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Does body colouration influence predation risk of coral-dwelling reef fish in bleached landscapes?

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Abstract: Coral reef fishes will be increasingly exposed to habitat degradation as climate change increases the frequency and intensity of coral bleaching events. This study explores how body colouration influences survivorship of coral-dwelling fishes during coral bleaching events. Specifically, we tested for differences in the vulnerability to predation between a bright yellow fish (*Pomacentrus moluccensis*) and a white/black fish (*Dascyllus aruanus*) in a range of different coral habitats, including healthy, bleached, recently dead and algal-covered coral colonies. Strike rates by predators against both damselfish species increased in bleached and dead coral habitats, compared to healthy coral habitats. There was no differences in strike rate towards either species of fish in any of the habitat conditions tested, suggesting that both the yellow and black/white colouration is equally visible to the predator (*Pseudochromis fuscus*). However, survivorship on bleached corals was lower for *D. aruanus* than for *P. moluccensis* suggesting that coral bleaching may have a disproportionate effect on brightly coloured reef fishes.

Key words: Climate change, Coral bleaching, Reef fishes, Habitat degradation, Selective predation

Introduction

Corals are essential for the survival of many species of coral reef fishes as they are the primary habitat-forming species in coral-reef environments (Connell et al. 1997). Live coral is a source of shelter, food and recruitment for many coral reef fishes (Pratchett et al. 2008, Jones et al. 2004) while increased topographic complexity moderates competition and predation (Beukers and Jones 1997, Holbrook and Schmitt 2002, Almany 2004). Coral cover and diversity can positively influence the abundance and diversity of coral reef fishes (Bell and Galzin 1984, Carpenter et al. 1981, Munday et al. 1997, Ohman and Rahajasura 1998) and changes in the condition or abundance of coral reef habitat may have considerable consequences for biotic interactions, abundance and diversity of reef fish assemblages (Syms and Jones 2000, Munday 2004, Pratchett et al. 2004, Wilson et al. 2006).

The pervasive view in literature investigating effects of climate-induced bleaching on fishes is that populations decline as a result of a loss in habitat structural complexity following bleaching induced coral loss (Lewis 1997, Bergman et al. 2000), while coral mortality *per se* has limited effects on fishes (Sale 1991, Lindahal et al. 2001). However, several recent studies suggest that mere bleaching of corals can have a detrimental effect on coral reef fishes, especially among those species that inhabit live corals (Ohman et al. 1999, Jones et al. 2004). Decline in the abundance of coral-dwelling fishes following host coral bleaching may be attributable to either movement of fishes to alternative habitat colonies, or mortality, which probably results from increased susceptibility to predation (Wilson et al. 2006, Pratchett et al. 2008). Coral-dwelling fishes may face an immediate increase in susceptibility to predation due to the increased conspicuousness of prey fishes against the white background of bleached corals.

Increased levels of predation could possibly be influenced by a reduction in camouflage of brightly coloured reef fish against the now pale/white habitat background. Different coloured fish associated with habitats exhibiting different levels of pigmentation are therefore predicted to experience a difference in their visibility to predators. Most coral-dwelling fishes are vividly coloured with yellow, blue, green and red which are important in communication and signalling (Lorenz 1962) and can be an effective camouflage against coral habitats (Cott 1940, Marshall 2000). It seems intuitive that brightly coloured fishes should be much more apparent against a bleached-white background, compared to the pink or brown hues of live coral. This contrast between coral-dwelling fishes and pale/white bleached coral is predicted to increase the risk of predation for brightly coloured fishes as they contrast against the degraded background.

The aim of this study was to compare predation risk of two coral-dwelling damselfish with highly contrasting colouration; one that is bright yellow: *P. moluccensis*, and one that is black and white: *D. aruanus*. The two contrasting fishes were presented to predators against different habitat backgrounds to test if there was a change in the visual detection of prey by a common predator when associated with healthy, bleached, dead and algal-covered coral habitats. Survivorship was also measured across the four different habitats to test the efficiency of the predators at capturing the two different coloured prey. Marshall (2000) found that the yellow coloration in fishes were a very close match to average reef colour with a colour distance of 0.04. Fishes also lack long wavelength photo receptors (Marshall 2000) meaning that yellow will be well camouflaged against an unbleached reef backdrop but will render them more obvious to predators against bleached white coral. The bright yellow colouration of *P. moluccensis* was expected to be more obvious to the predator against the bleached and dead background than the white/black colouration of *D. aruanus* and therefore *P. moluccensis* was expected to elicit a higher number of strikes and have lower survivorship in bleached habitat.

Materials and Methods

This study was conducted in April 2007, at Lizard Island Research Station (14°40'S, 145°28'E), on the northern Great Barrier Reef (GBR), Australia. Aquaria-based experiments were used to test the apparent conspicuousness of prey fish and compare predation risk in different habitat conditions. Coral habitat used in the experiments was *Pocillopora damicornis*, a common branching coral that is highly susceptible to bleaching (Marshall and Baird 2000) and used by many coral-dwelling fishes for habitat (Pratchett et al. 2004). Healthy and algal-covered colonies of similar size and complexity were collected from the lagoonal area. One third of the healthy colonies were randomly selected and subjected to osmotic stress (100% freshwater for 5 mins) to induce bleaching (Kerswell and Jones 2003). This was signified by a reduction of pigmentation within the live coral tissue. Another third were placed into a chlorine solution and rinsed well to remove all living tissue leaving bare white skeleton. Healthy and algal-covered colonies were kept in high flow-through tanks to ensure that they did not degrade.

Juvenile *Pomacentrus moluccensis* and *Dascyllus aruanus* (12-32mm in total length) were used in experiments. Both these planktivores associate with live branching coral and take refuge within the branches of their host coral colony when threatened (Allen 1991). *Pseudochromis fuscus* (53-72mm in total length), was selected as the predator to use in experiments because it a common resident predator on small coral-reef fishes and amenable to experimentation and to aquarium conditions (McCormick and Holmes 2006). Both prey fish and predators were collected from reefs within the Lizard Island lagoon using the anesthetic clove oil and small hand nets. Prey fish were kept in groups of up to ten individuals and fed daily using manufactured aquarium food. Predators were kept in separate aquaria due to their aggressive nature and starved a minimum of 2 days prior to each experiment. Each fish was used only once per trial for each experiment.

To test if the visual detection of two different coloured fish by a common predator varied against different backgrounds, individual juvenile *P. moluccensis* and *D. aruanus* were placed before life-sized laminated photos of i) healthy, ii) bleached, iii) dead and iv) algal-covered colonies. The use of photographic images was used to help eliminate variation in habitat complexity and olfactory stimuli that might influence predatory behaviour. The four pictures were fixed equal distance from each other around the periphery of a large circular plastic tub (113cm dia.). The bottom of the tub was covered in a thin layer of sand and the water level adjusted to the top of the pictures so that the predator remained at eye level to the image. An individual prey fish was placed within a small clear zip-lock bag (50 x 100mm), flooded and placed in front of an image. A predator was released onto a small fragment of coral in the centre of the aquarium. Each trial ran for 20 minutes and the number of strikes against prey in front of each habitat image during this time was recorded. Only one species of prey was used for each trial and each individual prey and predator was replaced after the completion of a trial.

If live, healthy coral provides effective camouflage for brightly coloured reef fishes, such as *P. moluccensis*, we predicted that strike rates by predators would be lower for prey placed in front of images of healthy colonies compared to bleached or dead coral colonies. We also predicted that strike rates would be higher for the bright yellow coloured *P. moluccensis* compared with *D. aruanus*. The black and white colouration of *D. aruanus* might be expected to offer better camouflage against bleached corals than the bright yellow colouration of *P. moluccensis*. Variation in strike rates between the two coral-dwelling fish was tested in a MANOVA, as recommended by Roa (1992) because individual strikes by predators might not be independent of each other.

Secondly, tests of survivorship with varying habitat condition were conducted to test predation rates. Here prey fishes were subject to predation by predators by placing four prey fish and one predator within an aquarium with one of the four different habitat treatments. Two individual *P. moluccensis* and two individual *D. aruanus* were placed within a glass aquarium (60 x 30 x 40cm) and survivorship recorded over a 75 hour period with the presence of a single *P. fuscus*. Each habitat treatment was replicated six times and survivorship compared. Two tanks were also run with the absence of a predator to control for tank and habitat effects on survivorship. Predators were placed into the tank at 17:00, one hour after the prey fish to allow them to acclimate to the tank and surrounding habitat. Variation in prey survivorship over 75 hours was tested in a MANOVA.

Results

The number of strikes against yellow versus white/black fish did not differ across the four different habitat conditions (MANOVA $F_{4,23}$=0.95, P=0.45). The number of strikes against both fish colours increased when the fish were presented against a background of bleached coral but decreased against backgrounds that depicted algal-covered coral (Fig.1). This suggests that there is no difference between the levels of visual perception between the two fish, even when placed before different habitat conditions. However, overall there was an increase in the number of strikes from healthy to bleached and to dead coral habitat, showing an increase in strike rates with coral degradation.

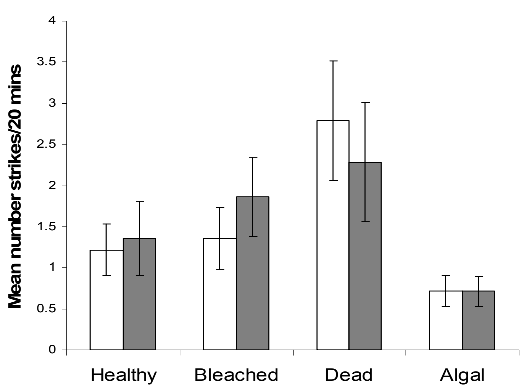

Figure 1. Mean number of strikes (±SE) against *D. aruanus* (□) and *P. moluccensis* (■) associated with four different habitat conditions over a 20 minute period.

In actual predation trials, survivorship between yellow and white/black fish was only significantly different for fish associated with bleached habitat (MANOVA F=7.10, df=1, P=0.04). In bleached coral habitats survivorship was twice as high for the white/black coral-dwelling fish (*D. aruanus*) compared to the yellow species (*P. moluccensis*) (Fig. 2). This suggests that the colour of prey fishes against their coral habitat is critical to evading predators and maximising survivorship.

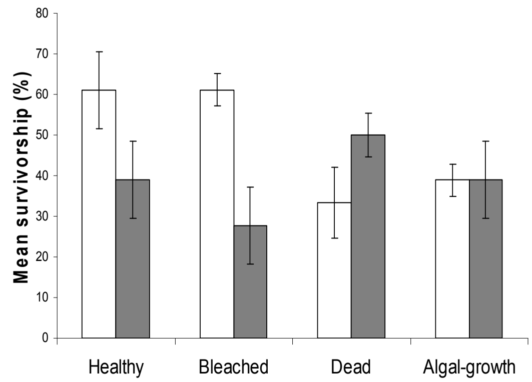

Figure 2. Mean survivorship (±SE) of *D. aruanus* (□) and *P. moluccensis* (■) associated with four different habitat conditions after being exposed to a predator for 75 hours.

Discussion

Predation is a fundamental process on coral reefs influencing the structure of ecological communities (Caley and St John 1996, Hixon and Carr 1997, Almany 2003). The effect that predators have on fish populations is largely driven by the method in which they select prey species and individuals (Hixon 1986). Furthermore, habitat complexity and habitat quality can certainly moderate the outcome of predator-prey interactions (Main 1987). This study explored if two different coloured fish vary in susceptibility to predation across a range of habitat conditions given that one species (*P. moluccensis*) is bright yellow and the other (*D. aruanus*) is white and black. We found that there was no significant difference in strike rates on these two contrasting prey fishes against a range of different background habitats and importantly, an increase with coral degradation for both fish colourations. Similarly, the survivorship of the two different coloured prey fish was broadly similar over a range of habitat conditions, except when the coral was bleached. In bleached coral habitats, it was clear that *D. aruanus* had a decided advantage in survivorship over *P. moluccensis*, possibly because bleached coral habitat continues to provide an appropriate background to minimise conspicuousness of white and black fishes.

Different predation rates on reef fishes associated with healthy, bleached, dead or algal-covered coral habitats is possibly a result of increased visual perception by predators. Many reef fishes are specifically coloured to camouflage against their habitat for hunting, hiding and signalling (Cott 1940, Marshall 2000). Camouflage is an important determinant in the distribution and habitat associations of many animals by matching body colouration with their surrounding habitats (Helfman et al. 1997). The similar strike rates on the two species of fish suggest that there was no difference in the visual detection by a predator of the yellow versus the white/black body colouration. Although the white/black colouration of *D. aruanus* might be expected to visually stand out against healthy and algal-covered coral habitats, there was no significant difference in the number of strikes observed compared with *P. moluccensis*. Both damselfishes received more strikes as the habitat degraded from healthy to bleached to dead colonies, although fish associated with algal-covered coral had the lowest number of strikes. Declines in the abundance of *P. moluccensis* immediately following coral bleaching have been repeatedly documented along with the declines in other coral-dwelling fishes (Booth and Beretta 2002, Pratchett et al. 2008). This is consistent with the expected visual contrast between fish and habitat. The low number of strikes for both prey colours on algal-covered coral might suggest that this dark brown/green habitat offers the best backdrop for the fish to camouflage against or that predators are used to looking for prey in healthy and similar looking habitats.

Survivorship between the two prey colourations was similar across the different habitat conditions except for bleached corals where mortality was slightly lower or *D. aruanus*. *Dascyllus aruanus* was expected to have better camouflage against the bleached habitat as the white background would have a reflectance similar to that of the fish; white fishes reflectance peaks between 330 and 390 nm while the black part has very low reflectance (Marshall 2000). This contrast between white and black could potentially provide disruptive camouflage that could confuse the predator against the bleached white background. Therefore, contrasting colour patterns as seen in *D. aruanus* could be just as important for predator avoidance as colour. The white and black contrasts could break up the body outline and confuse predators.

In conclusion, this study shows that bleaching is likely to have a disproportionate effect on brightly coloured fishes provided predation is the main proximal cause of mortality, and that colour vision plays a role in prey detection and predator avoidance through camouflage. While the predatory species used in this study (*P. fuscus*) is a conspicuous predator within coral habitats occupied by coral-dwelling damselfishes (Munday et al. 2003), it should be noted that other predators on coral-dwelling fishes may detect prey fishes at different distances or using other cues which may not be influenced by visual changes to habitat condition. Further research is needed to investigate how changes in habitat condition, through loss of pigmentation, live tissue cover and natural habitat structure, will impact the ability of coral-dwelling fishes to avoid predators. Colour could be one method of camouflage. Contrasting colour patterns may also be effective in reducing predation risk, especially in bleached coral habitat.

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