Impact of Fishing Pressure on Evolution of Queen Conch (*Strombus gigas*)

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The queen conch (*Strombus gigas*) is a large gastropod mollusc found in the warm shallow waters of the Caribbean Sea, Gulf of Mexico, Brazil, Bahamas, and Bermuda, "though some populations have become severely depleted" (Appeldorn, 1994; NOAA Fisheries, 2013; Patterson, 2013). Queen conchs are long-lived with a typical life span of about 25 years. Maturation occurs at slightly different ages for males and females, though it is typically around 3-5 years (NOAA Fisheries, 2013; Stoner, Mueller, Brown-Peterson, Davis, & Booker, 2012). Despite being listed as an Appendix 1 endangered species in the Convention on International Trade of Endangered Species (CITES, 2003; CITES, 2013) queen conch is still a major fishery in places like The Bahamas, and exceptions are made which allows the product to be shipped internationally. Recognizing the importance of the fishery, Bahamian conservation and research organizations have partnered on a new "Conchservation" campaign designed to raise awareness of the general public about the current status of Bahamian conch populations and the importance of conch to our culture, economy, and environment (Bahamas National Trust, 2014). A petition by WildEarth Guardians in 2012 requested that NOAA's National Marine Fisheries Service review queen conch for listing on the U.S. Endangered Species Act (ESA), which would have severely restricted trade of queen conch with the United States. A decision was finally made this November to not include the queen conch in the ESA. Caribbean countries who participate in the fishery were relieved, however conch populations do need to be monitored to ensure the fishery remains sustainable (The Eleutheran, 2014). Investigating evolutionary influences on queen conch can help us better understand how to reduce human impact on conch populations and how to work towards a sustainable fishery. An info graphic summarizing these ideas will be used to help raise public awareness about the status of queen conch in The Bahamas.

Factors Affecting Conch Survival

A naturally slow moving animal that engages in sexual reproduction, queen conch are susceptible to factors that can reduce offspring survival, called depensatory mechanisms (Gascoigne, Berec, Gregory, & Courchamp, 2009; Stoner et al., 2012). The four main processes affecting depensation are: “reduced probability of fertilisation, impaired group dynamics, conditioning of the environment, and predator saturation” (Liermann & Hilborn, 2001). Sometimes nature can balance out the effects of depensatory mechanisms, however the influence of external factors like fishing can make the effects more severe (Courchamp, Clutton-Brock, & Grenfell, 1999; Liermann & Hilborn, 2001). Queen conch are naturally predated on at various life stages by loggerhead turtles, tulip snails, spiny lobster, and spotted eagle rays among other species (Randall, 1964). Natural predation seems to affect small juvenile conch the most, with the largest individuals more likely to survive, though some seasonal differences have been observed. Those seasonal differences may be due to a variation in conch sizes as they mature as well as the variability in the presence or absence of predators with changing seasons (Stoner & Glazer, 1998). Few animals are strong enough to break through the shell of a mature conch (e.g. loggerhead turtle), however humans are very capable.

Fishing and Evolution

Fishing is a selective process that tends to remove the largest individuals from the population, giving the greatest return for investment, and potentially affecting the age and size structure of a population (Berkeley, S. A., Hixon, M. A., Larson, R. J., & Love, M. S., 2004; Kuparinen & Merila, 2007; Law, 2000; Stoner et al., 2012). Conching is a very selective fishery; each conch collected is hand chosen by the fisherman and consequently the fisherman’s decisions affect which individuals are left behind in the population. Larvae would have to be retained in the spawning area for localized fishing pressure to have an effect on the conch’s phenotype. However, if adjacent populations are also similarly fished, this could help perpetuate the change in phenotype (Stoner et al., 2012). Studies of prehistoric harvest of fighting conch indicate that subsistence harvest can have an impact on size at maturity, but that can be reversed if harvest practices are changed (O'Dea, Shaffer, Doughty, Wake, & Rodriguez, 2014). Research in Exuma, Bahamas and the Florida Keys has shown a difference in larval sources and juvenile recruitment (Stoner, Glazer, and Barile, 1996). The smaller stock population in

Florida may be fed by larvae from afar, Cuba for example, while the Exuma site seems to rely more heavily on local larval sources for recruitment (Stoner et *al*., 1996). This may not be applicable across the entire Bahamas chain due to differences in local current patterns, but should be considered.

Depensation and The Allee Effect

At least three depensation mechanisms can be linked to overfishing (predator saturation, reduced probability of fertilization, and impaired group dynamics) (Liermann & Hilborn, 2001). At the heart of this is a reduction in density through harvest. Stoner et *al*. (2012) report that "density in fished sites is approximately half that of un-fished sites" (pg. 93). A reduction in density means that conch are less likely to mate; a minimum density of approximately 56 mature conch per hectare is required to achieve successful mating, this may vary depending on population biogeography (Stoner et al., 1998; Stoner et al., 2000). Any decrease in density below that critical level can cause a population to incur an allee effect where changes in density can affect fitness-related behaviors such as mating (Stoner et *al*., 2012). A fisherman's harvest may unknowingly select for unsuccessful phenotypes to be perpetuated in the population. Queen conch populations in Berry Islands and Andros, Bahamas have been observed to have a different phenotype from un-fished populations. These "samba" conch are smaller at maturity, have thicker shells, and reduced mating frequencies (Stoner et *al*., 2012, pg. 89).

Outreach and Future Management

The infographic accompanying this paper was designed to show the possible impact of overfishing on the evolution of queen conch populations. Conservation measures need to be taken to ensure a sustainable fishery for the future. Suggested actions include monitoring local populations for density, rate of reproduction, and any changes in phenotype (Kuparinen & Merila, 2007). Some fisheries enact a "harvest control rule", which is basically a failsafe to help prevent overfishing, while ensuring a maximum sustainable yield to support the fishery (Deroba & Bence, 2008). If population numbers decrease too much, then the harvest control rule is enacted - usually limiting or removing fishing activity. Conservation and fisheries management for queen conch should be proactive to avoid the deleterious and irreversible consequences of the allee effect and depensation on their populations.

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