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The influence of flow velocity and food concentration on *Lophelia pertusa* (Scleractinia) zooplankton capture rates

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ABSTRACT

Lophelia pertusa is the most significant framework building scleractinian coral in European seas, yet the reproductive strategy, longevity, growth and food capture rates for the species remain poorly understood. In this study an experimental investigation into the ability of *L. pertusa* to capture zooplankton from suspension was conducted. By direct ROV sampling approximately 350 *L. pertusa* polyps were collected from the Tisler reef, Norway and maintained under temperature controlled conditions in recirculating flumes. These polyps were subdivided into three replicate groups of ~120 polyps and maintained in waters with flow velocities of 2.5 cm s^{-1} or 5.0 cm s^{-1}. Suspended *Artemia salina* nauplii food concentrations of between 345 and 1035 *A. salina* l^{-1} were introduced. *L. pertusa* net capture rates were assessed by monitoring the reduction in suspended *A. salina* concentration in each flume over 24 h. Maximum net capture rates were higher in flumes with a 2.5 cm s^{-1} flow regime, at 73.3 ± 2.0 *A. salina* $polyp^{-1}$ h^{-1} (mean ± SD) than those with 5 cm s^{-1} flow (19.8 ± 11.8 *A. salina* $polyp^{-1}$ h^{-1}). Maximum net capture rates were lower in flumes with *A. salina* densities of <690 *A. salina* l^{-1} than in flumes with higher food densities under comparable flow velocities. The maximum net capture rates observed represent maximum carbon capture rates of 66.4 ± 2.0 μg C $polyp^{-1}$ h^{-1} and 17.9 ± 10.7 μg C $polyp^{-1}$ h^{-1} under 2.5 and 5 cm^{-1} s^{-1} flow speeds respectively. The results of this study indicate that *L. pertusa* captures zooplankton more efficiently under slower flow velocities.

1. Introduction

The scleractinian coral *Lophelia pertusa* (Linneaus, 1758) is one of the most widespread of the reef building cold-water coral (CWC) species (Roberts et al., 2009). Unlike many tropical or warm water scleractinian corals, *L. pertusa* is azooxanthellate, not living in association with algal symbionts (Rogers, 1999; Freiwald et al., 2004). This lack of an algal symbiont allows for a species distribution outside of the photic zone (Zibrowius, 1989). *L. pertusa* forms bushy calcium carbonate colonies with growth, with a thin surface layer of living polyps growing on top of the dead skeletal material secreted by previous generations (Riding, 2002). The growth rate of *L. pertusa* has been observed to be a moderate 6–25 mm per year in most natural environments, with individual polyps attaining maximum dimensions of roughly 1 cm diameter and several cm length (Mikkelsen et al., 1982; Mortensen and Rapp, 1998; Orejas et al., 2008; Roberts et al., 2009). Extensive reefs have been found in many regions of the world ocean (Wilson, 1979; Roberts et al., 2006), often forming structures meters in height and km^2 in coverage area (De Mol et al., 2002). Such sizes imply reef longevities in the order of 100 to 1000 ky (Freiwald et al., 1999). The volume of these calcium carbonate structures may render *L. pertusa* reefs significant long-term carbon storage reservoirs (van Weering et al., 2003; Noé et al., 2006). A host of environmental factors influence reef distribution, with food availability and suitability of substrate being of paramount importance (Davies et al., 2008). *Lophelia pertusa* reefs are often associated with regions of the seabed exposed to elevated current velocities, such as seamounts and carbonate mounds (Dorschel et al., 2005; Huvenne et al., 2007), shelf margins (Fosså et al., 2002) or sills (Jonsson et al., 2004). At many of these sites however, periods with reduced flow velocities have been observed, often associated with tides (Davies et al., 2009).

It has been proposed that *Lophelia pertusa* reefs are hotspots of biodiversity (Henry and Roberts, 2007) and carbon cycling on continental margins (Van Oevelen et al., 2009). The dead skeletal reef material provides a varied habitat for both sessile and mobile benthic organisms (Mortensen et al., 1995). The complex reef structure can greatly influence the local hydrodynamics in the reef vicinity, providing further diversity in habitat niches (Dorschel et al., 2007; Roberts et al., 2008). It has been hypothesised that these variegated reef structures may provide refuge for juvenile fish of commercial species (Costello et al., 2005). This hypothesis is particularly prescient on the Norwegian Margin where *L. pertusa*

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reefs are well-developed (Mortensen et al., 2001) and where fishery activity is high (Fosså et al., 2002; Hall-Spencer et al., 2009). This is also a region where the offshore hydrocarbon industry is in operation and public/governmental concern over the potential impact of this industry on reef ecosystems is high (Lepland and Mortensen, 2008). In Norway, and progressively elsewhere in European waters, this concern has led to protective legislation being put in place soon after reefs are discovered. Examples of such legislation being the instigation of fishing exclusion zones and the requirement for detailed oceanographic and benthic surveys prior to granting of oil and gas exploration licenses across the Norwegian Margin (Davies et al., 2007; Fosså and Skjoldal, 2010).

The diet of *Lophelia pertusa* has been investigated previously by analysing stable isotope ratios (Duineveld et al., 2004) bulk fatty acid composition (Kiriakoulakis et al., 2005) and lipids (Dodds et al., 2009) of polyp samples collected from reefs in the northeast Atlantic. These direct analyses indicate that the diet of *L. pertusa* varies from site to site, and that the organism may be generally heterotrophic, taking whatever is available from the water column, as has been observed in other scleractinian corals (Sebens et al., 1996; Rosenfeld et al., 2003; Houlbreque et al., 2004; Van Oevelen et al., 2009). Samples collected with sediment traps or *in-situ* pumps have shown a great variety both temporally and spatially in the quality of organic material entering *L. pertusa* reef environments (Kiriakoulakis et al., 2007). Although there have been experimental investigations of food capture rates carried out with tropical scleractinian corals, gorgonians (Coles, 1969; Sebens and Johnson, 1991; Sebens et al., 1996; Ferrier-Pagès et al., 2003; Hii et al., 2009) and other anthozoans (Anthony, 1997) few have been conducted with scleractinian cold-water corals (Tsounis et al., 2010).

The objective of this study was to investigate in the laboratory whether net capture rates by *Lophelia pertusa* of live zooplankton (*Artemia salina*) is influenced by flow velocity or available *A. salina* food concentration. Two hypotheses were investigated. Firstly, that the net capture rate by *Lophelia pertusa* increases with increasing flow velocity, and secondly, that net capture rates are higher when available food concentration is higher.

2. Materials and methods

2.1. Lophelia pertusa collection site and sampling method

The live coral fragments used in this study were collected from the Tisler reef in the Norwegian section of the Skagerrak, several km north of the Swedish border. First surveyed in 2002 (Lavaleye et al., 2009), the reef forms an elongated structure ~1200 m by ~200 m on a sill between the Tisler islands and the Norwegian mainland, in water depths of 70–155 m. Clearly damaged by heavy trawl activity, a trawl ban was put in place at the reef in 2003(Fosså and Skjoldal, 2010). The reef is made up of a large number of ~2 m diameter, ~1 m high *Lophelia pertusa* thickets surrounded by fields of coral rubble (Purser et al., 2009). In some areas the thickets have merged into larger horizontal structures but there is little of the vertical growth apparent at some *L. pertusa* reefs, such as those on the Norwegian continental margin (Mortensen et al., 2001; Freiwald et al., 2002) or the Porcupine Seabight (Huvenne et al., 2007). Free stream velocities over the sill can vary between 0.0 and 40.0 cm s^{-1} throughout the year, with direction of flow fluctuating irregularly between NW and SE (Lavaleye et al., 2009). The composition of particulate material entering the Tisler reef has been investigated in several studies (Kiriakoulakis et al., 2005) and *in-situ* pump collections have shown periodically high concentrations of fresh phytoplankton and zooplankton swimmers within the bottom waters at the site during spring and summer (Lavaleye et al., 2009).

Due to the sensitivity of the ecosystem selective sampling was carried out using the specially modified arm of a Sperre SubFighter 7500 DC ROV in July 2008. Approximately 350 polyps were collected from trawl-displaced coral blocks originating in a less pristine section of the reef (58° 59.695 N; 10° 58.240 E). Coral branches were sampled in fragments each containing between 10 and 50 polyps from a number of displaced coral blocks. These fragments were placed in a collection drawer on the ROV for return to the surface. On deck they were transferred into a large coolbox filled with 8 °C bottom water and transported to the University of Gothenburg field station at Tjärnö. The total transport time from seabed to field station was less than 2 h.

2.2. Lophelia pertusa preparation

At the Tjärnö field centre the *Lophelia pertusa* fragments were transferred to a thermoconstant laboratory room maintained at 8 °C. The fragments were then further divided manually by cracking with latex-gloved fingers into 45 branches, each consisting of between 5 and 25 live polyps. Each of these branches was then photographed using a Fujifilm E900 9.0 megapixel digital camera and placed on a plastic grid in one of three flow-through 25 l plastic aquaria. Seawater supplied to each aquarium was pumped from 45 m depth in the adjacent Koster fjord. Salinity varied from 32 to 34 and temperature was maintained at 8 °C. Each aquarium was delivered sand-filtered seawater direct from the Kosterfjord from a depth of 45 m at a rate of ~2 l min^{-1}. The coral branches were maintained under these conditions for three weeks prior to the commencement of the experimental investigations and provided with a daily dose of ~0.5 g freshly hatched *Artemia salina* nauplii delivered to each aquarium. The intention of providing a uniform food supply to the experimental aquaria prior to conducting the experimental runs was to ideally equalize the polyps response to the experimental food concentrations, as branch orientation prior to collection could have influenced recent feeding history of individual polyps. The Sven Loven Centre has maintained *L. pertusa* successfully for a number of years under these flow and feeding regimes.

Each *Lophelia pertusa* fragment was numbered and number of living polyps counted. The diameter of each living polyp cup was determined by analysing the photographs using a PC and the ImageJ 1.42q software application.

2.3. Flume setup

Three replicate recirculating flumes (Fig. 1) were set up in an 8 °C thermoconstant room. Each flume was of 58 l volume and constructed primarily out of plexiglass, with a plastic return pipe fitted with a motor driven propeller to maintain recirculation (Berntsson et al., 2004). The motor driven propeller in each flume was capable of maintaining a constant flow of up to 7 cm s^{-1}.

The 45 coral branches were randomized into three sets of 15. These sets were each fixed to the acrylic bases of the flume test sections by inserting the branch bases into a 1 cm silicone hose section glued to the flume base. Five branches were mounted in each of three equally

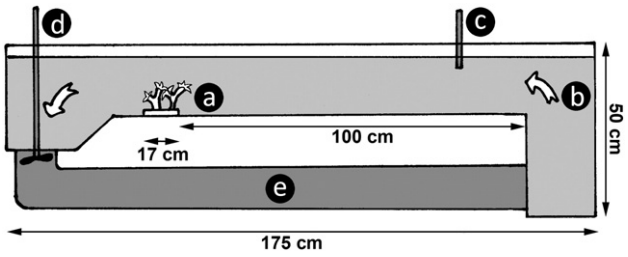

Fig. 1. Scale diagram of recirculating plexiglass flume setup. For all experimental runs, three identical flumes were maintained. a) Coral branches in plastic mount. b) Direction of circulation. c) *Artemia salina* delivery point and location of sampling for *A. salina* concentration determination. d) Motor. e) Opaque plastic return pipe.