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Effects of light pollution on the emergent fauna of shallow marine ecosystems: Amphipods as a case study

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ABSTRACT

Light pollution from coastal urban development is a widespread and increasing threat to biodiversity. Many amphipod species migrate between the benthos and the pelagic environment and light seems is a main ecological factor which regulates migration. We explore the effect of artificial lighting on amphipod assemblages using two kind of lights, LED and halogen, and control traps in shallow waters of the Great Barrier Reef. Both types of artificial light traps showed a significantly higher abundance of individuals for all species in comparison to control traps. LED lights showed a stronger effect over the amphipod assemblages, with these traps collecting a higher number of individuals and differing species composition, with some species showing a specific attraction to LED light. As emergent amphipods are a key ecological group in the shallow water environment, the impact of artificial light can affect the broader functioning of the ecosystem.

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1. Introduction

Artificial light pollution is a threat to biodiversity, as it affects the natural behavior of communication, migration and reproduction within species, as well as disrupting community interactions such as competition or predation (Longcore and Rich, 2004; Hölker et al., 2010). Two thirds of the world population lives in coastal zones, where artificial light pollution is most prevalent (Elvidge et al., 1997; Cinzano et al., 2001). Predicted demographic spread indicates that longer stretches of the shoreline will become illuminated (Depledge et al. 2010).

The effect of artificial light on ecosystem functioning is largely unknown and research has mainly focused on terrestrial fauna and ecosystems (Rich and Longcore, 2006; Hölker et al., 2010; Lyytimäki, 2013). In the marine environment the impact of artificial light pollution has been documented for marine turtles and marine birds but few other fauna (Black, 2005; Montevecchi, 2006; Bourgeois et al., 2009; Mazor et al., 2013; Merkel and Johansen, 2011). The extent to which artificial light affects marine shallow water ecosystems is, as yet, unknown (Depledge at al. 2010). To establish conservation polices which maintain ecosystem services it is necessary to quantify the specific influence of artificial light pollution on the marine environment.

Light phase guides the activity of many marine organisms. In shallow waters, natural cycles of light and dark are an important factor which regulate the diurnal vertical migration of emergent small mobile invertebrates. Organisms with this behavior, frequently called emergent, demersal or benthopelagic zooplankton, burrow within the substrate during the day and migrate within the water column at night (Alldredge and King, 1977). Laboratory and field studies identify light as the main factor driving vertical migration, acting both as a 'releasing and directional stimulus', with organisms moving towards areas of greater luminosity as they begin to vertically migrate when a decrease in light intensity is detected (Jansson and Källander, 1968; Tranter et al. 1981; Saigusa and Oishi, 2000; Anokhina, 2006; Nakajima et al., 2009). Artificial light pollution can potentially modify the movement of emergent fauna. In fact, artificial light traps are an established sampling method in crustacean biodiversity studies, taking advantage of the attractiveness of light to small mobile invertebrates (Meekan et al., 2001).

In the marine environment artificial light pollution has two forms: firstly, the ambient glow emitted from terrestrial structures such as streetlights and housing, and secondly in situ marine light, placed either at the water's surface or slightly submerged, this includes lighting on marinas, wharfs, pontoons and on boats.

This study examines the effect of different types of urban light pollution on emergent amphipod assemblages. Control and light treatments will be assessed to understand specific impacts on these small mobile marine invertebrates.

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2. Materials and methods

2.1. Study site

The experiments were carried out at Lizard Island (Northern Great Barrier Reef, Queensland, Australia) (Fig. 1). This remote location was chosen as it is not subject to urban light, previous studies have documented the amphipod fauna, and spatial variation of small mobile invertebrates for the region (Alldredge and King, 1977; Jones, 1984; Lowry and Myers, 2009). Experimental treatments were deployed 160 m from the shore at Casuarina Beach (14°40′46″S, 145°26′44″E) in 3.5 m depth of water. The reefal sediments beneath the treatments were composed of mainly soft sediment, with some coral-reef and seagrass patches. Alldredge and King (1977) identified this habitat as containing a high diversity and abundance of amphipods.

2.2. Light traps and sampling collection

We use a design similar to that used by Watson et al. (2002), with some modifications. Light traps were constructed from clear plastic storage boxes 40 cm long, 20 cm wide and 30 cm high. Ten entry points into the containers were made using a funnel devised from the neck of 2 l clear plastic soft drink bottles, held in position by clear silicone glue. Each funnel had a base of 15 cm diameter and a small aperture, 2 cm diameter, directed inward to the container. One additional funnel was set in reverse position at the bottom of the trap, with a drainage mesh at the end to collect the specimens when the trap was retrieved. Two lamps were installed inside each trap, fixed in position at the top of each box when submerged with lamps directing light towards the benthos (Fig. 2). Two different types of artificial light treatments were tested: 1. halogen and 2. Light Emitting Diodes (LED). Both lights are recommended for domestic use and street lighting with the aim of reducing energy consumption and light pollution (Directive 2009/125/EC of the European Parliament). Moreover, the use of high intensity LED is becoming more common to illuminate the water surrounding recreational boats. Light emission measurements of the traps were taken using a lux meter, approximately 30 cm away from the light source. Both halogen and LED showed a constant light intensity of 11 lux and 330 lux respectively during the entire duration of the experiment.

To compare the intensity of our traps with that present in an urban area, we also took light measures along Port Jackson, the body of water surrounded by the capital city of Sydney, Australia. Sixteen locations were measured at night using the lux meter. Locations were chosen based on an observed high level of artificial light pollution (tourist beaches, ferry wharfs). Six lux meter readings were made at each location from various water surface perspectives both horizontal and vertical. The mean value for

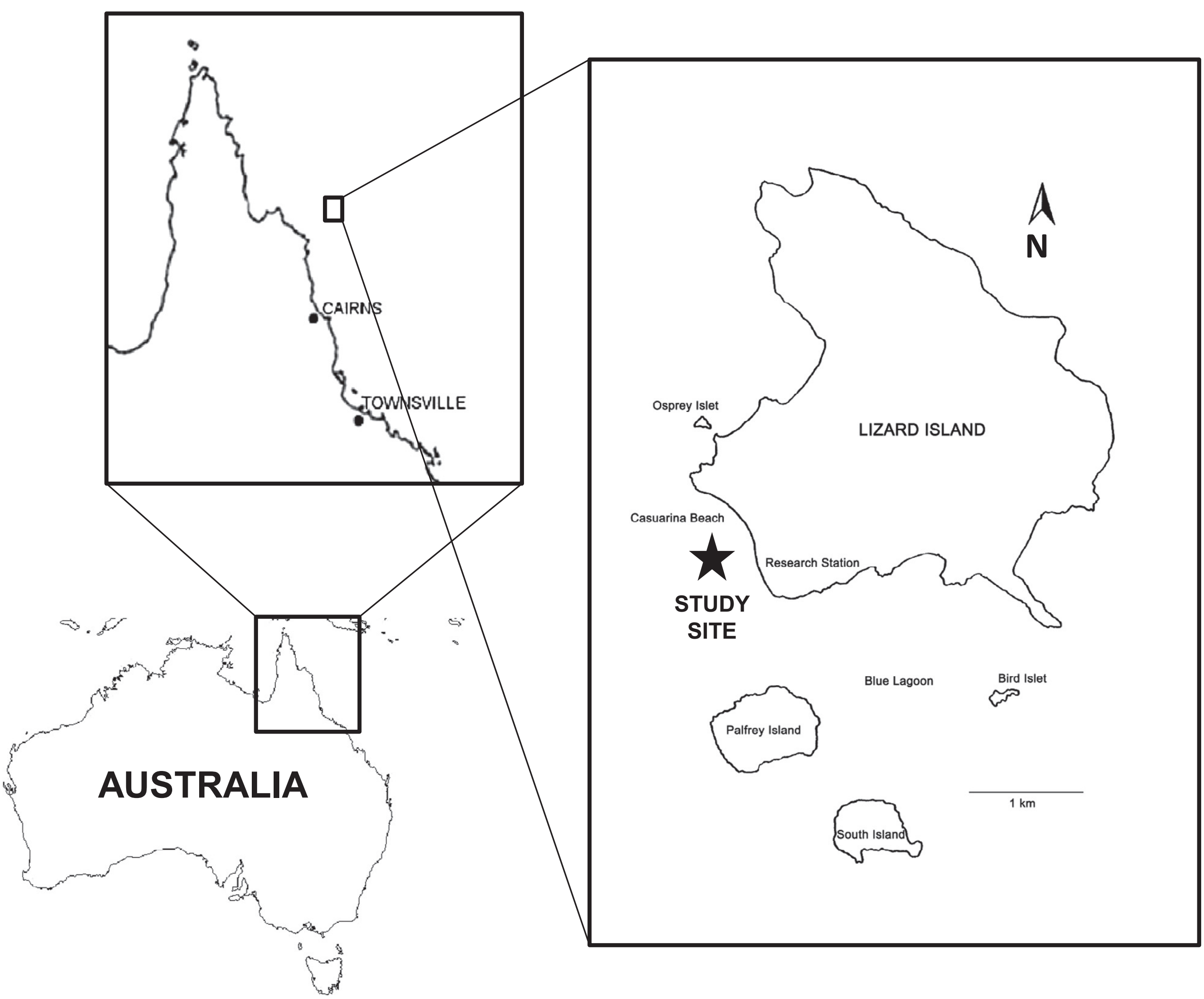

Fig. 1. Location of Lizard Island, the area of study.

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