Altered Behaviors of Reef Fish in Bleached Coral Environments and their Imposed Impacts on Reef Fish Populations

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Abstract

For the first time in history atmospheric carbon levels have reached and exceeded 400ppt. This exponential increase in atmospheric carbon has lead to the major changes in the climate that has significantly impacted coral reef health across the world. Global temperature rise is increasing ocean temperatures, and acidity. These stressors have lead to large scale bleaching of corals. The degradation of these corals has been linked to multiple noteworthy changes in the behaviours of reef fish inhabiting bleached corals. Reef fish are not responding to predator cues as they would in pristine reefs, as the cues related to the presence of a predator are not being detected by reef fish. Despite the loss of camouflage resulting from bleached white coral backgrounds reef fish have been displaying more aggressive behaviour, resulting in increased vulnerability to predators. The settlement preferences of reef fish have been altered, resulting in migration from their bleached environments to healthier reefs. These changes are lowering prey fish populations and influencing change in reef population dynamics. This review will synthesize key findings involving altered behavior of reef fish, and the impacts of these changes on reef populations.

1. Introduction

Coral bleaching is one of many impacts of climate change. As ocean temperatures increase, coral bleaching will too. There have been significant declines in global coral cover (Douglas 2003), including the recent pronounced death of the world’s largest coral reef— the Great Barrier Reef. As this continues to occur increasingly, reef fish habitats will be lost at greater rates. Coral bleaching has been linked to behavioral changes in reef fish that will alter population dynamics, harming overall health and durability of reef ecosystems (Coker et al. 2009; Lonnstedt et al. 2013, 2014; Coppack et al. 2013; Kok et al. 2016).

In response to environmental stressors corals bleach. This bleaching involves the loss of zooxanthellae an algae that resides in the corals tissues and provide the corals with nutrients and energy along with their pigment. Once lost the corals become a bleached white colour, since the zooxanthellae no longer provides colour to the coral. Without the algae, the corals are unable to obtain the nutrients needed to survive and will degrade and eventually die (Douglas 2003; Marshall et al. 2006).

As bleaching continues to occur, these altered behaviors will create problems involving shifts in population dynamics, potentially creating instability, and collapse of reef ecosystems, due to increased mortality rates of reef fish (Paddack et al. 2009; Pratchett et al. 2011). Increased mortality rates will alter fishing yields, inherently impacting economies of reliant on the fishing industry. If more research is done on entire reef ecosystems affected by the behavioral changes of inhabitants there will be an increased understanding of how drastic the impacts of these changes will be. These findings would help us better react to any issues surrounding the altered populations in the future.
Currently there are no direct syntheses on behavioral changes of reef fish resulting from degraded coral environments, and their impacts on reef populations. Little research has been done concerning how population changes impact reef ecosystems. This may be the result of contrasting findings on whether populations increase or decrease due to these behavioral changes, and whether the changes in behavior that increase risk of predation are related to the coral conditions or fish abundance.

To obtain a better understanding of how behavioral changes in reef fish will affect population dynamics of reef assemblages this review will summarize the key changes in reef fish behavior, including; the lack of response to chemical cues of predation, increases in aggressive/risk inducing behaviors, altered settlement preferences, and the impacts of these changes on reef fish populations.

2. Altered Reef Fish Behaviors

2.1 Coral Bleaching

Coral bleaching is a stress response resulting in the breakdown of its symbiotic relationship with the algae zooxanthellae, the main contributor to the coral pigment. Zooxanthella resides within the corals tissues, providing corals with an energy rich food source (Marshall et al 2006). Bleaching is the loss of this algae due to environmental stressors. Since zooxanthella provide the coral with pigment, when lost the corals become white causing them to appear bleached. The observably white colour of bleached coral is the corals calcium carbonate skeleton (Douglas 2003; Marshall et al 2006). Bleaching is typically the result of a protein associated with Photosystem II being damaged, disrupting the Calvin cycle, resulting in a lack of food for these algae (Douglas 2003). Corals can recover from bleaching events in proper conditions. However, they can experience complete death, typically weeks after the bleaching occurs (Douglas 2003; Marshall et al 2006). The main contributor to bleaching is increasing ocean temperatures, and acidity. Other stressors include turbidity, sunlight, salinity change, and pollutants or contaminants within the ocean (Douglas 2003; Marshall et al 2006).

2.2 Predator Prey Interactions

Reef fish use olfaction to detect chemical cues of predation which is essential to reducing the risk of mortality. This is especially important at night when other senses can’t be used to assess predation risk. Bleached and dead corals alter the perception of these chemical cues, thereby altering predator prey relations, by increasing the risk of predation.

Two studies by Lonnstedt et al. (2013, 2014) observed differences in response of reef fish to chemical cues in both degraded coral and healthy coral assemblages. After releasing cues related to predation (scents of injured members of the same species, along with predator scents) into the water in both lab and field environments. The 2013 study was conducted both in the lab and in the field, where an individual fish was sacrificed and cut to collect a cue to be released in the tank that would represent a naturally injured conspecific to the fish in the tank. The same experiment was used in the field using scuba equipment, and releasing the cues in coral assemblages that were deemed healthy, bleached, and dead (Lonnstedt et al 2013. In healthy reefs the release of the cues induced a reduced bite rates on food sources and activity level of reef fish, more time spent close to the base of corals, and fish often retreated within the coral. The fish inhabiting, degraded corals displayed very limited antipredator responses to the release of chemical predatory cues, even with the addition of a predator for visual stimulus (Lonnstedt et al. 2013). The 2014 study was unique in
that patch reefs were prepared to simulate natural environments for the fish being studied, and was set out to see how the limited response to chemical cues indicating risk of predation affected mortality rates of the reef fish. This was done by counting the original population and noting any changes over time, assuming all missing specimens were captured by prey. (Lonnstedt et al. 2014). In degraded environments, there was a large spike in predation related death, seen by a 75% increase in mortality. This came along with 79% of juvenile settlers in degraded reefs facing predation related mortality, while only 45% of settlers in healthy reefs faced predation related mortality (Lonnstedt et al 2013, 2014). This suggests the dead corals are interfering with the detection or the ability to use chemical cues (Lonnstedt et al 2013, 2014).

The findings of both Lonnstedt et al. (2013, 2014) studies correlate to the findings of the Coker et al (2009) study, in which predation was studied in environments containing both bleached and healthy coral assemblages. Predators displayed an observable preference to prey in bleached environments, as illustrated by 42% of prey subjects disappearing in the degraded coral environments, while only 25% experienced predation related mortality in healthy coral assemblages. This trend can be seen in Figure 1 with significant decreases in survivorship as reef health declines (Coker et al. 2009). This trend may be due to increased conspicuousness of reef fish against a bleached, white coral background, as they would be more susceptible to predators (Coker et al. 2009). However, it may be combined impacts of altered chemical cues and the increased conspicuousness of reef fish that caused such a significant increase in predation within degraded environments.

2.3 Increase in High Risk Aggressive Behavior

As reefs bleach, there is an observable increase in aggressive behavior of reef fish. The loss of structural coral increases the frequency of encounters between reef fish, due to increased competition for resources. There are significant increases in intensity of intra and interspecific aggression was seen in juvenile reef fish (Coker et al. 2009). This is depicted in Figure 2 with the highest number of fish on fish strikes occurring in unhealthy coral environments (Coker et al. 2009). These results correspond with those seen in the Lonnstedt et al study (2014), as fish in healthy coral environments remained closer to the base of corals, and those in degraded environments demonstrated more aggressive behaviour spending time higher up along coral assemblages while straying further from areas of coral refuge. This relation may coincide with the concept of bleached and degraded corals masking chemical predation cues, leading to the fish remaining further from areas where cues are impacted, to better react to predation (Lonnstedt et al. 2014).
A recent study by Kok et al (2016) set out to observe the changes in aggression in bleached environments. Patch reefs were constructed in different locations. Half were constructed with healthy corals, considered vulnerable to climate change, while the remainder were robust reefs composed of non-susceptible corals simulating reefs of the future. Aggressive behaviors consisted of chases, fin flaring, attacks, and any behavior increasing susceptibility to predation. The study found that reef fish are pushing farther from coral refuge, and that less refuge was taken during times of aggression within the climate robust reefs. This study found that the intensity of aggressive interactions of reef fish in climate robust, and climate vulnerable patch reefs to be equal, and suggested that the aggression seen is not correlated to composition of the coral but is merely due to the amount of available resources within the reefs.

It is still unknown whether degraded corals directly cause these changes or if it is an indirect impact of increased competition. However, additional reasoning from the Lonnstedt et al. (2014) study increases the plausibility that aggression is directly related to degraded corals. Despite this uncertainty, it is known that increased aggression will increase mortality rates of reef fish, as susceptibility of reef fish to predation increases when aggression increases. As seen by a 1.5-fold decrease in species diversity within robust/degraded environments (Kok et al. 2016).

2.4 Changes in Settlement Preference

The settlement preferences of reef fish will inherently change after bleaching events. Use of conspecific chemicals act as a primary method for locating suitable reef settlement. In the Coppock et al (2013) study scents of both degraded, and healthy corals with conspecific scents were placed in different locations of a tank to determine if degraded corals impact settlement preferences. Reef fish avoided the smell of degraded corals, resulting over 80% of subject fish’s time being spent in water with scents of healthy corals with conspecific scents. This distinct difference can be seen in Figure 3 where the white bars depict healthy coral scents with conspecifics and the grey bars illustrating time spent in areas with scents of degraded corals. Even with the addition of conspecific scents to the areas with scents of degraded corals the fish tended to avoid that area. This trend suggests that degraded and dead corals masks scents of conspecifics, reducing recruitment of reef fish to degraded coral assemblages. This will induce a cascading effect as time passes, and less recruitment will occur, as fewer conspecific scents will be present as time passes, impacting the replenishment of degraded coral communities (Coppack et al 2013). These findings align with others reviewed in this paper. All of which found that reef fish tend to avoid, or emigrate from degraded corals into healthier environments. This is most likely due to bleached white background of degraded corals makes reef fish more conspicuous and visible to predators, thus increasing risk of predation related mortality (Coker et al. 2009; Cole et al. 2014; Kok et al. 2016).
3. Combined Impacts of Reef Fish Behavioral Changes on Reef Populations

Behavior changes exhibited in reef fish when in degraded coral environments will undoubtedly have significant impacts in on the ecology of reef ecosystems. However, there is not a clear answer indicating how reef fish populations will be altered, due to contradictory findings. Reviews by Paddack et al (2009) and Pratchett et al. (2011) both suggest an overall decline in reef fish abundance. The declines in coral cover will be proportional to declines in both species richness and abundance of reef fish. Major bleaching events often see results after a lag period, in which the significant impacts are seen years after the event (Paddack et al 2009; Pratchett et al. 2011). This lag was seen in the Indo-Pacific Ocean after an 80% loss of live coral cover in mid 70s, with impacts seen 5-10 years afterwards (Paddack et al. 2009). This lag effect is beginning to be seen in the Caribbean, but has taken longer than other major bleaching events the past. In the Caribbean, there have been recent decreases in species density by 2.7%-6%, with declines in abundance across all trophic groups (Paddack et al. 2009). Reef fish abundance and diversity is expected to decline following loss of healthy coral (Lonnstedt et al. 2013, 2014; Kok et al. 2016). These effects may be due to increases in predation related mortality within damaged coral environments, and could threaten replenishment of reef ecosystems (Coker et al. 2009; Lonnstedt et al. 2014). With carbon emissions being higher than these lag effects could be detrimental once experienced worldwide.

Contrary to other findings a model of the effects of coral bleaching on Caribbean reef fish populations by Alva-Basurto and Arias-Gonzales (2014) displayed increases in total biomass of reef fish, with the species considered increasing in biomass within a range of 4-36.5%. The increases were primarily in large predatory species and small benthic communities that are would no longer fed on by small reef fish. The increase in predators caused a cascade decreasing small reef fish abundance significantly. Despite this difference, it seems more likely that there will be an overall decrease in biomass and abundance of reef fish, as studies involving field research saw decreases, and a larger number of findings suggested a decrease.

4. Conclusion
This review synthesized information on three distinct behavioral changes in reef fish, as result of degraded or bleached coral habitats, while providing insight on the implications these changes will have on reef fish populations. In degraded environments reef fish are not reacting to chemical cues that indicate danger of predation, as unhealthy corals impact the detection of these chemical cues (Lonnstedt et al. 2013, 2014). Reef fish have become more aggressive, and are spending more time away from refuge, increasing their susceptibility to predation, leading to increases of predation in degraded coral environments (Coker et al. 2009; Kok et al. 2016). The chemical ability to perceive conspecific cues is reduced in degraded coral environments, resulting in increasingly less recruitment and settlement of reef fish as time goes on, resulting in altered reef communities (Coppock et al. 2013). The impacts of these behavioral changes are already being seen with declines in abundance and diversity of reef fish (Paddack et al. 2009; Pratchett et al. 2011).

Given the small size of juvenile reef fish they are the most susceptible to predation related mortality. The behavioral changes seen in reef fish will impact juvenile the most due to extreme increases in predation related mortality within bleached, degraded, and dead coral assemblages. Due to the lag in resulting impacts of coral bleaching majority of the impacts from changed behaviors have not been seen yet. As resulting impacts from the bleaching begin to take effect we will face major problems concerning reef fish populations across the world. These issues will result from lowered populations of prey fish and significant increases in predatory fish, changing population dynamics, and may lead to a collapse in reef ecosystems worldwide. Due to the lack of knowledge on how these behavioral changes affect reef fish populations as whole there is currently a need to model the expected population changes resulting from these behavioral changes. This presents an extremely large project that would require global research collaboration to be completed. If this research was completed the actions required to reduce impacts of altered reef fish populations would be determinable, and made more achievable as there would be more time to solve any introduced problems, while encouraging reef conservation efforts across the world.

References:
