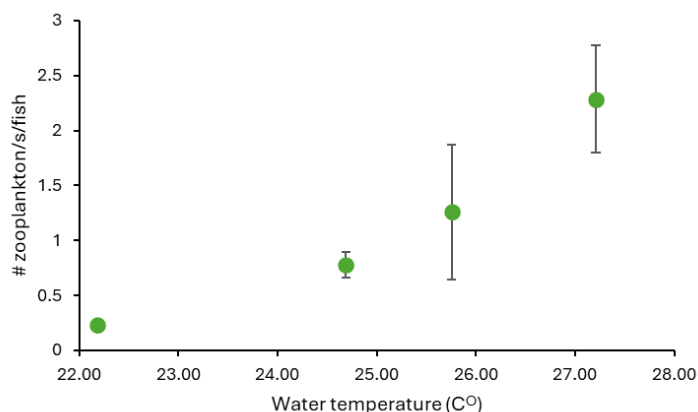


Figure 6: Mean (±SE) in-situ, per-capita feeding rates of *C. viridis* under different water temperature.

Summary

Through the combination of laboratory and field experiments, I demonstrated the remarkable effects of current speed, prey drifting path, water temperature, and prey density on zooplanktivory among coral-reef fishes, for the first time in situ. My study greatly contributed to the application of a novel, potentially ground-breaking tool for marine ecology, including the development of the in situ experimental design and the use of advance machine learning procedures to process the recorded images. The involvement of cognition in the foraging for drifting plankton in fish also contributed to our understanding of the complexities involved in these predator-prey interactions. Overall, I hope that my research now allows a better assessment of the role of fish planktivory to the trophic functioning of coral reefs.

References

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