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Two new methods for sampling zooplankton and larval assemblages in tropical reef ecosystems

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ABSTRACT

Sampling mobile zooplankton on reefs is a major challenge, mainly due to the problems faced when towing plankton nets inside complex reef mosaics. This study presents two new systems that permit precise point sampling of micro- and mesozooplankton and larvae of invertebrates and fish: the Channel Midwater Neuston Net (CMNN) and the Reef Edge Net (REN). Both are moored systems that are equipped with 64- and 300-μm mesh nets. The CMNN system was designed for continuous sampling in tidal channels between reef patches. It samples at three precise depth layers (epineuston: 0 m to 0.075 m, hyponeuston: 0.075 m to 0.225 m, 1 m layer: 0.925 m to 1.075 m depth). The REN system allows sampling at precise, adjustable depths at given distances from the reef edge. The objective of the REN is to collect organisms that are washed from reef tops and reef edges with the ebb flow. The performance of these two new systems was evaluated and compared with results obtained by using common Ring nets in horizontal subsurface tows. Fieldwork was performed at two reef patches of the Tamandaré reef system (Brazil) in November 2015. The CMNN and REN showed similar performance in comparison with Ring net tows, capturing microzooplankton communities as well as veliger, polychaete, decapod and barnacle larvae in similar abundances. For the mesozooplankton, the REN presented a similar performance to the Ring net tows, efficiently capturing decapod crustacean and fish larvae as well as fish eggs. The CMNN showed lower abundance of decapod larvae and fish eggs but showed a good performance for the quantification of fish larvae. The two new passive nets showed a high effectiveness in collecting larvae and advantages over tows with Ring nets since they stay for several hours continuously capturing larval aggregations during spawning events. This high capturing efficiency is probably related to the avoidance of sample reflux in the long nets that sink and close at slack tide for the CMNN, and due to the long, trap-like design with funnel-shaped internal "anti-reflux" nets, for the REN. Navigation safety and easy handling are further advantages of these moored systems, as compared to towing plankton nets at nighttime between reefs. CMNN and REN may become useful tools for the study of zooplankton and larval ecology and for integrated long-term studies in marine protected areas and reefs under multiple human impacts.

1. Introduction

Tropical reefs harbor diverse communities of benthic and pelagic organisms. Larval dispersal plays a key role in population dynamics and connectivity in these ecosystems (Oliver et al. 1992; Sheppard et al. 2009; D'Agostini et al. 2015; Kough and Paris 2015). In tropical regions, several species spawn during the dry season, when temperature is higher and winds, currents and turbidity are weaker. Several studies have shown that temperature and primary production have an influence on spawning and meroplankton (larvae and eggs) abundance in coastal waters (Williams et al. 1984; Anger 2001; Mwaluma et al. 2011; Fernandes et al. 2012; Ziadi et al. 2015).

In shallow tropical reefs, spawning events have been recorded mainly during nocturnal ebb tides (Forward 1987; Samoilys 1997; Francini et al. 2002; Nanami et al. 2013). Several species of fish and invertebrates have shown this behavior as a strategy to increase the chances of survival. Furthermore, many fish and invertebrates spawn during new moon periods (Babcock 1984; Williams et al. 1984; Francini et al. 2002; Padilla-Gamiño et al. 2011) probably to hinder the visualization of larvae by planktivores and other predators (Nolan and Danilowicz 2008).

To design an appropriate timed sampling strategy for surveys of larval production and dispersal is a considerable challenge. This is mainly due to the problems in defining the right time to capture newly hatched larvae. Standard plankton net tows have been extensively used to study zooplankton communities and larval abundance (Harding 2001; Castro

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et al. 2005; Hernandez et al., 2011; Mwaluma et al. 2011; Fernandes et al. 2012; Koettker and Lopes 2013; Ziadi et al. 2015; MacTavish et al. 2016). However, tows at given times of the night may underestimate the larval production if they are not conducted exactly during specific spawning events. Plankton patchiness is another serious concern for the assessment of larval abundance (Omori and Hamner 1982; White et al. 2014).

Marine zooplankton comprises a wide variety of organism, most of them ranging from a few micrometers to several centimeters (Lenz 2000). The most commonly accepted and used classification of plankton by organism size is that microzooplankton ranges from 20 μm to 200 μm length (generally captured with 20, 40, 50 or 64 μm mesh nets) and mesozooplankton (generally captured with 100, 120, 200 or 300 μm mesh nets) from 200 μm to 20 mm length (Sieburth et al. 1978; Omori and Ikeda 1984; Lenz 2000). Combined gears with specific mesh sizes are necessary for simultaneous quantitative sampling of these two size classes.

Several plankton trap and pump systems have been developed to obtain new insights into reef plankton, such as the horizontal in situ plankton sampler (Rützler et al. 1980), several types of light traps (Brogan 1994; Hickford and Schiel 1999), cone-shaped plankton traps to collect organisms on reef tops (Porter and Porter 1977; Ohlhorst 1982; Yahel and Yahel 2005; Melo et al. 2010) and zooplankton pump samplers (Heidelberg et al. 2004; Holzman et al. 2005; Yahel and Yahel 2005; Heidelberg et al. 2010).

However, it is still a considerable challenge to study the production of larvae during spawning and hatching events. Pump samplers are unable to collect vagile organisms due to their escape behavior. The destruction of fragile organisms in pumps is a further serious drawback. Light traps are not quantitative, and their efficiency depends on moon regime, turbidity, the animal's sensory capacity, behavioral response and swimming speed, etc. (Hickford and Schiel 1999). Light traps are generally used to assess settlement rates of reef fish (Brogan 1994; Hickford and Schiel 1999; Chan et al. 2016). Common channel nets (mesh size: 1 to 3 mm) and crestnets (mesh size: 2 mm) generally have large mesh sizes and are therefore also mainly designed for the capture of large pre-settlement stages of fish and shrimp (Shenker et al. 1993; Thorrold et al. 1994; Doherty and McIlwain 1996; Nolan and Danilowicz 2008; Criales et al. 2010). Therefore, these methods are not useful for the study of spawning events and larval production. Thus, in spite of the vast literature on this subject, there is still a lack of appropriate methods that are specifically designed to collect newly hatched larvae of invertebrates and fish.

The design of the two new systems described in the present study was based on several requirements to accurately quantify nocturnal larval release on reefs, as to deal with specific issues:

(I) Spawning occurs at discrete, often very narrow time spans, which are hard to predict, with a high risk of missing these peak events in standard plankton tows. (II) Towing plankton nets in between reef patches is often dangerous and in some situations simply impossible, even with a very small boat. This is especially critical in nighttime sampling and under rough weather conditions and new moon, when reefs may not be well perceived during navigation in complete darkness. Tows will always have to be conducted at a safe distance from the reef edge, thus the association of the samples with the reefs is weak, if any. (III) Tows cover large stretches, and thus cannot be associated to a specific sampling point or to a specific reef patch.

The aim of this study was: (I) to characterize and evaluate the performance of two new passive net systems in shallow coastal reef areas; (II) to compare data obtained with the two new passive nets and standard plankton net tows for sampling micro- and mesozooplankton (64 and 300 μm mesh sizes, respectively), with emphasis on larvae of fish and invertebrates; (III) to improve our ability to detect, quantify and understand the dynamics of larval production in reef ecosystems.

2. Materials and methods

2.1. Description of the two new passive net systems

Channel Midwater Neuston Net (CMNN) – A lightweight mini-catamaran equipped with six rectangular-conical plankton nets attached to two floating tubes (two PVC tubes with 2.15 m length and 100 mm diameter). Three depth layers are sampled: 1.) Epineuston: air-water interface, 0 m to 0.075 m (only the lower half of the mouth of the epineuston is immersed in the water), 2.) Hyponeuston: 0.075 m to 0.225 m, 3.) 1 m layer: 0.925 to 1.075 m (Fig. 1). Each depth layer of the CMNN contains two nets with different mesh sizes: 64 μm mesh for microzooplankton (mouth area: 0.15 m × 0.15 m, i.e., 0.023 m^2, length: 1.5 m) and 300 μm mesh for mesozooplankton and fish larvae (mouth area: 0.3 m × 0.15 m, i.e., 0.045 m^2, length: 2.5 m). The rear end of each net consisted of a cylindrical net bucket (diameter: 7.5 cm, length: 20 cm) made of thick pvc tubing, with a lateral window covered with gauze of the same mesh size as the net. The 300 μm mesh nets of the hyponeuston and 1 m layers were equipped with calibrated flowmeters (Hydro-Bios, Kiel, Germany) to measure filtered volume. The CMNN was designed to stay for several hours at a fixed station and sample during maximum ebb flow in tidal channels between reefs patches. The whole system is allowed to move freely according to the main current flow (Fig. 1).

Reef Edge Net (REN) – A lightweight moored system composed of two slim, long, double-conical plankton nets, each net being equipped with an internal "anti-reflux net". This internal net works similar to the funnel-shaped projections on the inside of common lobster traps, hindering the escape of vagile organisms (Arana et al. 2011; Major et al. 2017). It contains a 64 μm mesh net for microzooplankton (mouth area: 0.15 m × 0.15 m, i.e., 0.023 m^2) and a 300 μm mesh net for mesozooplankton and ichthyoplankton (mouth area: 0.3 m × 0.15 m, i.e., 0.045 m^2). Both nets have a length of 2 m (Fig. 2). The nets have an internal layer of the same mesh, an "anti-reflux net", designed to hold back the return of vagile organisms. The length of the inner anti-reflux net is 1.35 m, with an opening diameter of 8 cm at its rear end, being considerably narrower than the opening diameter (11 cm) of the external net towards the net bucket (Fig. 2). The internal net is held permanently stretched and open by two straps at the distant end (Fig. 2). The rear end of each net consisted of a cylindrical net bucket, exactly as in the CMMN. At the front of the net bucket of the 64 μm net, a sieve (1 mm mesh size) was loosely attached to prevent the entrance of large predators. The REN was firmly moored with two weights (20 kg of concrete at the front and 3 kg lead at the base of the net bucket) and maintained stretched out with a slim PVC tube that was placed alongside the net between the net bucket and the mouth (Fig. 2). Two floats (5 and 0.5 l buoyancy) kept the net in a fixed position in the water column. Ropes were adjusted as to have the net mouth exactly aligned with the upper reef edge and as to have the whole system always completely submerged. The 300 μm mesh net was equipped with a Hydro-Bios (Kiel, Germany) calibrated flowmeter to measure filtered volume.

The REN was designed to stay for several hours at a fixed station, thus sampling as close as possible to the reef edge during maximum ebb flow. The central objective of the REN is to collect organisms that are washed from the reef tops and reef edge with the ebb flow. It was designed to be as lightweight and small as possible, to be deployed manually and handled and transported in any small boat. Diving or snorkeling may be necessary for fine adjustments of the ropes that define position and depth of the REN, at least during the first use at a given location.

2.2. Case study: Tamandaré reefs

The new sampling systems were tested in the Tamandaré reefs, Brazil (Fig. 3). This reef complex is part of the "Costa dos Corais" Marine