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REVIEW

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Contemporary and emerging fisheries in The Bahamas—Conservation and management challenges, achievements and future directions

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Abstract

The harvest of marine resources has long-standing cultural and economic importance to The Bahamas and other small island developing states. Tourists and residents place a demand on local marine resources, particularly Caribbean spiny lobster, *Panulirus argus* (Latreille), queen conch, *Lobatus gigas* (Linnaeus) and Nassau grouper, *Epinephelus striatus* (Bloch), and many fishery products are also sold on the global market. Illegal, unreported and unregulated fishing coupled with inadequate regulations and enforcement are the main factors contributing to the decline of Bahamian fisheries along with other anthropogenic impacts. This article reviews the status of fisheries management in The Bahamas using economically and ecologically important species as case studies to highlight conservation successes, knowledge gaps and deficiencies in existing management approaches. The review concludes with an examination of how emerging fisheries and improved conservation management strategies have the potential to improve economic and food security throughout the archipelago.

KEYWORDS

commercial fisheries, extractive fisheries, marine protected areas, recreational fishing, small island developing states, sustainable fisheries management

1 | INTRODUCTION

Worldwide, fisheries are in decline by approximately 1.2 million tonnes per year (Pauly & Zeller, 2016) with an estimated 31% of marine fish species overfished (FAO, 2016). The Fisheries and Agriculture Organization (FAO) of the United Nations estimates that 56.6 million people are employed through the fisheries and aquaculture sector (FAO, 2016). However, anthropogenic impacts including overfishing, invasive species, climate change, coastal development and pollution are significant threats to biodiversity, ecosystem resilience and socioeconomic stability (Albins & Hixon, 2013; Cheung et al., 2012; Hoegh-Guldberg & Bruno, 2010). Although the status of fish stocks and the rate at which declines are occurring can be debated, there is agreement that declines are likely to persist without strategic management (e.g., Branch, Jensen, Ricard, Ye, & Hilborn, 2011; Worm et al., 2009). Small island developing states (SIDS), such as The Bahamas, are vulnerable to the impacts listed above and have experienced declining trends for many commercially important species (e.g., Stallings, 2009; Stoner, Davis, & Booker, 2012a; Stoner, Davis, & Booker, 2012b Sherman, Dahlgren, Stevens, & Tyler, 2016). Managing fisheries in SIDS is particularly challenging due to the combined effects of limited means for monitoring and enforcement, the strong sociocultural and economic drivers associated with harvesting resources for local consumption and export and the highly complex and dynamic nature of the marine ecosystems and governance frameworks under which they exist (Douglas, 2006; FAO, 1999).

Fisheries and marine resource management in The Bahamas is further complicated by its broad spatial scale. The country consists of 700 relatively flat islands and 3,000 cays encompassing ~300,000 km^2 of land and sea (Buchan, 2000; Figure 1). The islands of New Providence and Grand Bahama are the most developed and heavily populated with approximate population sizes of 250,000 and 50,000, respectively (Mackey et al., 2010). The remaining inhabited islands, referred to as Family Islands, are more remote with limited infrastructure and smaller population sizes (range 72–17,224 people; Mackey et al., 2010).

As of 2010, at least 1% of the surveyed population (351,461 people) directly earned a living through commercial fisheries in The Bahamas (Anon, 2010, 2012). While tourism is the primary industry, contributing 43.6% of the total gross domestic product (GDP) in 2014 to The Bahamas (Anon, 2014), fisheries are inherently connected to the industry with demands for local fish protein from both tourists and residents alike (Smith & Zeller, 2013). In addition to supporting the tourism industry, commercial fishing contributes to 2% of the GDP (Anon, 2014). Subsistence fishing for personal food security is undocumented but is critically important, particularly in the Family Islands. Given the importance of the fisheries sector to The Bahamas, and the current movement of the United Nations

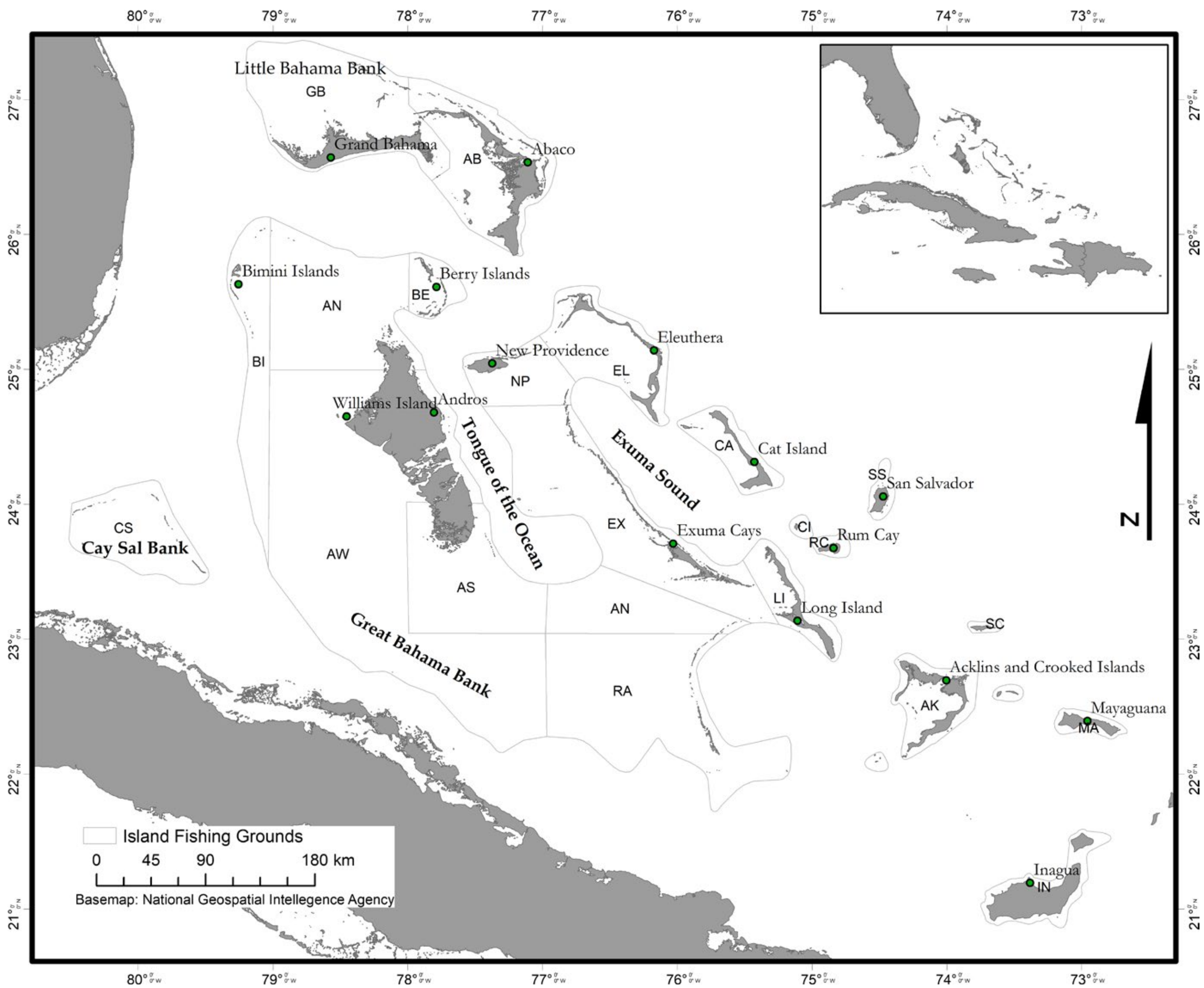

FIGURE 1 Map of The Bahamas showing major fishing islands and fishing banks

sustainable development goals (http://www.un.org/sustainabledevelopment/), this review aimed to: (a) provide a timely synthesis and assessment of the main contemporary extractive fisheries in terms of stock status and management challenges; (b) examine emerging fisheries and their implications for potential economic and food security; and (c) highlight conservation and management strategies for species that influence ecosystems and the economy in The Bahamas.

1.1 | Contemporary fisheries in The Bahamas

Contemporary Bahamian fisheries comprise commercial, sport, recreational and subsistence fishing, with most of the reported revenue generated from commercial fishing (Smith & Zeller, 2013). Commercial fishing typically occurs on Great Bahama, Little Bahama and Cay Sal banks and is legally restricted to vessels owned by Bahamians (Anon, 2008; Figure 1). Commercial fisheries data are collected via sampling at a proportion of frequently used landing sites and from purchasing reports from seafood processing companies (Smith & Zeller, 2013). Main landing sites in The Bahamas are located on the islands of New Providence, Eleuthera, Grand Bahama, Abaco and Long Island (FAO, 2009), although fishing occurs throughout the country. Data on recreational and subsistence fisheries sectors are not routinely collected due to limited resources. Sport fishery data are occasionally collected during tournaments, but the quality and accuracy of these data are variable (Smith & Zeller, 2013). However, in a recent economic valuation, recreational and sport fisheries have been reported to generate approximately US $527 million per annum (Maycock, 2016). Since 1980, the Department of Marine Resources (DMR) has produced annual reports based on data collated from the country.

All fisheries are primarily managed by the Government of The Bahamas through the DMR, which is responsible for the sustainable use of fisheries resources for the benefit of the Bahamian people. The Fisheries Resources (Jurisdiction and Conservation) Act 1977 (hereafter referred to as Fisheries Act) is the legislative framework governing the DMR and provides specific details on fisheries rules and regulations that can be enforced by DMR fisheries officers, and officers of the Royal Bahamas Defence Force (RBDF), Royal Bahamas Police Force and Customs (http://laws.bahamas.gov.bs/cms/images/LEGISLATION/PRINCIPAL/1977/1977-0013/FisheriesResourcesJurisdictionandConservationAct_1.pdf). Wardens from the Bahamas National Trust (BNT) also assist with fisheries management by enforcing regulations within the Bahamas National Protected Area System (BNPAS).

The main species currently targeted for commercial and subsistence fisheries include Caribbean spiny lobster, *Panulirus argus* (Latreille), queen conch, *Lobatus* (formerly *Strombus*) *gigas* (Linnaeus) and medium- to large-bodied reef fish, including Nassau grouper, *Epinephelus striatus* (Bloch), other groupers (Epinephelidae), snappers (Lutjanidae), grunts (Haemulidae) and jacks (Carangidae) as well as stone crab, *Menippe mercenaria* (Say) (BDF, 1986; FAO, 2009; Supporting Information Table S1). Recreational fisheries primarily target bonefish, *Albula vulpes* (Linnaeus), permit, *Trachinotus falcatus* (Linnaeus), tarpon, *Megalops atlanticus* Valenciennes, great barracuda *Sphyraena barracuda* (Edwards), larger demersal (e.g., black grouper, *Mycteroperca bonaci* [Poey]) and pelagic species (e.g., dolphinfish, *Coryphaena hippurus* Linnaeus, and wahoo, *Acanthocybium solandri* [Cuvier]). The most commonly used fishing methods include condominiums, also called condos or casitas (flat structures that attract lobsters) and wooden lathe traps [specifically for Caribbean spiny lobster], traps or fish pots, Hawaiian slings, pole spears, line fishing with hand-line or rod and reel and nets. For commercial fishing, only gillnets, drag nets, cast nets and seine nets with a minimum mesh size of 50.8 mm can be used with limited exceptions, for example, if harvesting herring (Clupeidae) or silversides (Atherinidae). Of the commercial and subsistence species, snappers, grunts, jacks and black grouper are currently unmanaged through specific fishery regulations such as size limits or closed seasons (Supporting Information Table S2). For recreational fisheries, foreign vessels are assigned bag limits that restrict harvest to 9.07 kg of scalefish, 6 conch and 10 spiny lobster per vessel at any time. However, for all marine species harvesting through SCUBA diving and the use of spear guns is prohibited throughout the country.

Of all fishery species, Caribbean spiny lobster, queen conch and Nassau grouper are monetarily the most valuable species, generating over US $1.4 billion per annum in combined commercial landings for The Bahamas over the past two decades (Supporting Information Table S1) but are at risk of overexploitation. Current management practices and monitoring efforts of the three most valuable species in The Bahamas are described below, followed by a discussion of how these fisheries could become sustainable through additional management actions.

2 | SPECIES AT RISK

2.1 | Caribbean spiny lobster

The Caribbean spiny lobster represents the mainstay of the commercial fishing industry in the archipelago (FAO, 2009). From 1995 to 2015, Caribbean spiny lobster represented 80–90% of the total value of the fisheries landings. The majority (>90%) of landed Caribbean spiny lobsters are exported as tails (FAO, 2009), with The Bahamas making up 13% of the Caribbean spiny lobster imports to the United States, second only to Brazil at 22% (Sullivan, 2013). Due to the volume of landings, the high value (Supporting Information Table S1), the number of fishers employed (approximately 9,300 individuals; FAO, 2009) and the use of vessels that can operate up to 4 weeks at sea, the Caribbean spiny lobster fishery is the only truly large-scale commercial fishery in The Bahamas (Smith & Zeller, 2013).

The IUCN Red List designation for the Caribbean spiny lobster is "data deficient" (Butler, Cockcroft, MacDiarmid, & Wahle, 2011; Supporting Information Table S2) and for The Bahamas the status of the stock has been unknown due to uncertainty in the length-converted-catch-curve estimates and estimated catch-per-unit-effort (CPUE) provided by DMR (CRFM, 2008). Since 2010, The

Bahamas Caribbean spiny lobster fishery has been in the process of receiving Marine Stewardship Council (MSC) certification to ensure the long-term sustainability of the fishery (WWF, 2013). To this end, DMR has requested that processors and fishers provide data on lobster tail weight, fishing location, gear used and by-catch to improve stock assessment, harvest control rules and reference points (MRAG Ltd., 2015).

Another critical issue challenging the Caribbean spiny lobster fishery is the government's capacity to address illegal, unreported and unregulated (IUU) fishing (CRFM, 2014). Approximately 36% of all Bahamian landings fall under the IUU category (Medley & Gittens, 2012) and most of this product enters the Dominican Republic, representing a major challenge for sustainable fisheries management. To combat local IUU fishing practices, local nongovernment organisations (NGOs) have been educating both fishers and the public about minimum size limits and other fishery regulations (MRAG Ltd., 2015). The Caribbean Regional Fisheries Mechanism (CRFM) members, including The Bahamas, are considering a common closed season (i.e., countries share the same closed season) for neighbouring countries to discourage foreign illegal fishing of Caribbean spiny lobsters (CRFM, 2014).

Due to the high reproductive potential of the Caribbean spiny lobster (Ehrhardt, 2005) and the relatively low-tech gear types used (Callwood, 2010), the Caribbean spiny lobster fishery in The Bahamas is poised to be a sustainable fishery if the challenges stated above can be addressed. However, new scientific data regarding population connectivity and potential for self-recruitment (proportion of larvae returning to their natal population; e.g., Callwood, 2010; Kough, Paris, & Butler, 2013; but see Naro-Maciel et al., 2011) may have direct management implications (e.g., Lipcius, Stockhausen, & Eggleston, 2013), further highlighting the need for a comprehensive stock assessment combined with spatial analysis of fishing effort (Callwood, 2016). High harvest of Caribbean spiny lobsters may have significant impacts on reef ecosystems because of their important ecological roles on reefs (e.g., Boudreau & Worm, 2012). Similarly, fishing gears like condos can affect benthic communities and patch reef dynamics (e.g., Mintz, Lipcius, Eggleston, & Seebo, 1994). As such, understanding the ecosystem impacts of high harvest of lobsters and use of fishing gears on benthic community structure are essential for ecosystem-based management efforts in The Bahamas.

2.2 | Queen conch

Queen conch has been a significant part of The Bahamas fishery since the time of the Lucayans (900–1,500 AD) and remains the most important fishery species as a dietary staple and cultural icon. Queen conch is also economically important, constituting the second biggest fishery in the country, with landings valued between US $3–5 million per year (Supporting Information Table S1). A total of 182,271 kg in queen conch meat and products generated over US $2.4 million in exports in 2015 (DMR unpublished data). Queen conch are generally harvested by free diving or with an air compressor (restricted for use within depths of 9.1–18.3 m), which requires a licence and SCUBA certification (Fisheries Act; Supporting Information Table S2). Regulations include a ban on fishing queen conch without the shell having a fully formed flared lip, a ban on use of SCUBA and an export quota (Supporting Information Table S2).

Queen conch are important grazers in seagrass and macroalgal communities, which in turn contribute to the health of coral reef systems (Lapointe et al., 2004). They exhibit slow growth and maturation, attaining sexual maturity at ~ 6 years old and a shell lip thickness of 15 mm (Stoner, Mueller, Brown-Peterson, Davis, & Booker, 2012). The species also exhibits density-dependent reproduction, with a minimum density of 50–75 adult queen conch/ha required for reproduction (Stoner et al., 2012a). Because of its life history characteristics, high market demand and unsustainable harvesting, queen conch populations are threatened throughout their range (Theile, 2005). As a result, queen conch has been listed on Appendix II of Convention on the International Trade of Endangered Species (CITES) since 1992 (https://www.cites.org/eng/prog/queen_conch). This appendix lists species that might be threatened with extinction, so trade of these species must be regulated to ensure their survival.

A few management strategies have been implemented to protect the queen conch fishery. The first includes limiting harvest to individuals with a flared shell lip. However, there is ambiguity in stakeholder interpretation of this feature. Research has shown that using the flared lip guideline as a management tool allows for legal harvest of juvenile queen conch, which impedes stock replenishment (Clark, Danylchuk, & Freeman, 2005). More recently, researchers and conservationists have advocated amending the fisheries regulation to prevent harvesting of immature queen conch with <15 mm lip thickness (Stoner, Mueller, et al., 2012; www.bnt.bs/science/conchservation). No-take marine protected areas (MPAs) have also been a partially effective management strategy for queen conch. The Exuma Cays Land and Sea Park (ECLSP) had historically healthy adult queen conch populations, but repeated surveys have shown that deep-water populations inside the no-take MPA are sharply declining and the overall population is ageing with little signs of recruitment (Kough, Cronin, Skubel, Belak, & Stoner, 2017). However, conch densities inside the ECLSP still surpass those outside the MPA (Stoner et al., 2012b).

A multipartner, multisector "Conchservation" campaign was launched in 2013 in The Bahamas with the goal of promoting a sustainable queen conch fishery. Objectives of the campaign are to increase public awareness about the status of queen conch stocks, update legislation to reflect the best science available and incorporate comanagement strategies for queen conch fisheries (www.bnt.bs/science/conchservation). In addition to education and legislative efforts, more comprehensive stock assessments are also needed. Although assessments have been completed in several queen conch fishing grounds (Stoner, Davis, & Booker, 2009, 2013; Thomas, Auscavitch, Brooks, & Stoner, 2015), large areas of the country have not been surveyed that are vulnerable to overfishing (Stoner, Davis, & Booker, 2015). As density is an important consideration for management, with a goal of maintaining minimum densities of 100 adult queen conch/ha (Stoner et al., 2013), these surveys are critically needed. Future research should also include identifying high-quality habitat and better understanding source–sink dynamics (Kough et al., 2017) to inform the placement of MPAs.

2.3 | Nassau grouper

Nassau grouper, widely dispersed among insular marine habitats (Sadovy & Eklund, 1999), are normally solitary but migrate long distances seasonally to reproduce at transient fish spawning aggregations (FSAs) in synchrony with the lunar cycle (Dahlgren, Buch, Rechisky, & Hixon, 2016). High catchability during the annual reproductive season at spatially predictable FSAs combined with slow growth and sexual maturity has led to significant declines (~60%) in global Nassau grouper populations (Sadovy de Mitcheson, & Colin, 2012). Consequently, Nassau grouper has been reclassified by the IUCN as critically endangered (Supporting Information Table S2) and was officially listed as threatened under the United States Endangered Species Act in June 2016 (Carpenter, Claro, Cowan, Sedberry, & Zapp-Sluis, 2015; Federal Register, 2016).

Like queen conch, Nassau grouper is an iconic species and a staple of the Bahamian diet, providing income for thousands of fishers through a commercial fishery (Cushion & Sullivan-Sealey, 2008). Sherman et al. (2016) reported that the average revenue generated from the commercial Nassau grouper fishery exceeds US $1 million per year. Over the last 20 years, a total of 4,698,310 kg of Nassau grouper, valued at more than US $32.5 million, have been landed in The Bahamas (Supporting Information Table S1). However, the overall economic contribution to the country remains unquantified because income derived from subsistence and recreational fisheries has not been evaluated.

Overfishing and subsequent FSA collapses have been reported throughout the native range of the species (Sala, Ballesteros, & Starr, 2001; Stump, Dahlgren, Sherman, & Knapp, 2017). Drastic reductions in Nassau grouper abundance are likely to impact negatively the long-term survivability of the species and overall reef health (Sadovy de Mitcheson & Colin, 2012). Compared with the Caribbean, densities and sighting frequencies of Nassau grouper in The Bahamas are relatively high (Dahlgren, Sherman, Lang, Kramer, & Marks, 2016; Stallings, 2009). This may be due to availability of required habitats or the occurrence of a greater number of reported Nassau grouper FSAs in the country. However, an analysis of long-term fishery-independent underwater visual survey data collected over 14 years shows significant declines in Nassau grouper densities throughout The Bahamas (Dahlgren, Sherman, et al., 2016; Marks & Lang, 2016).

These declines have occurred despite Nassau grouper having received some level of harvest restriction in The Bahamas for the past three decades (Sherman et al., 2016; Supporting Information Table S2). A minimum size limit (≥1.36 kg) and seasonal closures for Nassau grouper during several months when FSAs occur began in 2004 but varied annually in timing until the Fisheries Act was amended in 2015 to include a fixed closed season (Supporting Information Table S2). Overfishing, inadequate enforcement and annual variability in the length and timing of fisheries regulations have contributed to declines in abundance of 70% or more (Cheung, Sadovy, Braynen, & Gittens, 2013) with predictions of extinction due to overexploitation (Sadovy de Mitcheson et al., 2013). Sherman et al. (2016) reported that commercial landings of Nassau grouper have declined by 86% throughout the country, with 20%–40% of reported landings caught illegally during the closed season, highlighting the need for a more strategic approach to conservation management for the species. Evidence that most fish of the minimum size are immature (Sadovy & Colin, 1995) and do not make spawning migrations (Dahlgren, Buch, et al., 2016) also suggests that a larger minimum size is needed. Management recommendations for Nassau grouper have been outlined by Sherman et al. (2016), and a national conservation management plan is being developed to facilitate population recovery (Sherman, Dahlgren, & Knowles, 2018). Conservation of Nassau grouper is dependent on the timely implementation of science-based recommendations by policy makers and a shift in public attitudes and perceptions regarding compliance for national fishery regulations and ongoing conservations efforts (Sherman et al., 2016).

3 | ACHIEVEMENTS IN SPECIES CONSERVATION

While improved management of the Caribbean spiny lobster, queen conch and Nassau grouper fisheries is advocated, it is also valuable to highlight promising steps in the management of other Bahamian fisheries. Here, achievements in conservation for a variety of shark, sea turtle and bonefish species are discussed, along with future suggestions for their management.

3.1 | Shark conservation in The Bahamas

The Bahamas are home to a diverse and abundant elasmobranch assemblage which supports the largest shark-diving industry in the world, estimated to contribute US $113.8 million annually to the local economy (Haas, Fedler, & Brooks, 2017). Historically, commercial shark fisheries in The Bahamas have been limited. The first recorded commercial harvest of sharks in The Bahamas was reported in 1993 when 37 tonnes were declared to the Food and Agriculture Organisation of the United Nations (FAO FISHSTAT, 1950–2015), coinciding with the emergence of a nascent and completely unregulated longline fishery. In response to concerns regarding the sustainability of this new fishery, a ban of commercial longlines was declared in December 1993 (Burgess & Fordham, 2005). This ban outlawed the most economically viable method of commercial shark capture and subsequently the reported catches of sharks fell to 5, 3, 2 and 1 tonnes from 1996 to 1999, respectively. In the absence of a viable commercial shark fishery and recognising the financial importance of shark-related tourism, the Bahamian government further strengthened its protective regulations in 2011, declaring Bahamian waters a shark sanctuary and prohibiting the harvest of sharks by any capture method throughout the 654,715 km^2 Bahamian EEZ. This action was the result of a significant public relations campaign led by the BNT and the Pew Environment Group. The combination of the 1993 longline ban and the 2011 establishment of the shark sanctuary have ensured that there has been virtually no commercial harvest of elasmobranchs within the Bahamian EEZ.

These management decisions have been effective at protecting coastal species with limited home ranges (e.g., the reef shark, *Carcharhinus perezi* (Poey); Shipley et al., 2017), which exhibited no long-term (1979–2013) decline in abundance (Edward Brooks, Cape Eleuthera Institute, unpublished data). Conversely, the abundance of transboundary and highly migratory species with pelagic components to their life history, for example the tiger shark, *Galeocerdo cuvier* (Péron & Lesueur), which is known to move seasonally between North Atlantic and Bahamian waters (Lea et al., 2015), declined 22% in the same period (Edward Brooks, Cape Eleuthera Institute, unpublished data).

The continued exploitation of highly migratory species has implications for the economy of several Bahamian Family Islands. In particular, "rare-species" dives that focus on interactions with highly migratory charismatic species in specific locations at specific times of year are at risk: for example, oceanic whitetip shark, *Carcharhinus longimanus* (Poey), dives in southern Cat Island (Howey-Jordan et al., 2013), great hammerhead shark, *Sphyrna mokarran* (Rüppell), dives in South Bimini (Guttridge et al., 2017) and tiger shark dives in West End, Grand Bahama (Hammerschlag, Gutowsky, Gallagher, Matich, & Cooke, 2017). Despite rare-species dives only generating ~18% of the revenue of shark–dive tourism in The Bahamas, the importance of this income is greater in economically depauperate Family Islands where these interactions take place.

The ongoing capture of migratory shark species coupled with their economic value to the Bahamian economy highlights the need for the Bahamian government to engage further in regional collaborative management initiatives. The Bahamas has chaired the United Nations Save-Our-Sharks Coalition since 2013 and has advocated for the sustainable management and conservation of sharks at the United Nations via a series of meetings and workshops. The Bahamas is also a member of the CRFM and the Western Atlantic Fisheries Commission (WECAFC) but is not currently a member of the International Commission for the Conservation of Atlantic Tunas (ICCAT) that manages all high seas fisheries in the region. More recently, The Bahamas officially co-sponsored proposals resulting in the successful listing of the silky shark, *Carcharhinus falciformis* (Müller & Henle), common thresher shark, *Alopias vulpinus* (Bonnaterre) and devil rays (Mobulidae) in the CITES Appendices at CITES COP16. Given the importance of sharks and other highly migratory species such as tunas (Scombridae) and billfish (Istiophoridae and Xiphiidae; Genter, 2016) to the Bahamian economy, it is imperative that The Bahamas becomes an active participant in the regional management of these species to ensure that sustainable management and conservation practices are extended throughout their range.

3.2 | Sea turtle research and conservation

Four species of sea turtles—green, *Chelonia mydas* (Linnaeus), loggerhead, *Caretta caretta* (Linnaeus), hawksbill, *Eretmochelys imbricata* (Linnaeus) and leatherback, *Dermochelys coriacea* (Vandelli)—occupy Bahamian waters (Dodge, Galuardi, Miller, & Lutcavage, 2014; Lahanas et al., 1998; McClenachan, Jackson, & Newman, 2006). Historically, turtles and their eggs were harvested as a source of food or income for local fishers (Campbell, 2002). Since 1986, it has been illegal to kill adult hawksbill turtles or harvest their eggs. While landings data for sea turtles in The Bahamas are not comprehensive, DMR reported a peak of 52 tonnes of sea turtles landed in 1985 declining to 1 tonne in 2008 (DMR unpubl. data). In response to severe declines in global populations, the Government of The Bahamas passed legislation in 2009 providing full protection for all sea turtles found in Bahamian waters, making it illegal to harvest marine turtles and buy or sell any marine turtle products, but poaching of sea turtles and their eggs continues (Stephen Connett, Archie Carr Center for Sea Turtle Research, pers. comm.).

How the 2009 ban on sea turtle harvest has affected populations in The Bahamas is not entirely clear due to the prolonged life histories and transboundary movements typical of these species (Chaloupka et al., 2008). Emerging results indicate possible increases in sub-populations of juvenile green sea turtles since 2009, but these data must be interpreted cautiously as long-lived species such as turtles take many years for populations to recover (Chaloupka et al., 2008) and sea turtle growth rates are showing significant decline in relation to increasing sea surface temperatures (Bjorndal et al., 2017). Immigration of new recruits is also dependent on nesting success in other countries throughout the Caribbean and United States (Lahanas et al., 1998), and in 2015 green turtle nesting broke records with 14,152 nests recorded in the Archie Carr National Wildlife Refuge, where approximately 35% of all green sea turtles nest in Florida (https://conserveturtles.org/archie-carr-refuge-nesting-trends/). Long-term monitoring plans as well as multi-national collaboration are essential for evaluating management efficacy (Blumenthal et al., 2006). Several long-term monitoring studies of sea turtle aggregations across the Bahamian archipelago are providing an understanding of demographic characteristics (e.g., immigration and emigration), which gives insight to the overall population status. For example, results of a long-term mark–recapture study in a protected area in the southern Bahamas found that changes in immigration, not survival or emigration, were responsible for a 38.8% annual increase in the number of juvenile green sea turtles between 1979 and 1985. The population then decreased by 13.1% annually until 1994 and numbers did not stabilise until 2001 (Bjorndal, Bolten, & Chaloupka, 2005). This study determined that abundance can vary greatly despite long-term stability, so assessments over short time intervals can be misleading. As the harvest ban has only been in place for 8 years, full effects of the ban may not be realised for 20 years or more, highlighting the necessity for long-term monitoring.

Sea turtles play broad ecological roles as consumers on seagrass pastures (Aragones, Lawler, Foley, & Marsh, 2006) and sponges

(León & Bjorndal, 2002), nutrient enrichers of beach and dune systems during nesting (Vander Zanden, Bjorndal, Inglett, & Bolten, 2012) and as prey for various beach and marine predators. Research to date has focused on the foraging behaviour, movement patterns and growth rates of juvenile green and hawksbill sea turtles in tidal mangrove creeks and seagrass pastures (Bjorndal, Bolten, & Chaloupka, 2000; Bjorndal & Bolten, 2010). Studies that estimate carrying capacities of different habitats, as well as the positive and negative effects (Heithaus et al., 2014; Lal, Arthur, Marbà, Lill, & Alcoverro, 2010) of sea turtles within marine ecosystems will aid in future conservation strategies of these species.

3.3 | Bonefish research and management

Bonefish (*Albula* spp.) are the centrepiece of an economically and culturally important recreational flats fishery in The Bahamas (Fedler, 2010). Much of the historical fishing mortality on bonefish came from "hauling" (i.e., seining and block netting) and hand lining, and catch was often consumed or sold to local communities (Danylchuk, Adams, Cooke & Suski, 2008). The development of the recreational fishery in the mid-1960s along with regulations enacted in 1986 that prohibited hauling and commercial sale of bonefish changed this fishery to primarily catch and release (BDF, 1986). Today, the vast majority of fishing pressure comes from recreational fishing with few subsistence fishers that harvest bonefish for consumption (Danylchuk, Adams, et al., 2008). Overall, the fishery has evolved from primarily harvest to almost exclusively a high-value recreational catch-and-release sport fishery (Adams & Murchie, 2015).

This non-extractive fishery generates approximately US $140 million per year for The Bahamian economy, with most of the revenue going to Family Islands rather than the main population and tourism centres (Fedler, 2010). On some islands, these revenues are a substantial portion of overall tourism. For example, over 80% of the tourism expenditures on Andros come from flats anglers that spend money on guides, food, accommodation, tackle and airfare (Fedler, 2010). The conservation status of bonefish remains unknown throughout much of the world, including The Bahamas. Recently, bonefish were listed as near threatened on the ICUN Red List of Threatened Species, with particular emphasis on declining bonefish stocks in the Florida Keys, St. Croix, Bermuda and the Yucatan Peninsula (Adams et al., 2012). Although the causes of declines are unclear, bonefish display a high degree of site fidelity, which could make them particularly susceptible to habitat loss (Adams et al., 2012; Murchie et al., 2013). Bahamian bonefish stocks could face declines similar to those observed in Florida (see Santos et al., 2017) if conservation measures (e.g., habitat protection) are not implemented. Estimates of bonefish population structure and abundance in The Bahamas are priorities for determining their conservation status.

Substantial research on bonefish in The Bahamas has focused on best handling practices to ensure survival postrelease, resulting in publication of a leaflet that has been shared with anglers, guides and lodges (Adams & Cooke, 2015). Key findings indicate that limiting air exposure, minimising fight time, handling fish with wet hands, not using lip-gripping devices and fishing in locations with low predator densities improve survival (Cooke & Philipp, 2004; Cooke et al., 2008; Danylchuk et al., 2007; Danylchuk, Danylchuk, et al., 2008 Hannan, Zuckerman, Haak, & Shultz, 2015; Suski et al., 2007). Based on anecdotal evidence (i.e., informal discussions with anglers and guides, blog photos and popular press articles), it appears that anglers and guides have adopted many of these best practices; however, future research should evaluate the extent of the application of best practices. More recently, research priorities have shifted to focus on population connectivity by identifying migration corridors, spawning aggregations, larval dispersal and genetic structure throughout the region (Danylchuk et al., 2011; Murchie et al., 2013, 2015; Wallace & Tringali, 2016). Outcomes from these studies have the potential to influence the placement and management of MPAs that protect key habitats and stocks, thereby helping to conserve this species (Grüss, Robinson, Heppell, Heppell, & Semmens, 2014). The Government of The Bahamas designated marine parks on the north and east side of Grand Bahama, southern Abaco, and the west side of Andros that will protect several bonefish migration routes and spawning aggregations.

Identifying additional foraging habitat, migration routes, spawning aggregations and larval dispersal routes, particularly in the southern portion of the archipelago, should be the focus of future research. Lastly, research on the response of bonefish to climate change stressors in the nearshore environment has indicated that bonefish will likely be more vulnerable to increases in temperature than other fish species (Shultz, Zuckerman, Stewart, & Suski, 2014; Shultz, Zuckerman, & Suski, 2016). Bonefish habitats that act as thermal refuges (e.g., deeper water and upwellings) may be critical to include in MPAs as sea surface temperature increases in the future. Overall, due to its economic and cultural importance, coupled with high levels of catch and release by recreational anglers, this fishery has benefited from increased regulations by the DMR and self-regulation from the angling community (i.e., encouraging fellow anglers to follow best handling practices). Anglers and guides should unify and incorporate the best available science to lobby for improved regulations (e.g., fines for habitat destruction), additional enforcement and habitat protection to ensure that bonefish remain the centrepiece of Bahamian flats fisheries that benefit local economies.

4 | EMERGING FISHERIES

While traditional fishery taxa (e.g., Caribbean spiny lobster, groupers and snappers) are of greatest economic and cultural importance to the Bahamian fisheries sector, several new fisheries have recently emerged. These fisheries have become established due to declines in traditional fishery species and other influences including social and economic factors as well as advances in biomedical research, such as the use of bioactive compounds derived from marine organisms in drug development (e.g., Haefner, 2003). Emerging fisheries have the potential to expand the fishing sector, improve food security and provide income to a greater number of fishers. However, they present new challenges for management due to lack of data on landings, population dynamics and the ecological function of these species. Some examples of emerging fisheries include parrotfishes, sea cucumbers and gorgonians. Two examples of emerging fisheries within The Bahamas are presented.

4.1 | Parrotfishes

As recently as the mid-2000s, parrotfishes (Scarinae) were only taken as by-catch in fish pots and occasionally used for bait (Mumby et al., 2006). Over the past decade, however, large parrotfish species, such as stoplight parrotfish, *Sparisoma viride* (Bonnaterre), are commonly found at local landing sites and fish markets for sale on several islands, and surgeonfishes (Acanthuridae) are also seen on occasion (Craig Dahlgren, Perry Institute for Marine Science, unpublished data). The development of this fishery is of concern due to the ecological role that herbivores play as grazers on coral reefs. As high abundances of large parrotfishes are linked to decreases in macroalgal cover and increases in coral recruitment (Mumby et al., 2006, 2007), removal of individuals from the ecosystem may have detrimental effects. The role of parrotfishes as grazers is particularly important for reef health in The Bahamas, as other known important grazers such as the long-spined sea urchin, *Diadema antillarum* Philippi, are rare (Dahlgren, Sherman, et al., 2016). At present, The Bahamas has greater densities of large parrotfishes than other parts of the Caribbean (Dahlgren, Sherman, et al., 2016), but the development of this emerging fishery poses a danger to these populations and the ecological function that they serve. Research is currently underway to assess the harvest of parrotfish, including how it varies across The Bahamas, which species are being targeted and how the development of the fishery is affecting populations.

While studies into the extent of this fishery and factors driving its emergence have only just begun, contributing issues are likely the depletion of other fishery resources and an increased demand for parrotfish among immigrants from Haiti and other parts of the Caribbean where parrotfishes are a traditional food (e.g., Ferry & Kohler, 1987; Hawkins & Roberts, 2004). Other countries around the region, including Belize, Bonaire, Bermuda and the Dominican Republic have either banned parrotfish fishing or imposed gear restrictions to limit their harvest (e.g., Jackson, Donovan, Cramer, & Lam, 2014). Studies from Bermuda illustrate how fishing has reduced biomass and skewed sex ratios of parrotfish, although these effects may be reversible over 3–6 years following a fishing ban (O'Farrell, Harborne, Bozec, Luckhurst, & Mumby, 2015; O'Farrell, Luckhurst, Box, & Mumby, 2015). While the parrotfish fishery currently serves an emerging domestic market, and may be developing as an export fishery, management decisions must examine its value as a commercial fishery weighed against its ecological value in maintaining the health of coral reefs (Bozec, O'Farrell, Bruggemann, Luckhurst, & Mumby, 2016) and the ecosystem services that reefs provide to The Bahamas.

4.2 | Sea cucumbers

New access to international markets by Bahamian fishers has led to a fishery for holothurians or sea cucumbers that are a valuable commodity in many Asian markets. Unfortunately, due to density-dependent reproduction, many sea cucumbers stocks are easily overfished and have very slow rates of recovery (e.g., Friedman, Eriksson, Tardy, & Pakoa, 2011). Sea cucumbers play an important ecological role in tropical marine systems as bioturbators and processors of detritus, thereby altering infaunal communities (Dahlgren, Posey, & Hulbert, 1999) and enhancing benthic microalgae and eelgrass growth (Wolkenhauer, Uthicke, Burridge, Skewes, & Pitcher, 2010). Loss of sea cucumbers may have significant ecological consequences for other species that live or feed in soft substrates or seagrass habitats.

In 2010, a small-scale export fishery for sea cucumbers opened in north Andros targeting two commercially valuable shallow water species, the donkey dung or "brown" sea cucumber, *Holothuria mexicana* Ludwig, and the furry or "green" sea cucumber, *Astichopus multifidus* (Sluiter). This fishery engaged at least 120 fishers using small boats (2.5–7.6 m) on day trips with prices that typically varied from $0.20 to $0.45 per sea cucumber (Craig Dahlgren, Perry Institute for Marine Science & Lester Gittens, DMR, unpublished data). At the start of the fishery, non-conventional fishers, including women and children, gathered sea cucumbers by wading in shallow water while the traditional fishers, primarily men, gathered conch and other species. Subsequently, shallow areas were rapidly depleted and the fishery moved to water depths only accessible by free diving. Between February and July 2010, total sea cucumber landings were reduced by 60% as fishers dropped out of the fishery and distance travelled to sustain high landings increased throughout the year (Dahlgren, 2010; Craig Dahlgren, Perry Institute for Marine Science & Lester Gittens, DMR, unpublished data). After only 11 months, the fishery collapsed due to local stock depletion, high fuel costs and falling sea cucumber prices. By November 2010, stocks had been depleted to the point where sea cucumber densities in fished areas were 77%–83% lower than unfished areas (Craig Dahlgren, Perry Institute for Marine Science & Lester Gittens, DMR, unpublished data). Although this fishery was not successful, increased demand from Asia and favourable economic relations between The Bahamas and China have revived interest in sea cucumber harvesting. Since 2016, there have been reports of sea cucumbers being harvested in several parts of The Bahamas but no data on landings have been collected. Because sea cucumber fisheries around the world have proven difficult to manage sustainably, it may not be suitable for further development in The Bahamas unless better stock assessments and strict limits are placed on the fishery (Anderson, Flemming, Watson, & Lotze, 2011; Purcell et al., 2013).

5 | MANAGEMENT RECOMMENDATIONS

For both existing and emerging fishery species, there is a disparity between information required for effective species-specific management and the scale on which monitoring efforts and research are conducted in the country because of limited financial resources, reduced technical capacity, time and other logistical constraints. To address fisheries objectives for The Bahamas better (see Waugh, Braynen, Bethel, & Gittens, 2010) and prevent further declines in species and ecosystem function, sufficient data for more accurate stock assessments are needed to inform management strategies and harvest regulations for commercially important species. Integrative and interdisciplinary monitoring and research approaches are recommended to address multiple questions and potentially alleviate costs. For example, population genetics coupled with traditional and emerging in situ monitoring technologies (e.g., hydroacoustics and telemetry) are likely to help with stock identification and long-term monitoring of population status for species of interest (Paris et al., 2018).

From a management perspective, critical issues common across all fisheries sectors relate to the government's capacity to enforce existing regulations and address IUU fishing. RBDF currently is in the process of completing base repairs to its headquarters in New Providence and establishing another post in the southern Bahamas to increase its surveillance and enforcement capabilities. These improvements, along with training programs for enforcement officers (including DMR fishery officers), should help address problems of IUU fishing (local and foreign) throughout the archipelago. New technologies, such as vessel monitoring systems and drones, along with additional water-based patrol capacities are also important for monitoring and deterring illegal fishing activity. Regional (e.g., CRFM) and international (e.g., ICCAT) partnerships should be further explored to reduce the amount of IUU fishing and protect highly migratory species. However, more emphasis needs to be placed on routine data collection and management systems across DMR and enforcement agencies to monitor and regulate fishing activities better (e.g., through licensing of all fishing vessels, gears and recreational fishers) and to promote consistency, accuracy and timely reporting across all fishery sectors (e.g., via standardised reporting systems such as the newly implemented Fisheries Management and Information Systems (FISMIS) for DMR).

Countries with limited means for conventional fisheries management, including The Bahamas, are often particularly interested in the fisheries roles of MPAs. For example, in areas of The Bahamas lacking robust fisheries enforcement, MPAs are currently the main management tool being used to promote fisheries sustainability (e.g., Stoner et al., 2012b). Fisheries bioeconomic models suggest that for enhanced fisheries yields, MPAs should be placed where fish productivity and dispersal, via either larval or adult export, are high enough that fishers' foregone harvests can be compensated by consistently larger yields and profits from surrounding areas (e.g., Sanchirico & Wilen, 2001). Other analyses suggest that when economic benefit-sharing is structured in appropriate ways, ecotourism value can provide sustainable compensation for forgone fisheries extraction from no-take MPAs (Sala et al., 2016; Wabnitz, Cisneros-Montemayor, Hanich, & Ota, 2018). In addition, other social considerations, such as the design and implementation of locally appropriate MPA governance and management regimes are increasingly recognised as being important for MPA effectiveness through facilitation of public support and compliance (Bennett & Dearden, 2014; Kaplan et al., 2015).

Given biophysical and economic variability across MPAs systematic understanding of how such social factors influence MPA effectiveness for fisheries management and biological conservation objectives remains challenging and requires more careful and sophisticated approaches to design, monitoring and assessment of MPA management (Ahmadia et al., 2015). In the meantime, however, better integration of fisheries management and conservation goals in MPA planning is underway in The Bahamas (Green et al., 2016; Knowles, Green, Dahlgren, Arnett, & Knowles, 2017), and further stakeholder engagement and strengthening of more integrated management offers the promise of simultaneously enhancing both MPA and fisheries management (Brumbaugh, 2017; Weigel et al., 2014).

6 | CONCLUSION

The future of fisheries depends on the successful use of adaptive measures to address both current and predicted anthropogenic and natural impacts to species and their habitats. In The Bahamas and other SIDS, exploited species provide key ecological functions that are critical to maintain healthy marine ecosystems. Their continued overexploitation therefore, beyond reducing stock productivity and prolonging recovery, may also reduce ecosystem resilience. In contrast to most single- or even multispecies management approaches, ecosystem-based fisheries management attempts to integrate more ecosystem components so that unintended ecological impacts from fishing can be minimised, trends in ecosystems can be better predicted and other human interests, and associated ecosystem services can be included and sustained. Precautionary and ecosystem-based approaches should be applied to all species and habitats, especially where data are limited or non-existent, to promote sustainable fisheries and maintain biodiversity. The use of MPAs is a good example of these approaches, but to be effective for managing fisheries, conserving biodiversity and protecting ecosystem function, MPAs need to be well designed, managed and prohibitive of activities that are extractive or degrade habitat quality.

Finally, in addition to the need for more targeted science and complementary precautionary management policies, scientific reasoning needs to be more accessible to policymakers and the public. Scientists and environmental organisations must therefore craft and deliver a range of succinct, science-grounded messages targeting multiple audiences to support legislation for species and ecosystem sustainability. Such a multi-faceted approach will help ensure that culturally and economically important natural resources will be available for future generations. The Bahamas has made considerable progress towards assessing the status of some species and protecting key habitats. While additional research is required, preliminary results have highlighted both successful conservation actions and areas where fisheries regulations can be improved. Moving forward, the development and implementation of species-specific fishery regulations, national management plans (and where appropriate, regional plans), as well as greater exploration and development of ecosystem-based management approaches, will be important approaches to promote recovery and sustainability for current and emerging Bahamian fisheries and the ecosystems on which they depend.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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