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Juvenile damselfish are affected but desensitize to small motor boat noise

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ABSTRACT

Anthropogenic noise pollution is rapidly increasing in the marine environment. Anthropogenic noise can mask biotic sounds, disrupting the successful transmission between caller and receiver, and can cause physical, physiological and behavioural changes in some species. The effect of noise pollution produced by small motorboats is of particular interest in shallow, coastal habitats where vessel numbers are steadily increasing. The present field study examined the effect of small motorboat noise on the behaviour of the juvenile common damselfish, *Pomacentrus amboinensis*, and their potential to perform typical behaviours when presented with increased noise over a short time period. Behavioural observations in the field (before, 1, 10 and 20 min after the start of boat noise) found there was an immediate decrease in the boldness and relative distance moved by *P. amboinensis* in response to the noise produced by a boat with a 30 hp 2-stroke engine travelling 30–80 m away. However, fish appeared to return to pre-boat noise exposure behaviours within 20 min. The immediate change in behaviour may alter mortality rates in the short-term, but the potential for de-sensitization to boat noise may allow long-term persistence in noisy environments if they survive the initial disruption.

1. Introduction

Noise produced by human activities is one of the most rapidly increasing pollutants in the marine environment (Hildebrand, 2009; Popper and Hastings, 2009; Andrew et al., 2002). Anthropogenic noise occupies many of the same frequencies as biotic sounds and, if sufficiently intense, may lead to the masking of auditory signals used by animals to communicate (Pollack, 1975; Brungart, 2001; McDonald et al., 2006; Normandeau Inc., 2012). Increased noise levels can lead to physiological damage and stress in some species (see Knight and Swaddle, 2011). Sporadic exposure to noise may even affect reproductive success and survival of some marine invertebrates (Aguilar de Soto et al., 2013; Nedelec et al., 2014), with the potential to alter population dynamics, community structure and energy flows within assemblages (Slabbekoorn et al., 2010). While research to date suggests that some forms of noise can greatly impact population processes, anthropogenic noise is one of the least studied sources of pollution (Hawkins et al., 2014).

Research on the impact of anthropogenic noise on marine organisms has primarily focused on how noise from shipping, acoustic surveys or construction affect cetaceans and commercially important fish species (Engås and Løkkeborg, 1996; Sarà et al., 2007; Hatch et al., 2008; Brandt et al., 2011; Erbe et al., 2012; Melcón et al., 2012). Most of these studies have been conducted away from the structurally complex inshore coastal margin. While the response of these groups is important, most of these organisms have large home ranges and are capable of moving away from the immediate area affected by noise.

Much of the biodiversity in the marine environment occurs in the shallow coastal zone, particularly in tropical coral reef ecosystems. These coastal areas are heavily frequented by a range of vessels including large bulk carriers, fishing vessels and small motorboats. While small motorboats produce neither the amplitude nor low frequency sounds of bulk carriers, they can potentially have substantial impacts on shallow reef communities because of their large number (GBRMPA, 2014) and close proximity to marine organisms. Although legislation has been implemented in Europe to regulate anthropogenic noise pollution (Pottering and Lenarcic, 2008), many coastal countries have no regulation and there is little data on which to base management decisions.

Currently, there is a lack of information on the in situ effect of noise from small motorboats on small site attached species that spend all of their post-settlement life stages at one particular site. Studies investigating the impact of boat noise on fish have mostly been laboratory-based or field studies that have used speaker playback of small boat noise or pure tones rather than actual boats, focusing on potential disruption of communication rather than direct behavioural impacts

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(Vasconcelos et al., 2007; Codarin et al., 2009; Picciulin et al., 2010). Nedelec et al. (2014) found playback of recorded boat noise reduced successful development of tropical sea hare embryos by 21% and increased mortality of recently hatched larvae by 22% compared to controls. The response to visual stimuli was investigated in the laboratory, with Voellmy et al. (2014) finding playback of vessel noise affected anti-predator response. One recent study using noise from real motorboats in the field found that boat noise reduced the escape response of juvenile damselfish and lead to a doubling of the mortality from a small benthic predator (Simpson et al., 2016). Overall, studies to date on fishes suggest that boat noise may adversely affect fish behaviour by reducing their ability to orientate to a favourable environment (Holles et al., 2013) and reduce foraging and polarisation when schooling (Bracciali et al., 2012).

The impact of noise from motorboats covers a spectrum of potential disturbances (Neo et al., 2016a) from infrequent acute events through to more continuous and chronic occurrences associated with marinas, boat channels and harbour entrances. The few studies using actual boats used short-term and intense treatments of noise, and it is often difficult to discern the effects of the surprise from any new stimulus on the organisms from the disruptive influence of the noise that emanates from boats. The present study investigated the influence of noise from small motorboats on the behaviour of a juvenile tropical damselfish, *Pomacentrus amboinensis* (Pomacentridae), and determined their potential capacity to return to pre-disturbance behaviours while exposed to continuous real motorboat noise in the field. Our prediction based of previous studies of the stress response in fishes (e.g., Spiga et al., 2012; Johansson et al., 2016) was that the behaviour of fish would be immediately disrupted by the onset of the noise, but persistent exposure to the stimulus would lead to a slow return to behavioural norms as fish became desensitized. The current study focused on juveniles immediately after settlement as this life stage involves dramatic changes in structure, physiology and behaviour which makes them vulnerable to predators (McCormick et al., 2002; Nilsson et al., 2007). Anything that disrupts their sensory information may affect their ability to assess risk and make appropriate decisions that affect survival (Munday et al., 2010; McCormick and Lönnstedt, 2013). Previous research has shown that recently settled damselfishes generally have good hearing with auditory thresholds that hear best within 100 to 1000 Hz (Kenyon, 1996; Egner and Mann, 2005; Wright et al., 2011; Colleye et al., 2016), which is a hearing range that directly overlaps with the noise frequencies produced by small motorboats (e.g., Simpson et al., 2016).

2. Materials and methods

2.1. Study site and species

Small boat traffic on the Great Barrier Reef has greatly expanded over the past 30 years and it is predicted that there will be half a million recreational motorboats using the inshore waters of the GRB by 2040 (GBRMPA, 2014). Many of these motorboats are used for recreational activities such as fishing, scuba diving and snorkelling that are directly over or within very close proximity (< 10 m) to the fish communities that inhabit coral reefs.

The study species, the Ambon damselfish, *Pomacentrus amboinensis*, is protogynous, site attached fish that is a common member of the shallow water fauna of Indo-Pacific reefs (McCormick, 2016). For this species, metamorphosis occurs at the same time as settlement and involves a major change in pigmentation (transparent to coloured) that occurs within hours, but involves little obvious change in shape (McCormick et al., 2002). However, settlement does involve major changes in physiology (Nilsson et al., 2007) and it is likely that marked changes also occur in the sensory systems (Shand, 1997). Research on newly settled *P. amboinensis* has shown that fish enter the reef with high variability in their behavioural traits (e.g., boldness, aggression) and these traits are displayed in a manner that is consistent on small time scales of hours to days (McCormick and Meekan, 2007; White et al., 2015). Establishment of dominance hierarchies occurs within minutes of settlement (Meekan et al., 2010; Killen et al., 2014).

The present study was conducted in the lagoon at Lizard Island, Great Barrier Reef, Australia (14°41′S, 145°27′E), from November to December 2014. Settlement stage *Pomacentrus amboinensis* juveniles (11 to 13 mm standard length) were collected using light traps moored overnight > 100 m from the reef at two locations on Lizard Island fringing reef. Light traps were positioned 1 m from the surface and catches were collected at 5.30 am each morning. Fish were brought back to the laboratory in 60 L containers filled with aerated seawater. Upon return to the Lizard Island research station, fish were sorted to species level and placed in 35 L flow-through aquaria with aerated seawater entering via a submerged pipe to reduce ambient noise. Fish were fed newly hatched *Artemia* sp. twice a day and held for 48 h prior to use in experiments to make sure they had fully recovered from the stress of capture.

2.2. Ethics statement

This research was carried out in accordance with James Cook University ethics guidelines under ethics approval A2081 and conducted in accordance with the Queensland Department of Primary Industries collection permit (170251) and a Great Barrier Reef Marine Park Authority research permit (G12/35117.1). All sampling procedures and/or experimental manipulations were reviewed and approved as part of obtaining the above field and ethics permits.

2.3. Experimental procedure

Two study sites were set up 500 m apart consisting of small patch reefs (20 × 20 × 20 cm) made of *Pocillopora damicornis* fragments on sand. Two sites were used to increase replication because of the time necessary for habituation to the patch reefs. In this way a fish could be habituating to the ambient reef conditions of the patch reef at one site while the experiment was being run at the other. Sites were similar but separated by complex barriers of hard coral matrix that were emergent at a very low tide, effectively acoustically isolating the sites. Each experimental site was > 10 m from the nearest hard reef habitat at a depth of 2–3 m, dependent on the tide (range 1 m). Individual juvenile *P. amboinensis* were placed at the separate sites to ensure acclimation to the habitat patch in the absence of boat noise. Fish were transported to study sites in individual 1 L plastic click-seal bags of aerated seawater, placed inside a thick-sided polystyrene foam box, held on the lap of a passenger in a boat to limit noise exposure. Individual fish were released onto a patch reef and a 30 × 30 × 30 cm cage (6 mm^2 mesh) was placed over the top to allow acclimation to their new environment in the absence of a predation threat. Fish were given 30 min of acclimation time prior to the start of a trial. This time period was chosen as a suitable acclimation time based on previous studies observing behaviour of damselfish (Lönnstedt et al., 2013, 2014). Cages were removed before trials and 3 min behavioural observations were recorded on SCUBA following the protocol of McCormick (2009). Five aspects of behaviour were measured: 1) the number of feeding strikes (successful or otherwise); 2) total distance moved (over the 3 min period); 3) maximum distance ventured from shelter, 4) relative distance ventured from shelter (classified by percentage of time spent at 0, 2, 5 and 10 cm from the coral patch), and 5) boldness (recorded on a continuous scale from 0 to 3, where: 0 is hiding in hole and seldom emerging; 1 is retreating to hole when approached and taking > 5 s to re-emerge, weakly or tentatively striking at food; 2 is shying to shelter of patch when startled but quickly emerging, purposeful strikes at food; and 3 is not hiding when approached, exploring around the coral patch, and striking aggressively at food). Other studies using this boldness metric have found it a repeatable and related to survival (e.g., Fuiman et al., 2010; McCormick and Meekan, 2010; White et al., 2015). Recent