Report on Monitoring of Lobster Fishery Impacts on Endangered, Threatened and Protected Species in The Bahamas

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Contents

Cover Image: Turtle foraging at artificial lobster habitat in The Bahamas. Image © Nicholas Higgs.

Management Summary

The Marine Stewardship Council defines Endangered, Threatened and Protected (ETP) species as those species protected by national ETP legislation. Bahamian statute provides varying degrees of 'protection' to different marine species, so only those groups afforded total protection from capture are designated ETP species in this report; namely: turtles, sharks, marine mammals and corals. Other species mentioned in the legislation (grouper, conch, stone crab and sponges) are regulated as fisheries species and so considered 'Secondary' species under MSC terminology.

None of the designated ETP species are mortally threatened by the lobster fishing activities. Most of the interactions between the lobster fishery and ETP species are indirect, whereby lobster fishing gear modifies the distribution or behaviour of incidental species. Therefore negative impacts on ETP species are relatively weak compared to more direct threats such as climate change and pollution.

ETP species interactions with the lobster fisheries are not necessarily negative. Artificial lobster shelters act as patch reefs that support coral growth and provide shelter or food numerous other species that may derive useful benefits such as shelter and food. The degree to which the artificial shelters are truly beneficial to these species remains controversial, since it is not known whether the shelters actually enhance populations or simply attract individuals away from natural reef and other habitats.

There is an extensive range of monitoring activity going on throughout The Bahamas on endangered, threatened and protected species. In many cases this monitoring is adequate for detecting of population status trends; in some species it is not. Even in cases where population trends can be detected, it would not be possible to attribute any population changes to impacts from the lobster fishery because such impacts are weak or uncertain, compared to other threats to ETP species.

Most of the monitoring is carried out with the permission of, or in collaboration with, The Bahamas Government's Department of Marine Resources, but much of the scientific research and monitoring programs are dependent on external funding sources. This means that the future of monitoring programmes is precarious and there is no guarantee of their continuity. Management plans should contain a financial strategy with adequate funding set aside for continued monitoring of ETP species (MSC principle 3).

This report has not directly considered the effects of illegal activities in its evaluations and assumed that current policies are fully implemented. There are however, concerns and evidenced reports that fisheries regulations are violated by Bahamian fishers or not fully enforced, especially in the family islands[1]. Needless to say, any management policies will be ineffective without proper compliance and enforcement.

[1] E.g. Killing of endangered hammerhead sharks; violation of turtle fishing ban; violation of grouper ban

Introduction

Rationale

The Bahamas is known for its productive spiny lobster (*Panulirus argus*) fishery and is one of the leading exporters of lobster tails worldwide. To improve management and sustainability of the lobster fishery, The Bahamas Department of Marine Resources, The Bahamas Marine Exporters Association (BMEA), The Nature Conservancy, Friends of the Environment in Abaco and other conservation partners are working with the World Wildlife Fund (WWF) to implement a fishery improvement project (FIP) for the Bahamian spiny lobster fishery. The goal of the FIP is to move the lobster fishery toward meeting the Marine Stewardship Council (MSC) standard for sustainable fisheries.

Principle 2 of the Marine Stewardship Council (MSC) principles for sustainable fisheries states that fishing operations should allow for the maintenance of the structure, productivity, function and diversity of the ecosystem on which the fishery depends. In order for The Bahamas spiny lobster fishery to achieve the goal of MSC certification it must be demonstrated that the fishery is conducted in a manner that minimises mortality of, or injuries to endangered, threatened or protected species (ETPs). Therefore, there must be adequate assessment of the potential impacts of the lobster fishery on ETPs and monitoring of ETP populations.

In addition to these FIP goals The Bahamas has an obligation under international law to protect its natural heritage from overexploitation. Sustainable management of marine resources is mandated by the United Nations Convention on the Law of the Seas (UNCLOS) and the Convention on Biological Diversity (CBD), both of which The Bahamas is a signatory to.

The Spiny Lobster Fishery in The Bahamas

The Bahamas spiny lobster fishery is mostly undertaken through large-scale industrial operations that accounts for 71% of all commercial fishery landings, with small scale artisanal, subsistence and recreational fisheries (collectively termed 'small-scale fisheries' in this report) contributing the rest[2]. Large-scale fisheries operations are undertaken on mother-ships that will stay out at sea for ~3-5 weeks, with numerous smaller tender vessels that go out to fish each day from the mother-ship. In contrast, the small-scale fisheries mainly utilise small skiffs that go out from port on day trips, returning to land their catch each day. The industrialised operations tend to focus their efforts across the entirety of the Bahama Banks, whereas artisanal and recreational fisheries are more localised, tending to utilise inshore habitats.

Spiny lobster are primarily harvested using two distinct methods in the large-scale commercial fishery. The first utilises traditional wooden slat lobster traps deployed and recovered by rope line. This activity is directly monitored, since their use requires a government permit. The second method utilises artificial shelters (also known as condos or casitas) that act as aggregation devices, which are then harvested by divers using hooks or spears. This method is not directly monitored and consequently estimates of the prevalence of condos are somewhat uncertain. In 2001 it was estimated that

[2] Smith, NS & Zeller, D (2016) Unreported catch and tourist demand on local fisheries of small island states: the case of The Bahamas, 1950-2010. Fishery Bulletin 114:117–131.

105,000 lobster traps were in use in the Bahamas, whilst ~650,000 artificial shelters were deployed[3]; i.e. the latter method is approximately six times more popular with fishers than the former. By 2009 this ratio had shifted further in favour of condos, with fewer and fewer of new fishers employing traps[4]. Thus the primary mode of interaction with ecosystems will be centred around artificial-shelter based fishing and these potential interactions will be the primary consideration of this report, whilst some consideration will also be given to trap-based fishing interactions.

Endangered, Threatened or Protected Species in The Bahamas

Under Marine Stewardship Council (MSC) Requirements and Guidance for Certification of Fisheries[5] the classification of endangered, threatened or protected (ETP) species is afforded to:

- Species that are recognised by national ETP legislation;
- Species listed in certain binding international agreements;
- Species classified as 'out-of scope' (amphibians, reptiles, birds and mammals) that are listed in the IUCN Redlist as vulnerable (VU), endangered (EN) or critically endangered (CE)

No further definition of the term 'protected' is given in this publication. The Bahamian *Fisheries Resources (Jurisdiction and Conservation) Act 1977* (as amended) ("Act") is unusual in that within this one Act both the regulation of certain fishing resources is provided for and the conservation of other species is secured by partial or total prohibitions on their being exploited (Table 1). There is no separate conservation legislative provision for endangered or threatened species.

It is grammatically arguable that the statutory management of any fishery resource is 'protection' of species. However, not all species covered in the Act automatically qualify as ETP species under Principle 2 of the MSC guidance because their populations have not been shown to be severely depleted in the Bahamas and they may be subject to targeted fisheries themselves (separate from the lobster fishery). Such species mentioned within The Act include Nassau grouper (*Epinephelus striatus*), conch (*Lobatus gigas*), Bonefish (*Albula vulpes*), stone crab (*Menippe mercenaria*), and various sponge species. Because they are not managed with limits or target reference points they are designated as 'Secondary species' under the MSC rubric.

In the MSC assessment framework these Secondary species fall outside the scope of this report. Nevertheless, some species (e.g. grouper and conch) might be considered regionally endangered under other assessment regimes and so are considered here to provide a comprehensive overview under the broadest possible definition of the term 'protected species'.

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[3] Deleveaux, V.K.W. & Bethel, G. 2001. National report on the spiny lobster fishery in the Bahamas. *FAO Fishery Report* No. 619: 161-167.

[4] MRAG Americas (2009) Pre-Assessment of the Bahamian Lobster Fishery. *Bahamas Lobster Fishery Improvement Project*. 29pp.

[5] Marine Stewardship Council (2014) MSC Fisheries Certification Requirements and Guidance, version 2.0, p 133. Accessible at www.msc.org

Table 1: Species or groups of species afforded protection under the Bahamian *Fisheries Resources (Jurisdiction and Conservation) Act 1977* (as amended) and their designation under MSC guidelines.

Common name	Scientific name	Legislation paragraphs	Level of Protection
ETP species			
Sea Turtles	Chelonidae	29, 31, 32	Prohibition of taking, possessing, buying or selling turtles or parts
Sharks	Selachii	36	Prohibition of fishing, landing or selling sharks or parts
Marine Mammals	Cetacea & Sirenia	41	Prohibition of fishing, molesting or interfering with mammals
Corals	Anthazoa	12, 70	Prohibition of damaging, taking or selling of hard or soft corals
Secondary species			
Conch	*Lobatus gigas*	27, 28	Prohibition of taking undeveloped conch; export controls
Nassau Grouper	*Epinephelus striatus*	35	Annual closed season during spawning
Stone Crab	*Menippe mercenaria*	37,38,39,40	Annual closed season, minimum size, protection of females
Sponges	Porifera	42, 43	Minimum size for fishing of sponges; export controls

Specific 'out-of-scope' species that are designated as 'endangered' or 'critically endangered' on International Union for Conservation of Nature's (IUCN) Red List available online[6]. Note that the IUCN classification is only relevant for the designation of of amphibians, reptiles, birds and mammals as ETP species. Some species on this list are highly unlikely to be impacted by the spiny lobster fishery because their habitat does not overlap with fishing activities, and so only those in Table 1 are considered in this report. Similarly, Bone fish (protected under fisheries regulations) are unlikely to be impacted by lobster fisheries, since they are found in shallow flats away from lobster fishing activities and don't rely on small lobsters for food[7], so therefore will not be considered further.

Status of ETP and Secondary species and interactions with the lobster fishery

This section outlines knowledge on current population status and trends of each ETP and Secondary species or group and current management strategies described. Potential interactions with the spiny lobster fishery will be analysed to justify their inclusion in this report. The next section will go on to evaluate current monitoring programmes for each species or group.

[6] Permanent link to this list: http://www.iucnredlist.org/search/link/569cd564-7fb5455e

[7] Colton, DE & Alevizon (1983) Feeding Ecology of Bonefish in Bahamian Waters, Transactions of the American Fisheries Society, 112:2A, 178-184.

ETP Species

Sea Turtles

The extensive Bahama Banks, covered in seagrass beds and reefs, attract sea turtles from across the wider Caribbean. The Bahamas hosts five of the world's seven sea turtle species: green, loggerhead, hawksbill, leatherback and Kemp's Ridley turtles. However, Caribbean sea turtle populations are estimated to have declined to 5% of their 15th century population sizes due to human fishing pressure. The critically endangered Hawksbill turtle has been protected by Bahamian law since 1986 and in 2009 The Bahamas government announced full protection for all sea turtle species, prohibiting capture, sale and molestation of nesting turtles. The state of knowledge on Bahamian green turtle populations (the best studied species) is summarised by Bjorndal, Bolten and Chaloupka:

> *"Our results indicate that numbers of green turtles in protected sites in the central and southern Bahamas have been stable over the course of the studies [>30 years]. Whether the same trend has occurred in areas in The Bahamas not protected from exploitation is not known, but it is unlikely given the high levels of exploitation and the low recapture rates in capture–mark–recapture studies at other sites in the archipelago"*[8]

Loggerhead turtles are known to be natural predators of spiny lobsters and are frequently observed at artificial shelters used in the Bahamian lobster fishery[9]. This may put them in conflict with fishers if perceived to be a threat to lobsters. Similarly, smaller hawksbill turtles also take refuge at artificial shelters (N. Higgs, personal observation), and can apparently forage successfully in seagrass habitats[10]. Thus, sea turtles may gain some shelter and food benefits from artificial shelters.

A potentially more serious threat to sea turtle populations from lobster fisheries may occur through the discard of plastic waste at sea (unintentional or otherwise). Turtles are particularly threatened by marine debris, which is commonly ingested and blocks the gastrointestinal tract, leading to decline and eventual death[11]. In The Bahamas, solid wastes have caused mortalities and reduced the reproductive success of sea turtles[12]. The Bahamas is a signatory to the MARPOL Convention, which prohibits the discharge of any plastic debris into the sea from *any* vessel. It is not clear to what extent these regulations are enforced on the fishing industry though, since no fishery representatives were in attendance at a recent workshop on MARPOL Annex V implementation[13].

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[8] Bjorndal et al. (2005) Evaluating Trends in Abundance of Immature Green Turtles, *Chelonia mydas*, in the Greater Caribbean. *Ecological Applications*, 15:304-314.

[9] Gutzler, BC et al. (2015) Casitas: a location-dependent ecological trap for juvenile Caribbean spiny lobsters, *Panulirus argus*. *ICES Journal of Marine Science*, 72:177-184.

[10] Bjorndal, KA & Bolton, AB (2010) Hawksbill sea turtles in seagrass pastures: success in a peripheral habitat. *Marine Biology*, 157:135-145.

[11] Schuyler, Q (2014) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles. *Conservation Biology*, *28*(1), 129-139.

[12] UNEP (2004) Villasol, A. and J. Beltrán. Global International Waters Assessment, Caribbean Islands, GIWA Regional assessment 4. Fortnam, M. and P. Blime (eds.) University of Kalmar, Sweden.

[13] RAC/REMPEITC-Caribe (2012) Workshop Report: National Workshop on Ratification, Implementation, and Enforcement of the MARPOL Convention, Annexes I and V. Nassau, Bahamas 13-15 November.

It should be stressed that this remains a *hypothetical* impact, since there is no information on plastic waste pollution from the fishing industry. Even if there is a potential problem with fishery debris impacting sea turtle populations, one might question how important this threat actually is compared with many others that turtles face. In a recent survey of expert opinion, researchers listed pollution (including marine debris) as the second most threatening hazard facing Caribbean turtles after coastal development[14], (excluding fisheries bycatch and direct harvesting which are not applicable to The Bahamas), suggesting that it is a threat worth considering in this evaluation.

Sharks

Shark populations in The Bahamas appear to be relatively healthy compared to other regions of the Caribbean, with a recent study stating that "the greatest concentration of… sharks, other than nurse sharks, occurred in The Bahamas"[15]. This is largely attributed to the ban on longline fishing that has been in place for over 20 years and the relatively low human population densities near Bahamian reefs. Further protection was afforded to all shark species by an amendment to the Fisheries Resources act in 2011, prohibiting the fishing and sale of all shark species (Selachii).

There is little evidence of any direct interaction between the spiny lobster fisheries and shark populations (e.g. bycatch) and any indirect interactions are likely to be positive. For example, nurse sharks (*Ginglyostoma cirratum*) are thought to be common predators of spiny lobsters, although recent research suggests that lobsters only make up a small part of their diet in The Bahamas[16]. The artificial shelters used in the fishery also provide shelter (and potential prey) to this species, which inhabit the shelters during the day and leave to forage outside at night[17]. The lobster fishery also produces a high volume of discarded lobster carapaces, since only the tails are kept in most (99%) cases. These discarded carapaces may provide a food source to other scavenging or opportunistic species of shark, such as tiger sharks (*Galeocerdo cuvier*) or bonnethead sharks (*Sphyrna tiburo*), which are known to feed on spiny lobster. The degree to which the two IUCN red-listed species of *Sphyrna* feed on lobster is unknown and therefore it can be assumed that there is little interaction with these species.

Marine Mammals

Twenty-four different species of marine mammal have been recorded in the The Bahamas, including resident populations of bottlenose dolphins (*Tursiops truncatus*), deep-diving beaked whales (Ziphiidae) and West Indian Manatees (*Trichechus manatus*). Bahamian legislation not only outlaws killing any marine mammal, but also prohibits anyone to "molest or otherwise interfere with any marine mammal". Further detailed provisions are made in the Marine Mammal Protection Act (2005).

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[14] Donlan et al. (2010) Using Expert Opinion Surveys to Rank Threats to Endangered Species: A Case Study with Sea Turtles. *Conservation Biology*, 24(6):1586–1595.

[15] Ward-Paige, C.A. (2010) Large-Scale Absence of Sharks on Reefs in the Greater-Caribbean: A Footprint of Human Pressures. PLoS ONE 5(8): e11968.

[16] Castro (2000) The biology of the nurse shark, *Ginglymostoma cirratum*, off the Florida east coast and the Bahama Islands. *Environmental Biology of Fishes*, 58: 1–22.

[17] Eggleston, D.G. & Lipcius, R.N (1992) Shelter Selection by Spiny Lobster Under Variable Predation Risk, Social Conditions, and Shelter Size. *Ecology*, 73:992-1011.

Much of the detailed studies of marine mammal populations has been undertaken by The Bahamas Marine Mammal Research Organisation (BMMRO), based in Abaco. Intensive monitoring of bottlenose dolphin populations across the Little Bahama Bank has found apparently healthy populations (<1,000 individuals) that "exhibit a relatively high level of genetic diversity, in contrast to more depleted populations of dolphins around the world, further indicating the healthy status of this population"[18]. This species is of particular relevance because they appear to be restricted to the shallow bank area that also supports a spiny lobster fishery. Many of the larger whale species inhabit the deep water canyons and do not significantly overlap with lobster fishing activities.

The primary impact of the spiny lobster fishery on the marine mammal populations, particularly bottlenose dolphins, is likely to be behavioral rather than mortally threatening. Dolphins may be impacted by the noise pollution associated with the outboard engines of lobster fishing skiffs, which may be interpreted as molestation if intentional. Research on bottlenose dolphin populations in Florida found changes in communication and behavior when motorboats approached[19], however recent studies suggest that this altered behavior has no significant biological consequences[20].

Figure 1: Bottlenose dolphin at artificial shelter

A more positive interaction with the fishery occurs through the provisioning of food to the dolphins, which feed at artificial lobster shelters. Fishers have observed dolphins turning over shelters to catch associated fish and upside down shelters are a common finding in areas of high dolphin populations. This interaction remains anecdotal, but may well impact foraging behavior of sub-populations that learn to use shelters as foraging devices[21].

Marine mammal species listed on the IUCN red list do not occur over lobster fishing grounds, but may be at risk of ship strike from fishing vessels commuting to the banks. However, the risk of ship strike from international shipping through the deep-water channels poses a much greater risk than the relatively infrequent lobster vessel traffic in these waters.

Corals

Bahamian law prohibits the destruction, taking or selling of hard and soft corals (Table 1) and several species of coral also feature on the IUCN endangered species list. Both

[18] Bahamas Marine Mammal Research Organisation website: http://bahamaswhales.org/aboutus/index.html Accessed February 2016

[19] Buckstaff, K.C. (2004) Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*, 20:709-725.

[20] New, L.F. et al. (2013) Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology*, 27:314:322.

[21] Daura-Jorge, F.G. et al. (2013) Seasonal abundance and adult survival of bottlenose dolphins (*Tursiops truncatus*) in a community that cooperatively forages with fishermen in southern Brazil. *Marine Mammal Science*, 29:293-311.

Staghorn coral (*Acropora cervicornis*) and Elkhorn coral (*Acropora palmata*) are listed as critically endangered, whilst the boulder star corals (*Montastraea annularis* and *Montastraea faveolata*) are listed as endangered. This section will specifically look at the particular red-listed species only, rather than 'coral reef' habitat *per se*, which will be reviewed in the report on ecosystems and habitats.

In the late 1970s an outbreak of white band disease led to a major decline (90% loss) in acroporid corals across the Caribbean region, including The Bahamas[22]. Despite this region wide decline, surveys in the late 1990's found "surprisingly large stands of live *A. palmata*" at the Andros barrier reef. Recent surveys at the northern tip of Andros have also found that "populations [of *A. cervicornis*] on these reefs were among the largest observed in The Bahamas at present"[23]. Current Bahamian populations of *A*. *palmata* and *A. cervicornis* have relatively low genotypic diversity and show significant regional population structure[24,25]. This suggests that recruitment from local populations is important for persistence of these species in The Bahamas[25], therefore management at the local scale is important.

Boulder-star coral colonies formed of *Montastraea* spp. complex are indistinguishable at the species level in The Bahamas[26] and are monitored at the generic level of identification. Bleaching events in 1998 and 2005 have led to a decline in *Montastraea* coral in The Bahamas. Colonies surveyed on the Cay Sal Bank, Andros and Inagua, show some of the lowest densities for this genus in the Caribbean, but much of this appears to be related to older mortality events[27]. Recent reef surveys in the southeast Bahamas and northern Andros have found relatively healthy colonies of *Montastraea*[27], suggesting that these species' status may be variable across locations in The Bahamas.

Artificial shelters are deployed in seagrass habitats and are unlikely to have any direct effects on the endangered coral species, but may smother small isolated colonies. Conversely, artificial shelters may provide beneficial hard substrate in soft sediment bottoms that corals such as *A. cervicornis* can settle on (Figure 2), which could potentially contribute recruits to the wider coral populations.

In contrast to artificial shelters, lobster traps may be set very close to or on reefs, leading to direct impact damage to coral species or damage when the pot is moved through recovery or dragged away in a storm[28]. With their prominent branching characteristics the *Acropora* species are likely to be predominantly affected by entanglement in lobster trap and associated ropes. Despite the ubiquity of lost fishing gear it appears that only ~0.2% of corals in the Florida Keys are impacted by lost gear[29]

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[22] Gardner *et al.* (2003) Long-term region-wide declines in Caribbean corals. *Science*, 301:958-960.

[23] Dahlgren, C. (2014) REA of the Fish and Benthic communities for the Joulter Cays, Bahamas.

[24] Baums IB *et al.* (2006) Geographic variation in clonal structure in a reef-building Caribbean coral, *Acropora palmata*. *Ecological Monographs*, 76:503–519.

[25] Garcia Reyes, J. & Schizas, N (2010) No two reefs are created equal: fine-scale population structure in the threatened coral species *Acropora palmata* and *A. cervicornis*. *Aquatic Biology*, 10:69-83.

[26] Fukami *at al.* (2004) Geographic differences in species boundaries among members of the *Montastraea annularis* complex based on molecular and morphological markers. *Evolution,* 58:324–337.

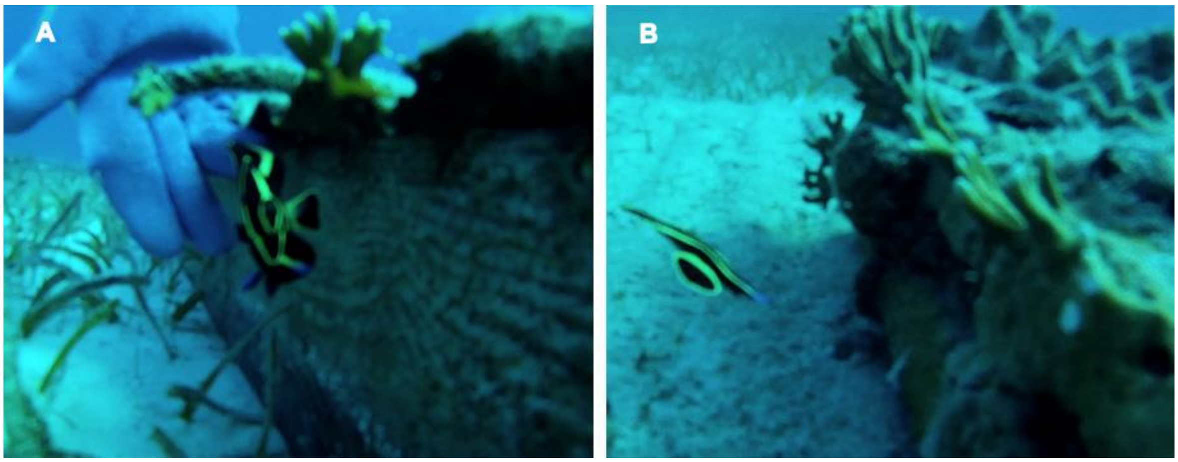
[27] Bruckner, AW (2012) Factors contributing to the regional decline of *Montastraea annularis* (complex). *Proc. 12th Int. Coral Reef Symp., Cairns 11B:1.*

[28] Lewis et al. (2009) Lobster trap impact on coral reefs: effects of wind-driven trap movement. *New Zealand Journal of Marine and Freshwater Research 43:* 271-282.

[29] Chiappone (2005) Impacts of lost fishing gear on coral reef sessile invertebrates in the Florida Keys National Marine Sanctuary. *Biological Conservation* 121:221-230.

(which has a more extensive lobster trapping fishery) and so is not likely to be a major threat to endangered corals in The Bahamas. However, localised concentrations of fishing effort may impact small areas more than others, so even though the total impact may be negligible the local impact might be high.

Figure 2: Still images from a video showing staghorn coral growing on: (A) the corrugated metal and (B) the concrete block, parts of an artificial lobster shelter.



Secondary Species

Queen Conch

The queen conch (*Lobatus gigas*) has been widely depleted throughout much of its geographical range to the extent that fisheries have been partially or totally closed in a range of Caribbean territories, including Bahamian neighbours Florida and Cuba. As a result, conch has been listed as an Appendix II species by the Convention on International Trade in Endangered Species (CITES), restricting international export from The Bahamas to 570,000 lbs annually. The taking or sale of sub-adult conchs in The Bahamas (defined as lacking a well-formed lip) is against the law, providing a degree of legal protection to this species.

The latest assessment of conch stocks across The Bahamas undertaken by the NGO *Community Conch*[30] do not paint a favourable picture of conch populations, stating that:

> *"the vast majority of fishing grounds have been overfished. Only the Jumentos Cays still have densities of adults and age structure indicating a healthy and mature population. This is no doubt related to the remoteness of the location and distance from primary markets. It is clear that current management strategy for queen conch in The Bahamas is not working well enough for a sustainable fishery and changes are needed."*

The lobster fishing activities are unlikely to have any direct impact on conch populations in themselves, although impacts on seagrass beds (see Ecosystems and Habitat Report) may affect conch. On the other hand, the lobster fishery seems to divert fishing pressure away from conch exploitation in favour of the more economically valuable lobster catch. Over 70% of conch landings take place when the lobster season is closed[31].

Conch may be taken as a secondary catch by lobster fishers to supplement income and can be monitored through catch landing forms from the lobster fishery. The wide-ranging nature of the lobster fishery means that more remote conch populations (such as those at the Jumentos Cays), away from traditional conch-fishing grounds, may be subject to fishing pressure that would not otherwise be economically viable if it wasn't being subsidised by the lobster catch. Whilst current conch catches by lobster fishers is likely to be minimal this may change should lobster populations decline.

In addition to Bahamian lobster fishers targeting conch, illegal foreign poachers may be drawn to conch populations whilst seeking lobster, which would otherwise be left alone. Numerous reports of Dominican poaching boats apprehended by the Royal Bahamas Defence Force find conch among the catch[32]. Because they are already fishing illegally, these poachers are also likely to take undersized conch as well as adults.

[30] Stoner et al. (2015) Queen Conch stock Assessment, Eastern Sand Bores, Tongue of the Ocean, Bahamas. *Community Conch*. 16 pp.

[31] Lester Gittens (Department of Marine Resources) personal communication May 2016

[32] Pinder, C (2013) Letter to the editor: Fishing in The Bahamas. The Tribune, April 24th 2013. Accessed at: www.tribune242.com/news/2013/apr/21/fishing-in-the-bahamas/

Nassau Grouper

Nassau grouper (*Epinephelus striatus*) is one of the most sought after fish species in Caribbean and populations have suffered intense fisheries pressure to the point that the species is commercially extinct in many countries throughout the region. Consequently, the Nassau grouper is protected by Bahamian law, with a minimum landing size of 3 lbs in weight and a closed season during the months of winter spawning aggregations. At the turn of the century it was estimated that grouper populations in The Bahamas were “being utilized at exploitation levels that are close to the limit of acceptance from a maximum sustainable yield standpoint”[33]. Reanalysis of this and subsequent data suggested that “there is a significant chance that the population may now be over-exploited if fishing mortality remains at the 1998 to 2001 level”[34]. However, both studies point out that there is a lack of data to make reliable stock assessments. These high levels of exploitation have led to a 70% decline in grouper landings since 1994[34]. Region-wide genetic analyses show that “Nassau grouper aggregations in The Bahamas are both isolated and potentially self-seeding”[35], suggesting that local management is important for maintaining stocks.

Figure 3: Juvenile Nassau grouper (arrow) at an artificial lobster shelter.

Nassau grouper may be taken directly by lobster fishers, especially small-scale fishers working in reef areas, to supplement income or for personal use. As with conch, the lobster fishery may be leading to fishing of grouper populations that would otherwise not be targeted. Outside of reef habitats, artificial lobster shelters act as patch reefs that have been shown to provide suitable shelter for juvenile grouper (>15 cm in length) as they grow and shift from algal-coral nursery habitats[36] (Figure 3). Juvenile groupers will feed on small lobsters and other associated invertebrate fauna, so also obtain prey from

[33] Ehrhardt, NM & Deleveaux, VKW (2007) The Bahamas’ Nassau grouper (*Epinephelus striatus*) fishery – two assessment methods applied to a data – deficient coastal population. *Fisheries Research*, 87:17-27.

[34] Cheung, WWL *et al.* (2013) Are the last remaining Nassau grouper *Epinephelus striatus* fisheries sustainable? Status quo in The Bahamas. *Endangered Species Research*, 20:27-39.

[35] Jackson, AM *et al*. (2014) Population structure and phylogeography in Nassau grouper (*Epinephelus striatus*), a mass-aggregating marine fish. *PloS One* 9:e97508.

[36] Eggleston, DB (1995) Recruitment in Nassau grouper *Epinephelus striatus*. Marine Ecology Progress Series, 124:9-22.

around the shelters[37]. These juveniles are too small to be sold so are unlikely to be taken by lobster fishers.

Stone Crab

An early report on the feasibility of aquaculture for stone crab identified that this species is "far from abundant" in The Bahamas[38], highlighting the relatively smaller stocks found in The Bahamas, compared to neighbouring Florida. Legal protection for this highly sought after species consists of an annual closed season between 1st June and 15th October, and prohibition on the taking of females or any crab with claws less than 4 inches in length. The current status of stone crab populations in The Bahamas is unknown. Landings appear to have been stable at 40-50 tonnes (Figure 4) until an erratic period between 2004 and 2008, after which landings increased to >70 tonnes in 2013.

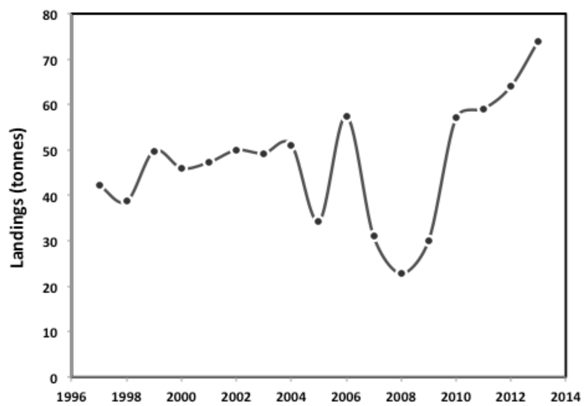


Figure 4: Landings of stone crab in The Bahamas

Stone crabs are commonly found as part of the resident invertebrate community at artificial lobster shelters, since they too are limited by the availability of crevice habitat. They are known predators of juvenile lobsters, but also compete with lobsters for mollusc prey, suggesting that there may be complex ecological interactions between the two species. This provision of shelter and food is likely to boost adult stone crab populations[39].

Stone crab mortality results from two interactions with the spiny lobster fishery. Firstly, there is a high potential for the stone crabs to be caught in lobster pots. A recent study of 'ghost-fishing' found that stone crabs accounted for 84% of invertebrate by-catch in lobster pots off Florida[40]; however, potting studies in The Bahamas have not shown this level of bycatch[41], probably reflecting the smaller populations of stone crab compared with Florida. Secondly, stone crabs at lobster shelters and pots are taken by lobster fishers to supplement income or for personal consumption. In this case the lobster fishing gears are also acting as stone crab fishery devices and their very presence may lead to higher mortality than would otherwise occur with a crab only fishing effort. This fishing mortality may be offset by the enhanced population effects described above, but such calculations remain speculative in the absence of any information on stone crab populations.

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[37] Eggleston, DB (1998) Ontogenetic diet shifts in Nassau grouper: trophic linkages and predatory impact. *Bulletin of Marine Science* 63:111-126.

[38] Idyll, C.P & Wildsmith, B. (1983) Aquaculture Legislation For The Commonwealth Of The Bahamas. *Food and Agriculture Organization*.

[39] Beck, M.W. (1995) Size-Specific Shelter Limitation in Stone Crabs: A Test of The Demographic Bottleneck Hypothesis. *Ecology*, 76:968-980.

[40] Butler, C.B. & Matthews, T.R. (2015) Effects of ghost fishing lobster traps in the Florida Keys. *ICES Journal of Marine Science*, 72:185-198.

[41] MRAG (2015) A review of the potential ecological impact of lobster traps in the Bahamas. 9pp.

Sponges

Several sponge species are protected in the Fishery Resources Act through minimum size and export regulations, primarily because of a historical sponge-fishing industry. The particular species are the wool sponge (*Hippospongia lachne*), grass sponge (*Spongia tubulifera*), hard-head sponge (*Spongia agaricina dura*), and reef sponge (*S. petusa*). Fishing pressure has declined since the heyday of the early 1900s and these species are no longer deemed threatened, although there is still a demand for exports of wild and farmed sponges[42]. The current status of these particular sponge species in The Bahamas is unknown, but not thought to be in decline.

Sponges may be damaged or smothered by the emplacement or movement of lobster fishing gear, although the well-known ability of sponges to repair damaged tissues suggests that this impact would be low. The hard substrate of artificial shelters may also facilitate the growth of sponges that lack suitable attachment substrate cover photo).

Monitoring Programs for ETP and Secondary species

This section will review current and future monitoring programs for ETP and Secondary species and evaluate their potential to detect impacts of the spiny lobster fishery on their populations.

ETP Species

Sea Turtles

Sea turtle populations in The Bahamas have been monitored at Union Creek Reserve, Great Inagua since 1975 and Conception Island since 1989 by the *Archie Carr Center for Sea Turtle Research* at the University of Florida. In addition, they coordinate the Family Island Research and Education organization's tagging program in other family islands of The Bahamas. This is in collaboration with a monitoring program on foraging grounds near Eleuthera, operated by the Cape Eleuthera Institute[43]. Turtle researchers & and a wide range of local stakeholders met in Nassau, Bahamas for a 3-day workshop in 2006 to develop The Bahamas sea turtle conservation strategy[44]. An external, long-term funding opportunity is now allowing a full conservation and implementation plan to be developed, which should be completed in the final quarter of 2016[45]. This will include an extended monitoring element.

The long term monitoring programs already in place have provided useful measures of the growth and physiology of turtle populations at Union Creek and Conception Creek, that allow comparison with other populations[46]. They have also proven useful for evaluation long-term changes in these populations[8], and would presumably be able to detect any potential population decline. However, it would be difficult to specifically ascribe any change in sea turtle populations to interactions with the spiny lobster fishery,

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[42] Oronti, A. *et al.* (2012). Assessing the feasibility of sponge aquaculture as a sustainable industry in The Bahamas. *Aquaculture International* 20, 295–303.
[43] Annabelle Brooks (Cape Eleuthera Institute), personal communication March 2016
[44] http://accstr.ufl.edu/research-conservation/conservation-policy/ Accessed March 2016
[45] Alan Bolten (Archie Carr Centre for Sea Turtle Research), personal communication March 2016
[46] Bjorndal, KA et al. (2003) Survival probability estimates for immature green turtles *Chelonia mydas* in The Bahamas. *Marine Ecology Progress Series*, 252:273-281.

which is largely focused on the Little and Great Bahama Bank. The sea turtle populations are sourced from rookeries across the central Atlantic and the sea turtles forage widely, including over lobster fishing grounds. Any range of impacts occurring across the region may have deleterious consequences. For example, the recent ban on shark fishing may increase predation risk or behavioral change, as shark populations increase[47]. Without specific research and data on the interactions of sea turtles with artificial lobster shelters and debris, it would not be possible to know if the spiny lobster fishery is having an impact (negative or positive) on sea turtle populations in The Bahamas.

Sharks

The Shark Lab at the Bimini Biological Field Station has been monitoring local shark populations for over twenty years, using a combination of genetics, biotelemetry, longline surveys & baited cameras to gather data of the population structure and demographics of local (mainly lemon shark) populations. Similar methods have been used by the Cape Eleuthera Institute since 2006 to study shark biology. The only quantitative information on shark populations outside of Bimini and Eleuthera comes from trained recreational/volunteer diver surveys undertaken by the Reef Environmental Education Foundation, recording sightings using a roving diver technique[15].

Because of their limited geographical scope, it would be unlikely that any fishery impacts would be detected by these research programs, which primarily look at fundamental ecology rather than population sizes per se. Additionally, the most relevant species to the lobster fishery (nurse sharks) are not thought to be threatened and so receive little attention. Because the potential interaction of the spiny lobster fishery with shark populations is weak (or potentially positive), current management strategies are adequate for managing lobster fishery impacts on shark populations.

Marine Mammals

BMMRO has been documenting marine mammal fauna around the islands of The Bahamas since 1991. To date, they have had over 5,000 sightings in The Bahamas, providing the only long-term marine mammal dataset in the region. Monitoring is mainly undertaken across the northern and central Bahamas, with most efforts focused around their base on Abaco. Other areas monitored include the AUTEC deep-water naval testing ranges in the Tongue of the Ocean. The monitoring across the Little Bahama Bank provides the best potential for detecting any impacts of the lobster fishery on marine mammals since this overlaps with lobster fishing activities. The BMMRO have been submitting monitoring reports to The Bahamas Government since 2004 under scientific permit reporting obligations and Government should therefore take recommended steps (see BMMRO reports[48]) to ensuring that this monitoring work can continue.

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[47] Heithaus et al. (2008) A review of lethal and non-lethal effects of predators on adult marine turtles. *Journal of Experimental Marine Biology and Ecology*, 356:43-51.

[48] www.bahamaswhales.org/research/index.html Accessed March 2016

Long-term continuous surveys around the Little Bahama Banks have demonstrated the ability of BMMRO monitoring to detect changes in bottlenose dolphin populations[49]. However; linking these changes to a particular factor is difficult. The long-term population decline observed in the east of Abaco was attributed to hurricane frequency and an increase in anthropogenic use of the habitat (development & recreational boating). If lobster fisheries were having an effect on marine mammal populations, it would be difficult to detect the fishery as the source of the effect under current survey practice. Nevertheless any large-scale changes in populations should be detected under current survey regimes. Should this cause concern (there is currently no evidence for wide-scale decline; see above), studies on the effects of fishing boat traffic and lobster fishing gear might be warranted.

Corals

Extensive coral reef monitoring has taken place in The Bahamas in recent years, in anticipation of the designation of new marine reserves and is summarised in the report on monitoring of habitats and ecosystems. These surveys pay particular attention to the status of endangered species, providing robust baselines for the detection of population changes and the reader is referred to that report for further detail. Again, because lobster fisheries' impacts on coral species are either low in severity and incidence or unknown it is unlikely that changes in coral populations could be attributed to fisheries impacts.

Secondary Species

Queen Conch

Since 2009 the NGO Community Conch has been working with various conservation organizations and the Department of Marine Resources to conduct annual surveys of conch stocks on important fishing grounds throughout The Bahamas[50]. Their first conch stock assessment was completed around the Berry Islands, the closest viable fishery to the population center of Nassau. Since then, surveys have been completed in the traditional and commercial fishing grounds of Andros Island, the Exuma Cays, the Bight of Abaco, the Jumento Cays/Ragged Island chain, and the Little Bahama Bank. The Shedd Aquarium have started a project in association with Community Conch to study dispersal conch and connectivity between different habitats, which will provide useful data on the ability of fished populations to recover from exploitation[51]. The Cape Eleuthera Institute also has a programme of research monitoring local conch populations and aspects of their biology[52].

So far these stock assessments are limited to a single time period, but this baseline data is critical for long term monitoring of conch populations. Stock assessments on the Great Bahama bank would allow assessment of any impact of secondary catch effect from the lobster fishery, as opposed to the other regions that are targeted conch fishing

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[49] Fearnbach et al. (2012) Photographic mark–recapture analysis of local dynamics within an open population of dolphins. *Ecological Applications*, 22(5):1689-1700.
[50] http://www.communityconch.org/our-research/ Accessed March 2016
[51] http://www.thebahamasweekly.com/publish/caribbean-news/Shedd_Aquarium_expands_Caribbean_research_team_printer.shtml
[52] http://www.ceibahamas.org/research/sustainable-fisheries/ Accesses March 2016

grounds. In any case the current program of conch monitoring has been effective in detecting population changes and should be supported in order to detect any potential interactions with the lobster fishery.

Nassau Grouper

As a commercially important fisheries species, grouper are recorded in most habitat surveys in The Bahamas (see report on habitats and ecosystems). Grouper landings and exports are also recorded by the Department for Marine Resources, however this data has proven insufficient for providing robust stock assessments[34]. A new multi-year project (Nassau Grouper Spawning Project) began in 2014 that aims to address this data deficiency, with one of the outputs being a more robust stock assessment[53].The project will "investigate the status and dynamics of Nassau grouper spawning aggregations throughout The Bahamas… using cutting edge research techniques including advanced acoustic telemetry, genetic analyses, blood physiology, bathymetric mapping and biophysical modeling"[54]. The combination on long-term fisheries statistics, with new information to be delivered by the research described above should provide a firm baseline assessment of grouper populations in The Bahamas.

Whilst this monitoring might help with detecting changes in the grouper population, the negative impacts from the lobster fisheries, as outlined above, would be difficult to separate out from the primary grouper fishery. Targeted research on patch reefs on the Great Bahama Bank might allow for fishery specific impacts to be detected.

Stone Crab

There is not currently any targeted monitoring of stone crab populations, other than annual landings statistics collected by the Department for Marine Resources. These statistics could provide warning of declining populations, but given the recent large fluctuations in landings trends it is hard to define what kind of change might signal a serious decline. It would be impossible to link this to the lobster fishery impacts without further research. Additionally, recreational and subsistence fisheries may also have an impact on this small fishery that is not accounted for in the landings statistics[55].

Sponges

There is no specific monitoring of sponge populations in The Bahamas. Export data are recorded, providing some insight into fluctuations in the sponge market, that could be an indicator of sponge population decline. Indeed, there has been a general decline in exports from a peak of 86.3 tonnes in 1999 to 33.4 tonnes in 2007, but it is not clear to what extent this reflects market changes or changes in sponge availability.

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[53] K. Sherman (University of Exeter), personal communication March 2016

[54] http://coastalanglermag.com/bahamas/nassau-grouper-spawning-project-designed-to-strengthen-sustainable-management/ Accessed March 2016.

[55] Smith NS & Zeller D (2016) Unreported catch and tourist demand on local fisheries of small island states: the case of The Bahamas, 1950–2010. *Fishery Bulletin*, 114:117–131.

Summary Table

Protected Group	Population Status: Current Status	Population Status: Confidence	Latest Assessment	Fishery Impacts: Type	Fishery Impacts: Severity	Monitoring: Trends	Monitoring: Impacts
ETP Species							
Turtles	Unknown	High	2010[10]	Indirect	– – ?	Yes	Maybe
Sharks	Good	High	2010[15]	Indirect	+	Maybe	No
Marine Mammals	Good	Moderate	2015[48]	Indirect	+	Yes	No
Corals	Moderate	Moderate	2014[23]	Direct Indirect	– & + – ?	Yes	No
Secondary Species							
Nassau Grouper	Moderate	Moderate†	2013[34]	Direct Indirect	– – ++	Yes	Maybe
Stone Crab	Unknown	Low	–	Direct Indirect	– – –? + +	No	No
Conch	Poor	Moderate	2015[30]	Direct	–	Yes	No
Sponges	Good	Low	–	Direct Indirect	– +	No	No

† Although evidence comes from peer reviewed literature, the methodologies acknowledge uncertainty

Descriptors

Current Status
Good = Populations are stable or increasing
Moderate = Populations are depleted but stable
Poor = Populations are declining

Confidence
High = Evidence from Bahamas related peer-reviewed literature
Medium = Evidence from expert reports or foreign case studies
Low = Expert opinion or landings/export trends

Impact Severity & Direction
The number of signs (1-3) is proportional to severity:
– = negative interaction between species and lobster fishery
+ = positive interaction between species and lobster fishery
? = impact severity is uncertain

Monitoring Trends
Is current or planned monitoring capable of detecting population trends? Yes/No. Maybe indicates that additional data may allow adequate monitoring.

Monitoring Impacts
Is current or planned monitoring capable of detecting lobster-fishery specific impacts on populations? Yes/No. Maybe indicates that additional data may allow adequate monitoring.