The physical, biochemical and socioeconomic impacts of blast fishing, cyanide fishing and bottom trawling on coral reefs

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Abstract

Coral reefs are in decline worldwide due to anthropogenic stressors including coral bleaching, but also by illegal fishing methods. Illegal fishing methods affect the physical structure of coral reefs, marine trophic webs and fish dependant on reefs. Illegal unreported and unregulated fishing methods (UUI) like blast, cyanide fishing and bottom trawling compromise the 3-dimensional habitat that coral structures provide to other species, induces biological function changes, and reshapes the seafloor composition, thus limiting coral recovery. The global rate at which biodiversity and biomass are lost due to illegal fishing methods remain unknown along with coral's recovery period. The purpose of this literature review is to increase knowledge and awareness about the main impacts of blast, cyanide fishing and bottom trawling on coral reef habitats, while considering the socioeconomic context. This review aims to point out realistic marine management strategies to effectively reduce illegal fishing. Filling knowledge gaps such as UUI impacts on the marine biodiversity and populations can also improve marine management to regulate harvesting quotas, adapt fisheries management and mitigate species extinction risk. Future research should include statistically studying organisms affected by UUI and tracking species and their population dynamics and fluctuations.

Introduction

Illegal unreported and unregulated fishing methods (UUI) such as blast-fishing, cyanide fishing and bottom trawling have detrimental biochemical, physical and socioeconomic impacts on coral reefs (Cervino et al. 2003; Fox et al. 2003; Puig et al. 2012; Hill et al. 2014). Illegal fishing methods are still regularly used despite regulations, especially in developing countries (Wells 2009; Johannes and Riepen 1995; Pet and Djohani 1998). UUI fishing methods affect coral reefs by impairing coral tissue structure, biological functions (photosynthesis, protein synthesis), environment, coral survival, and therefore reef-dependant fish. Blast-fishing involves explosives thrown in shallower regions of the ocean. The resulting blast destroys coral exoskeletons and ruptures the swim bladder of fish. This fishing method causes the fish to float or sink, allowing the fishermen to easily collect more fish at once. Similarly, bottom trawling decreases the effort per catch and destroys coral reefs. Bottom trawling boats that carry weighted nets drag the seafloor on several kilometers, collecting all benthic and pelagic organisms, which scrapes off all the 3-dimensional structure (Puig et al. 2012). Following a bottom trawling event, potential coral recovery can take several decades (Tyler et al. 2011). Since 25% of all marine life in the ocean is dependant on coral reefs, including primary producers and commercially important species of fish, destroying reef structure compromises marine productivity, diversity, ecology and population descendance. The loss of reef structure due to phase shifts promotes the replacement of hard coral cover by macroalgae that suffocates the coral or by competing soft coral species (Fox et al. 2003).

In our global warming context, increasingly higher proportion and incidence of coral bleaching are happening which results from the rise in global ocean temperature (Jones and Hoegh-Guldberg, 1999). Combined with global warming and climate change, the use of cyanide on reefs causes coral bleaching, impairs coral photosynthesis and calcification (Cervino et al. 2003). Cyanide is a poison that stuns fish, and was first used by collectors to catch exotic fish without killing them but is now also used to catch fish for food (Cervino et al. 2003). Moreover, some coral died after being experimentally exposed to cyanide only twice in 4 months (Cervino et al. 2003). When bleached, coral polyps expulse endosymbiotic algae out of their tissues, a coral defense mechanism against the toxin secreted by the endosymbiotic algae in warm conditions (Hill et al. 2014). However, the coral-algae endosymbiotic relationship is essential for coral reefs productivity (Hill et al. 2014). Coral death is happening at a much higher rate than its regeneration capacity (Fox et al. 2003). Coral bleaching caused by cyanide fishing and physically destructive fishing practices such as blast fishing and bottom trawling, severely disturb the seafloor, destroy reef structure, and threaten the supporting structure of a quarter of all marine life. It is imperative to better understand how UUI fishing methods affects coral reefs to better protect them and improve marine management.

Considering the rapid loss in biodiversity that has happened over the two last decades (Worm et al. 2006), more efficient marine management is urgently needed. Since coral reefs are vital to reef dependant species, including commercially exploited species, marine quotas and population tracking cannot be realistic or efficient without a true quantification of the loss in biomass due to the impacts of UUI on reefs. The total global loss by illegal fishing methods is not clearly known, and neither are the recovery time and parameters required by the reefs to recover from UUI fishing methods. Measuring the global loss in biodiversity caused by unreported and unregulated operations could tell us how much and how fast coral reefs and fish stocks are being depleted. A truthful portrait of UUI catch data is ambitious but needed to prevent communities collapse, species extinction and threats to fishing communities' survival. Failing to quantify the impacts of illegal fishing makes our current fisheries quotas and marine management inadequate. Thus, the purpose of this review is to increase knowledge and raise awareness about the physical, biochemical and socioeconomic impacts that UUI such as blast, cyanide fishing and bottom trawling have on corals reefs. This review aims to point out better marine management strategies.

Physical Impacts

Explosives and bottom trawling modify the seafloor's physical properties, destroy the 3-dimensionnal structure essential to corals dependant species, decrease coral reef productivity and impair their recovery. Trawling plows the 3-dimensional reef structures leaving only piles of rubble behind (Fox et al. 2003). Blast fishing has similar effects, where the calcium carbonate corals skeleton shatters under the impacts. Coral larvae need an immobile, hard and rough surface to settle and develop, but the rubbles move constantly with currents and becomes often covered with motile sand and silt (Fox et al. 2003). Fox et al. (2003) showed an increase in survival rate from 40 to 65% upon substrate stabilization (Fox et al. 2003). Thus, chronic blast and bottom trawling's softens the seafloor and inhibit coral regrowth by altering primary adhesion of coral larvae (Fox et al. 2003).

In rubble fields, the destruction of 3-dimensional structure induces a phase shift in the community structure where the re-establishing species assemblages differ from the original (Fox et al. 2003). More competitive and resilient soft coral species or algae colonize substrate and grow faster outcompeting slower growing hard-coral species (Fox et al. 2003). As shown in figure 1 below, algae have an inversely proportional and competitive relationship with coral.

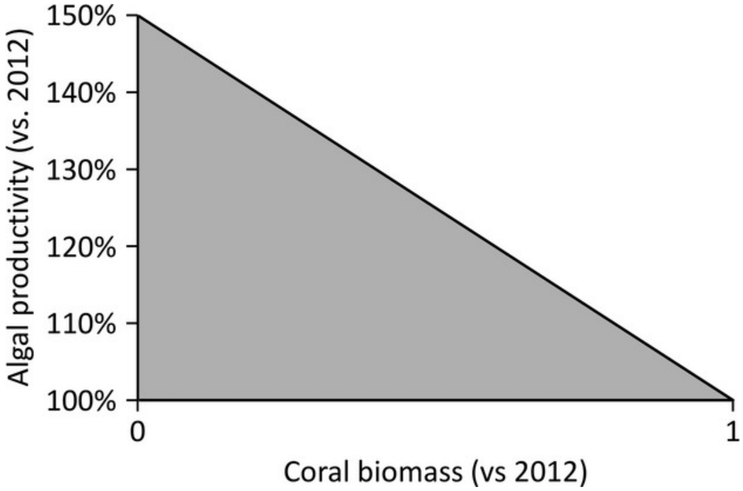

Figure 1. A low coral biomass corresponds to an increased benthic algal productivity in the oceans (Ainsworth and Mumby 2015).

The changes in community structure make the original coral assemblage and their reef-dependant fish species migrate elsewhere for survival, thereby contributing to the post-destruction phase shift. Tyler et al. (2011) studied fish and habitats using underwater visual census (UVC) and belt transects on individual reefs. The authors recommended halting bottom trawling as early as 2003 and showed no recovery signs from blast fishing activity after 16 years, suggesting that blast and bottom trawling impairs coral reefs regrowth minimally for decades (Tyler, 2011).

There is conflicting evidence to support the notion that in rubble fields, larval recruitment for coral reestablishment must originate from elsewhere since most resulting coral fragments post blast or trawling do not survive (Fox et al. 2003; Sawall et al, 2013). Fox et al. (2003) and Sawall et al. (2013) investigated the long-term impacts of bottom trawling and blast fishing using settlement tiles and transects in shallow high current areas. Fox et al. (2003) sought out to determine the requirements for coral regrowth requirements and quantified larval recruitment in rubble fields. Over 9 blasted sites in Komodo and Bunaken National Parks in Indonesia, Fox et al. (2003) showed no significant coral recovery after 5 years. Species analysis in recovering corals revealed that larval recruitment came from neighboring live corals patches, not nearby coral fragments (Fox et al. 2003). Therefore, larvae recruitment in rubble fields is also affected by the distance between living and recovering corals reefs (Fox et al. 2003). Conversely, Sawall et al. (2013) found that blast fishing did not reduce coral larvae recruitment. For 2 years, they monitored coral recruitment (Sawall et al, 2013) with settlement tiles along permanent line intercept transects (English et al. 1997). Their coral spat analysis showed an unchanged larval availability in Supermonde, Indonesia while blast fishing continued to occur in the area (Sawall et al, 2013). Both Sawall et al. (2013) and Fox et al. (2003) studies differed in that Sawall et al. (2013) did not evaluate larvae survival but only recruitment, did not lay the transects in rubble fields and had a much shorter study period. Thus, it seems reasonable to anticipate a significant long-term loss in coral reef and reef-dependant species due to the lack of larvae settlement ability in large areas where chronic blast fishing and bottom trawling occur.

Biochemical

Cyanide fishing triggers individual and systemic detrimental functional changes in coral polyps and coral reefs (Cervino et al. 2003). The use of cyanide started around 1960, when the tropical fish trade became popular for exotic fish collectors (Cervino et al. 2003). Cyanide solutions are typically poured directly over the reef to confuse and stun hidden fish to catch them more easily (Tyler et al. 2011). Cervino et al. (2003) looked at the structural and functional changes in corals, upon release of cyanide (HCN) around corals with the following concentrations: 50, 100, 300 and 600 mg/l. They found that corals exposed to cyanide concentration of 600mg/l exhibited life threatening morphological changes (Cervino et al. 2003). The highest experimental concentration of 600mg/l was much lower than the estimated concentration used by fishermen of 1500 to 120,000 mg/l (Johannes and Riepen 1995; Pet and Djohani 1998; Jones and Hoegh-Guldberg 1999). Some coral species exposed to experimental concentration of 50mg/l instantly died, exhibited changes in protein synthesis (shown in gel electrophoresis), tissue detachment, decay of mesoglea, loss of pigments in zooxanthellae and decreased cell division (Cervino et al. 2003). While coral photosynthetic abilities are affected by thermal stress, cyanide also impairs photosystem II in coral reefs also linked to endosymbiont expulsion (Cervino et al. 2003), an alarming situation for coral reefs in the present global warming context.

Cyanide fishing induces coral bleaching when combined with thermal stress by impairing photosynthesis in zooxanthellae algae (Hill et al. 2014). Photosynthesis is essential because corals feed on the carbohydrates produced by the endosymbiotic zooxanthellae algae in their tissues. The experiment used two photosynthetic impairers glycolaldehyde (GA) and KCN (potassium cyanide). GA had no impact on the bleaching response whereas 20 $\mu mol\ l^{-1}$ KCN and GA at 3 $mmol\ l^{-1}$ disrupted coral oxygen production and caused photosynthesis system II to stop (Hill et al. 2014). To investigate the effects of cyanide on the photosynthesis of zooxanthellae, Hill et al. (2014) released increasing concentrations of potassium cyanide (KCN), over living corals under thermal stress and recorded the zooxanthellae's photosynthetic response using chlorophyll fluorescence. KCN exposure induced coral bleaching and the endogenous production of highly reactive and toxic oxygen hydroxide (Hill et al. 2014). Thus, given the current global warming context, the accelerated bleaching response caused by cyanide fishing justifies stronger enforcement and the establishment of stricter laws and sanctions.

Socioeconomic

Typically, fishermen use illegal fishing methods such as cyanide or blast fishing directly on reefs to increase their yield per catch (per effort) but the effects on biomass are opposite. Since cyanide and blast fishing target reef dependant species of fish (Tyler et al. 2011), destroying reefs keeps fishermen in a vicious circle (Tyler et al. 2011). Coral reefs become quickly unresponsive, leading to reduced fish populations and trapping fisherman in poverty (Wallner-Hahn et al. 2016). By achieving underwater transects, community interviews and coastal surveys, Ainsworth and Mumby (2015) estimated fish decrease in a 100% coral loss scenario. In their results, the global fish biomass dropped by 46%, while the reef-dependant small reef fish, medium sized fish and plankton feeders decreased by 97%, 61% and 78%, respectfully. Some developing countries have also unsuccessfully tried partially protected areas, trying to decrease fish biodiversity loss due to illegal fishing without banning fishermen (Tyler et all 2013). Using underwater visual census inspections and belt transects, Tyler et al. (2013) showed that there was no significant biodiversity difference between partially protected and unprotected marine areas (P value < 0.01) (Tyler et al 2013). As our global biodiversity is already decreasing (Worm et al. 2006), finding solutions to UUI is an urgent challenge where many strategies are currently failing to protect both fishermen livelihood and biodiversity.

Strategies to reduce illegal fishing can vary and its success may depend on the human social and economic context, and culture specific to the area. Wells et al. (2008) showed that, despite severe sanctions and compliance enforcement, members of powerful and influential families still used blast fishing in Tanzania. The continuous lack of compliance forces an eventual zero tolerance approach, where social shaming seems to be most efficient deterrent for UUI fishing methods usage (Wells 2008). In their study, the government invited villagers to participate in the collection of video and picture evidence against dynamite fishers (Wells, 2008). In this case, empowering the community trough contribution to the investigations was a successful approach that decreased dynamite fishing incidence.

A fisherman's capacity and attitude towards a more sustainable gear choice is influenced by local cultural and social factors, and that considering these factors increases marine management's success (Wallner-Hahn et al. 2016). Fishermen's choices are affected by social acceptance, local tradition, identification to groups, economical means, local culture, common practices and tradition (Wallner-Hahn et al. 2016). Interviews and observations of fishermen revealed decisive factors in their selection of sustainable gear choice including education about the revenues yield, understanding of the advantages to changing gear and technical knowledge about the new gear (Wallner-Hahn et al. 2016). Thus, incorporating factors influential to fishermen into strategies to reduce illegal fishing is likely to yield higher success.

Conclusion

To conclude, unreported and unregulated illegal fishing practices are directly and indirectly damaging reef-associated fish and corals, impairing biological functions and jeopardizing population persistence by environmental disturbance (Cervino et al. 2003; Puig et al. 2012; Hill et al. 2014). Blast fishing and bottom trawling destroy the 3-dimensional structure that provides home to a quarter of all marine life. Coral reef damage and destruction rate due to illegal fishing methods is too high for the corals lifecycle to compensate. Indeed, physically destructive illegal fishing methods wipe out the habitat of reef associated fish, leaving only rubble fields biologically infertile to coral for decades (Fox et al. 2003). Blast fishing and bottom trawling also deeply modify reef community structure by creating phase shifts limiting coral succession. In rubble fields, the large distance between recovering and living coral reefs decreases larvae settlement success and survival rate (Fox et al. 2003). Cyanide impairs the coral-algae endosymbiotic relationship which then inhibits photosynthesis and promotes coral bleaching. A question that remains is how far can cyanide travel and how many reef organisms it can affect before becoming inactive? Moreover, recovery after blast or trawling fishing takes decades, even after a single event (Tyler et al. 2003; Fox et al. 2003).

In our global warming context, UUI may lead to depletion of coral reefs and reef-dependant fish stocks. The purpose of this literature review was to increase knowledge, raise awareness about the importance of UUI and to synthesize solutions most likely to be efficient against these practices. Considering the common significative occurrence of illegal fishing in many countries (Wells 2009; Johannes and Riepen 1995; Pet and Djohani 1998) and the dramatic impacts UUI fishing methods have on coral reefs, solving this issue is urgent. Observations of significant regrowth and complexification post-destruction have not observed yet (Fox et al. 2003) even after many decades of research, suggesting that coral regrowth is significantly slow. Future research on the topic should include quantifying biomass and biodiversity loss due to illegal fishing. This would require international concerted action, a detailed action plan, excellent communication, and would be very challenging but possible over the long term. Only this will allow us to understand the global UUI impact and to adapt marine management. In addition, understanding the cultural context of fishermen while working with them, using empowerment and social shaming approaches, are most promising in reducing illegal fishing (Wallner-Hahn et al. 2016). Research and repair of reef damage are crucial to coral recovery and the current coral replanting projects are essential to coral preservation, but so is reducing the incidence of its initial destruction. To efficiently reduce initial destruction of coral reefs by UUI, fishermen' social context must be considered when collecting biological data and establishing action plans. Future research should include statistics for globally affected and lost biodiversity due to UUIs is currently lacking. Finally, collaborative approaches with fishermen are strategies that are most likely to improve marine management to prevent further coral loss and extinction of reef associated species and corals.

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