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Research article

Time to stop mucking around? Impacts of underwater photography on cryptobenthic fauna found in soft sediment habitats

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ABSTRACT

Scuba diving tourism is a sustainable source of income for many coastal communities, but can have negative environmental impacts if not managed effectively. Diving on soft sediment habitats, typically referred to as 'muck diving', is a growing multi-million dollar industry with a strong focus on photographing cryptobenthic fauna. We assessed how the environmental impacts of scuba divers are affected by the activity they are engaged in while diving and the habitat they dive in. To do this, we observed 66 divers on coral reefs and soft sediment habitats in Indonesia and the Philippines. We found diver activity, specifically interacting with and photographing fauna, causes greater environmental disturbances than effects caused by certification level, gender, dive experience or age. Divers touched the substrate more often while diving on soft sediment habitats than on coral reefs, but this did not result in greater environmental damage on soft sediment sites. Divers had a higher impact on the substrate and touch animals more frequently when observing or photographing cryptobenthic fauna. When using dSLR-cameras, divers spent up to five times longer interacting with fauna. With the unknown, long-term impacts on cryptobenthic fauna or soft sediment habitats, and the increasing popularity of underwater photography, we argue for the introduction of a muck diving code of conduct.

1. Introduction

The cumulative impacts of fishing, pollution and climate change are causing a decline in the health of oceans habitats across the world (Burke et al., 2011; Alongi, 2015; Halpern et al., 2015; Wernberg et al., 2016). The effects of this decline are felt most strongly in countries that depend on ocean resources for people's livelihoods (Burke et al., 2011; Lavides et al., 2016). Developing countries in particular often have a high proportion of their population reliant on marine ecosystems through subsistence fishing, building materials, or food production (Barange et al., 2014; Lavides et al., 2016). Livelihoods created by marine tourism are often suggested as sustainable alternatives to extractive activities such as fishing (Job and Paesler, 2013).

Scuba diving is one of the world's fastest growing recreational sports (Musa and Dimmock, 2012), estimated to be worth over a billion dollar globally (Garrod, 2008). Scuba diving tourism creates thousands of jobs in developing countries which can be sustainable if managed correctly (Vianna et al., 2012; Job and Paesler, 2013; De Brauwer et al., 2017). However, scuba diving can also have considerable impacts on fragile fauna living on coral reefs (Hasler and Ott, 2008). Poorly managed dive tourism can alter fish behaviour (Shackley, 1998), increase pollution, and cause habitat degradation (Wong, 1998). Careless diver behaviour has been repeatedly shown to cause damage to corals (e.g. Rouphael and Inglis, 2001; Hasler and Ott, 2008), with heavily dived sites having a higher incidence of coral disease (Lamb et al., 2014). Divers tend to cause the greatest amount of damage at the start of a dive while they are still adjusting buoyancy (Rouphael and Inglis, 2001; Roche et al., 2016). Inexperienced divers with poorly developed technical skills are more likely to cause damage than more experienced divers (Thapa et al., 2006; Chung et al., 2013), while goal orientated diving behaviour such as photography has a higher impact than general dive activities (Uyarra and Côté, 2007; Chung et al., 2013).

Divers not only have a potential impact on a reef's structure, they also affect coral-associated fauna. While the effects of divers

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on habitat forming structures, such as corals have been comprehensively described, less is known about how scuba diving impacts mobile animals (Trave et al., 2017). Studies on megafauna such as sharks and rays have shown that diver interactions can reduce mobility and change feeding behaviour (Shackley, 1998; Clua et al., 2010). For small cryptic fishes, interactions with divers can lead to short-term behavioural changes (Harasti and Gladstone, 2013). The presence of divers can also disturb fish spawning aggregations (Heyman et al., 2010), and boat can noise disrupt fish larvae from settling onto coral reefs (Holles et al., 2013).

The literature on diver impacts on coral reefs is extensive (Rouphael and Inglis, 2001; Hasler and Ott, 2008; Au et al., 2014), but scuba diving is not limited to coral reefs. There has been little research into the impacts of divers in other habitats (e.g. Sala et al., 1996; Bravo et al., 2015). Divers are more likely to touch benthic organisms on artificial reefs than on coral reefs, leading to more damage (Giglio et al., 2016). High numbers of snorkelers can alter the morphology and growth of seagrass (Herrera-Silveira et al., 2010). Understanding these impacts is imperative because ecosystems such as soft sediment habitats or seagrass beds are often more productive than coral reefs and have similarly high economic values (Boucher et al., 1998; Costanza et al., 2014). Considering the millions of active divers in areas without coral and the rise of alternative dive destinations away from coral reefs (Lew, 2013), it is important to assess the impacts divers might have on these non-reef environments.

One such alternative type of diving is diving on soft sediment, typically referred to as 'muck diving'. Muck diving is increasingly popular and is valued at over USD$ 152 million per year in Indonesia and the Philippines (De Brauwer et al., 2017). It is estimated that more than 100,000 divers annually visit muck diving destinations in Southeast Asia. Typical muck dive sites have no or very sparse coral cover, instead consisting mainly of sand with sporadic sponge or algal growth. This specialised diving activity focuses on observing or photographing cryptobenthic species such as frogfishes or seahorses that are rarely encountered on coral reefs. The search for rare species makes this a highly goal-driven type of diving that attracts very experienced divers and large numbers of photographers (De Brauwer et al., 2017). Photographers occasionally use 'muck sticks' to coax animals into better position for photographs, which could lead to stress in animals (Roche et al., 2016). Goal driven diving activities, such as photography, that focus on cryptic fish causes more damage on coral reefs than diving with a non-cryptic focus (Uyarra and Côté, 2007), but it remains unclear if this is the same on soft sediment habitats.

Multiple factors can alter the behaviour of divers. The strong focus on observing cryptic species in muck diving raises the question of whether a diver's behaviour might change depending on the species that is observed. Encountering and photographing animals that are considered rare could lead to decreased compliance to environmental ethics (Uyarra and Côté, 2007). The best predictors for high impact diver behaviours have yet to be fully identified.

The aim of this study is to better understand the varying impacts of diver activities in different marine environments. We do this by assessing diver behaviour in both coral reef and soft sediment (muck) habitats, the specific goals of this study are to investigate if the impacts of diver behaviour change with:

1) the activity divers are engaged in,
2) the habitat divers are found,
3) the type of camera divers are using, and
4) diver certification level, age, and experience.

We also investigate:

5) how these factors affect the duration of divers interaction with cryptobenthic fauna.

2. Methods

2.1. Location

Diver surveys were conducted between March and May 2016 on 33 sites in three locations in Indonesia (Bali, Nusa Tenggara, Lembeh Strait) and one location in Philippines (Dauin). All locations are important dive destinations with coral reef and soft sediment dive sites, which are visited by divers interested in photography (De Brauwer et al., 2017). Sites were determined independently by the dive centres without the influence of the researchers. At all four locations, divers were observed on both coral reefs (coral, $N = 15$ sites) and soft sediment slopes (muck, $N = 18$ sites). Maximum depth for all dives was 30 m, topography of coral reef sites were comparable to each other, and soft sediment sites all had a similar, sloping topography. Ten visited dive sites were protected areas where no fishing was allowed, but the majority of sites ($N = 23$ sites) had no form of official protection.

2.2. Diver observations

Divers were observed during dives conducted with eight different dive centres that offered muck and coral reef dives. All dive centres gave pre-dive briefings which outlined dive profile and included advice not to touch fragile marine life. The divers were observed ad hoc, starting with the diver closest to the observer and rotating between divers until all divers in the group had been observed. When limited divers were available over the course of a day, the same divers were observed during multiple dives, which could be on different substrates ($N = 30$ divers). Two types of observations were conducted: "standard observations" and "interaction observations", adapted from the methods used by Uyarra and Côté (2007). "Standard observations" were used to gauge normal diver behaviour, whereas "interaction observations" investigated divers' behaviour close to cryptobenthic fauna. Standard and interaction observations occurred during the same dives. An initial five minute standard observation was conducted for each diver after they had established neutral buoyancy and were swimming normally while watching, or photographing non-cryptic reef fauna. Divers generally cause more damage in the first phase of a dive (Camp and Fraser, 2012), but this study aimed to investigate behaviour during the body of the dive, rather than the initial buoyancy adjusting phase. Interaction observations where conducted when divers observed, photographed or otherwise interacted with cryptobenthic fauna. Interaction observations ran as long as the diver interacted with cryptobenthic fauna. If divers encountered cryptobenthic fauna during standard observations, observations were paused until the diver resumed normal swimming. Both recreational divers (tourists) and professional divers (dive guides) were observed during this study. No observations were made when conditions were suboptimal, such as strong currents or very low visibility (<4 m). Observations were conducted from a distance of 2 m – 4 m from divers, which was sufficient to observe divers and cryptobenthic fauna. To ensure normal diver behaviour divers were made aware that a marine scientist had joined the dive, but were unaware that the marine scientist would be observing their behaviours.

During interaction observations, we recorded duration of interactions, number of times a diver made contact with the substrate or an animal, and whether contacts were intentional or not (Uyarra and Côté, 2007). We further noted which part of the body or