CONTRIBUTION 6.11

Recommended Strategies to Protect Parrotfish Populations in Barbados

Christopher Parker and Shelly-Ann Cox

Fisheries Division, Bridgetown, Barbados
Corresponding author: Christopher.Parker@barbados.gov.bb

Abstract

Parrotfish are considered ecologically keystone species that play key roles as grazers, agents of bio-erosion of calcareous substrate, sediment production and transport in coral reef ecosystems and shoreline stabilisation. Recent reported declines in populations of some parrotfish species on Barbadian reefs due to several anthropogenic factors, has raised understandable alarm resulting in calls to significantly reduce or completely ban fishing of parrotfish. This of course will have significant impacts on the livelihoods of the many people involved in the island's reef fisheries especially given the high commercial and cultural value of parrotfish more commonly known locally as 'chubs'.

Relevant scientific information on this issue is critically examined in this paper and a recommended holistic strategy is proposed to protect parrotfish populations while selectively mitigating the social and economic impacts on the more vulnerable participants in the reef fisheries that harvest parrotfish. The first overarching recommendation is that selective protection of parrotfishes or any subset of species in the family (i.e., corallivorous or non-corallivorous) is not supported. Instead, it is recommended that the focus should be on reducing fishing pressure on all reef fish species eliminating the incidences of wasteful ghost fishing and physical damage to reefs caused by the fishing activities. A co-management approach is recommended as being essential in the implementation of adaptive management measures that are grounded in participatory action research. This approach engenders buy-in, cooperation and effective compliance with a "carrot" rather than the "stick" approach, as is considered vital to the success of these initiatives.

KEYWORDS: sustainable, parrotfish, co-management, coral reefs, Barbados

CITATION: Parker, C. and S-A. Cox, 2026. Recommended Strategies to Protect Parrotfish Populations in Barbados. Contribution 6.11, p485-492 *IN* CRFM, 2026. Volume I: Technical Papers. Presented at the CRFM 20th Anniversary Scientific Conference, 28-31 August 2023. CRFM Special Publication No. 37, CRFM Secretariat https://www.crfm.int/index.php?option=com_k2&view=item&id=941

1. INTRODUCTION

By the early 21st century it was estimated that reefs throughout the Caribbean had lost, on average, 80% of coral cover over the time span of just 30 years (Gardner et al., 2003). Loss of coral cover facilitates an increase in algal growth and algae dominating the benthic community. This transition is technically referred to as the "coral-algal phase shift", which results from a complex of factors and processes (see McManus & Polsenberg, 2004 for a comprehensive review). This shift can in some cases be reversed but often leads to a more permanent ecological alternative stable state.

There are myriad causes for decreased coral health that may eventually lead to their death. These include global-scale events such as mass coral bleaching often associated with increased sea surface temperature (Diaz-Pulido and McCook, 2002; Oxenford at al., 2010), also caused, or exacerbated, by other factors such as increased DIN (Dissolved Inorganic Nitrogen) levels (Lapoint et al., 2019), and potentially ocean acidification (Hoegh-Guldberg et al., 2007), periodic local-scale physically damaging events ranging from hurricanes and cyclones (Mah and Stearn, 1986; Hughes and Connell, 1999) to anchor damage (Flynn and Forrester, 2019; Small and Oxenford, 2022), degraded water quality from elevated loading of nutrients, sediments and chemical pollutants through terrestrial runoff (see Rogers and Ramos-Scharrón, 2022 for review) and disease (Bruckner, 2002 for a review). It should be noted that a number of these stressors can interact with each other triggering even more coral damage and mortality. For example, pollution factors associated with terrestrial run-off has been linked to increased susceptibility of corals to diseases and the severity of diseases, such as yellow band disease in the important reef-building corals *Montastraea annularis* and *M. franksii* (Bruno et al., 2003). Of especial concern in the context of Caribbean reefs is the loss of three species of framework-building coral species that historically dominated shallow Caribbean reefs (Goreau 1959), namely *Acropora palmata* and *A. cervicornis* from white band disease in the early 1980's (Gladfelter 1982) and *Montastrea annularis* (Edmunds and Elahi, 2007) some from yellow band disease (Bruckner and Bruckner, 2006(a) and (b). The list of coral diseases continues to grow with Stony Coral Tissue Loss Disease (SCTLD) being the latest of great concern. This lethal disease was first identified off the Miami-Dade County coast of Florida in 2014 (Precht et al., 2016) and is known to affect more than 30 coral species including the framework species, *Agaricia* spp, *Orbicella* (formerly *Montastrea*) spp., *Siderastrea siderea* as well as some species of brain coral. At the time of writing the disease is known to have spread to at least 28 countries and territories in the Caribbean Basin, including Barbados, where the disease was first reported in November 2022 (Kramer at al., 2019).

Even in the absence of these stressors, the proliferation of benthic algal growth on coral reefs must be controlled to prevent or reverse coral-algal phase shifts, which if left unchecked can snowball into significant degradation of the coral reef ecosystem. In this context, it should be noted that contact with benthic macroalgae can harm corals in various ways including overgrowth, physical abrasion, shading and allelopathic interactions that may eventually result in reduced coral growth, fecundity, as well as increasing coral mortality (Jompa and McCook, 2003; Foster et al. 2008; Rasher et al., 2011) Some algae can stimulate bacterial respiration at the algae-coral interface encouraging the invasion of virulent bacteria on corals (Barott et al., 2012; Haas et al, 2016). Some species of macroalgae can reduce the settlement and survivorship of coral larvae in a variety of ways ranging from physically monopolising suitable settlement areas, and allelopathic destabilization of coral microbiomes (Birrell et al., 2008; Paul et al. 2011). Algae may be common reservoirs of coral pathogens (Sweet et al., 2013) and transmit pathogens to corals (Nugues et al., 2004),

In coral reef ecosystems the important role of controlling algal abundance is performed by the multispecies ecological guild of grazing organisms primarily comprised of sea urchins and a

few fish species (Carpenter, 1981; 1986; Hay, 1991). The black sea urchin *Diadema antillarum* was historically the most abundant and important herbivore on Caribbean coral reefs (Carpenter, 1986). From 1983 to 1984 the species suffered a mass mortality that resulted in a reduction of between 95-100% of the populations in the region (e.g. Hunte et al. 1986; Lessios 1988; 2016). Within just five days of the loss of *D. antillarum* there was a 20% increase in algal biomass on reefs at St. Croix, U.S. Virgin Islands (Carpenter, 1988). The loss of this key grazer was catastrophic as in the following years, filamentous algal turfs and macroalgae became the dominant benthic groups on many reefs throughout the region (e.g. Carpenter, 1986; 1990; Hughes et al., 1987). According to Levitan et al. (2023) over the last 40 years following the mass mortality, *D. antillarum* has exhibited only limited and patchy population recovery in shallow water. However, the recovery of the species in the region was further stymied by another mass mortality event in 2022 reported at several Caribbean reefs (Hylkema et al., 2022). Unlike the case in the 1983-84 mortality event, the pathogen responsible for the 2022 event was identified as a scuticociliate (Hewson et al., 2023). With the loss of *D. antillarum* the role of regulating algal biomass on Caribbean reefs fell to the remaining species in the grazer guild. In this context, parrotfishes were identified as becoming the dominant grazer group (Mumby et al., 2006).

Endolithic microganisms and a number of macrofaunal grazers are the main agents of the bioerosion of calcium carbonate substrate from coral reefs that results in the production and transport of sediments essential for maintenance of the reef complex and coastline stability. On West Indian coral reefs, the major macrofauna guild of bioeroders that historically performs this service are sea urchins, particularly *Diadema antillarum* (Scoffin et al. 1980; Carpenter, 1988), and parrotfish (Perry et al., 2014). Before the 1983-84 mass mortality, the bulk of bio-erosion on local reefs was attributed to *D. antillarum* (when the average population size was 23 individuals m^{-2}) (Scoffin et al., 1980). Parrotfish possess certain morphological features, particularly a structure known as the pharyngeal mill, in which ingested matter is finely ground and the inedible calcium-carbonate excreted as the fine white sand for which the beaches of Barbados is well known. With the loss of *D. antillarum* most of the vital superficial bioerosion of reefs is now performed by the parrotfish group (Perry et al., 2014). However, the quantity of sand produced and thus the relative importance of each species of parrotfish in terms of this function varies among species. In this regard some species graze without scraping much of the underlying structure while others scrape more deeply or even take larger or deeper bites removing either only a thin layer of the underlying hard substrate or much deeper layers. The former group of species are referred to as "scrapers" and the latter group are described as "excavators" (s*ensu* Bellwood and Choat, 1990). The Queen parrotfish (*Scarus vetula*) and the stoplight parrotfish (*Sparisoma viride*) are the primary eroding species on Caribbean reefs and can remove material at a rate that is comparable to local calcification rates (Bruggemann et al., 1996). Notably these two species were comparatively described as being found on surveyed Barbados reefs "with intermediate frequency" (Vallès et al., 2015). While many parrotfish species do not actually feed on live coral tissue, an ecologically important subset of species actually do, although it should be noted that even these corallivorous parrotfish are primarily grazers and are only facultative rather than obligate corallivores. Of the 8 species of parrotfish found by Vallès et al. (2015) on surveyed Barbadian reefs, at least four of the species (*Scarus taeniopterus*, *Sparisoma aurofrenatum*, *S. vetula* and *Sp. viride*) are known to be corallivores (Rotjan and Lewis, 2006; Burkepile, et al. 2019).

The preeminent status afforded parrotfish by several researchers, primarily in the context of the group's role as keystone grazers, snowballed into a concerted conservationist's crusade to protect parrotfish populations. Specific conservation recommendations invariably range, usually exclusively, from reducing to totally banning fishing of the species group. This campaign has been successful whereby regulations including banning the fishing of parrotfishes have been instituted in a number of territories (Harms-Tuohy, 2021). Harms-Tuohy (*op. cit.*)

also notes that while recognizing the important ecological roles of parrotfish, the species group is "a critical resource for food security and income for thousands of coastal communities across the wider Caribbean region." As such "conservation and management must marry their concepts and agree on a solution". This well describes the objectives of this report, namely, based on a critical review of relevant scientific information, to recommend a management strategy that will best conserve parrotfish populations, notably in the context of holistic coral reef protection and rehabilitation, while mitigating the social and economic impacts, in particular, the more vulnerable participants in the local fisheries that depend on fishing reef species for their livelihood.

2. METHODS

This study involved a semi-systematic literature review of numerous academic publications primarily from on-line sources. A content analysis was then conducted as a method for identifying, analysing, and reporting patterns in the form of themes related to management strategies to protect parrotfish populations.

3. RESULTS

Available scientific evidence indicates that the structural complexity of coral reefs in the region has declined while macro-algae abundance has increased that has likely led to region-wide decreases in the abundance of extant reef fish populations (Vallès and Oxenford (2015). In the case of Barbados reefs, there is a marked difference in the apparent health of fringing reefs along the west coast and patch reefs along the south coast of the island, as well as for bank reefs. CERMES (2018) in a review of the results of surveys conducted at several index reefs along the west and south coasts of Barbados over the period 2007 through 2017, under the collaborative CZMU and UWI reef monitoring program, reported *inter alia* that there was a net decline in hard coral cover on west coast reefs, with the greatest losses primarily occurring during the period 2007 to 2012, and with little further decline, indeed with some insignificant recovery occurring on some reefs during the second half of the study period. In the case of the west coast fringing reefs, macroalgal cover significantly increased over the period 2007-2012 but then decreased from 2012 to 2017 while the cover of turf algae increased over the entire period of study (2007-2017). On the other hand, coral cover on south coast patch reefs increased slightly over the period while turf algal cover decreased especially during the first half of the study period, while macroalgal cover remained at a low level. The long-term coral mortality associated with a Caribbean-wide coral bleaching event that occurred during the summer of 2005 (Oxenford et al., 2008; 2010) is believed to have been a major contributor to the significant reduction in coral cover observed by 2012 reported by CERMES (*op. cit.).*

Nevertheless, the overall hard coral cover of the once luxuriant west coast reefs ranges from the relatively low level of 12% to the healthier level of 18% of benthic area, while south coast patch reefs supported slightly greater hard coral cover of between 15-20%, but this was augmented with a high density of soft corals that were virtually absent on the west coast fringing reefs. Based on the results of the 2017 reef surveys, the overall health of west coast coral reefs was adjudged as being fair while the health of the south coast reefs was viewed as good. On the other hand, the abundance of herbivorous fishes including parrotfish was adjudged in the coral reef report card as between poor and fair, never good, on west coast fringing and south coast patch reefs respectively while the state of commercial fish species was viewed as very poor on the reefs, except on bank reefs, along both coasts (Irvine et al., 2021). CERMES (2018) suggested that the continued recovery of hard corals on south coast patch reefs, observed during the period 2007-2017, despite the massive coral bleaching event of 2010 that badly impacted

west coast reefs (including bank reefs), may have been facilitated by the reduction of sewage pollution by the southwest coast sewerage system commissioned in 2003.

It is noteworthy that all of the environmental stress factors that can lead to coral death listed in the introduction to this paper have at some point been observed in Barbados. Of interest in this context is a study conducted by Tomascik and Sanders (1985) between 1981 and 1982, notably just before the 1983 mass mortality of *D. antillarum*, and thus without any confounding impacts on reef health due to the loss of these key grazers, as well as before the operationalization of the Barbados Marine Reserve (1982), in which the authors identified the existence of an environmental gradient resulting from increasing levels of eutrophication of coastal waters along the 14 reefs along the west coast that they surveyed. The growth rate of the important frame-work coral, *Orbicella annularis* (formerly *Montastrea annularis*) was highly correlated to several water quality variables measured along the environmental gradient. Of these water quality parameters suspended particulate matter (SPM) was found to have a great impact on coral growth whereby, up to a certain threshold level The SPM supplied energy and enhanced coral growth. However, SPM concentration above this level became deleterious to growth by smothering the corals while reducing light levels and zooxanthellae photosynthesis. This study indicates that environmental stressors, including eutrophication and sediment loading, associated with terrestrial run-off have, and miost likely to continue, to be major drivers of the degradation of the island's west coast reefs.

In addition, while the local *D. antillarum* population did recover somewhat over time, the abundance of these keystone grazers has never recovered to levels that are even close to those that existed before the disease and this has further negatively impacted on local reef health. Finally, in 1999 the bacteria *Steptococcus iniae* spread through Barbados, Trinidad and Tobago, Guyana, Grenada and St. Vincent and the Grenadines causing a mass mortality of a wide variety of reef fish including parrotfishes (Ferguson et. al., 2001). It should be noted that while the area of the mortality including all coasts except for the west coast of Barbados. However, given the influence of island-wide current patterns on larval transport and thus spatial recruitment patterns, it is possible that at least some parrotfish recruits on the west coast may be sourced from populations located in the areas that were known to be affected by the disease. In addition, it is believed that the pathogen may now be endemic in some fish populations and as such may continue to impact the recruitment of susceptible reef fish species all around the island.

The characterisation by Irvine et al. (2021) of commercial reef fish species in 2017 being very poor despite reef health being either fair or good implies that available reef habitat could support more abundant fish populations leaving overfishing as the more likely reason for the observed low abundance of commercially harvested fish stocks. As such there is no question that the biomass of reef fish stocks is currently lower than expected and as such fishing pressure should be limited to avoid disastrous stock collapses. Furthermore, the collapse of populations of keystone species, including parrotfishes, could result in serious destabilisation and even destruction of whole coral reef ecosystems. There is therefore a clear conservation imperative to restrict fishing pressure on demersal reef fishes particularly ensuring the sustainability of the reef's grazer guild. However, in the context of the parrotfish group, while the benefits of algal grazing to the coral reef ecosystem are clear, there is much on-going debate among scientists as to the relative negative vs. positive impacts of corallivory on reef ecosystem health, and therefore targeted preservation of corallivorous parrotfish species. This is especially in the case of already stressed reefs and those at risk of further deterioration due to climate change, where any additional reduction in live coral abundance may significantly negatively impact on the survival, let alone recovery, of the coral community.

Recent studies suggest that the importance of parrotfish in reducing fleshy algal biomass *per se* may be overestimated since parrotfishes are primarily microphagous, targeting cyanobacteria

and other microorganisms living on or within calcareous substrata and epiphytes on algae or seagrasses (Clements et al., 2017). Given that epiphytes tend to live on the distal and senescent portions of the fronds, rather than significantly reducing the macroalgal biomass overall, this feeding strategy would be akin to pruning the plant thus allowing the younger portions to flourish. As such herbivore diversity is of paramount importance for the overall control of algal biomass and thus the maintenance of healthy coral reef ecosystems (Bellwood et al. 2003, 2006; Burkepile and Hay 2008; 2011; Hoey and Bellwood 2009, Cheal et al. 2010; Nash et al., 2016). This is especially important in the context of the control of alien invasive algal species that only a limited number of grazers are likely to consume (Stamoulis et al., 2017).

In addition, a recent study showed that large scars in corals from parrotfish predation were unlikely to heal in the sense of live coral tissue completely covering the exposed calcareous surface before colonisation by algae (Rempel et al, 2020), and parrotfish bites may provide a vector for coral disease transmission as well as enriching rare and distinct bacterial taxa (Rotjan & Lewis 2008; Ezzat et al., 2020). Increased nutrient loads increase bacterial opportunism and mortality in corals bitten by parrotfish (Zanefield et al., 2016). Furthermore, the chronic impacts of corallivory can also reduce the resilience of coral colonies to acute disturbances like coral bleaching (Rotjan et al. 2006; 2022) and although corallivory was not likely to have been a significant source of coral morbidity or mortality in the past when coral cover is high, the reduction in coral abundance would focus predation on remaining colonies, making it a greater threat to the remaining coral population particularly when they are abundant corallivorous parrotfishes (Rotjan & Lewis 2008; Burkepile, 2012). Indeed Perry et al. (2014) expressed similar concerns suggesting that "while reef-conservation efforts have focused on fishery management as the solution to coral-reef degradation, the parrotfishes we have been protecting have been steadily destroying the reef structures that remain, and carbonate budget deficits on reefs are predicted to worsen as reef communities shift to slower-calcifying taxa". Similarly, Bruno et al. (2019) caution that "the protection of herbivorous fishes, especially parrotfishes, which is a focus of managed resilience, is not ecologically benign. In large numbers, some parrotfishes can consume corals, increase bioerosion, and reduce coral accretion rates".

This may be especially problematic in terms of the reef framework, as corallivorous parrotfish preferentially feed on some of the most important reef-building corals in the Caribbean such as the *Orbicella* spp. complex (Rotjan and Lewis, 2006). In the context of this information, it has even been suggested by some authors that greater benefits may redound to the ecosystem through protecting non-corallivorous species rather than protecting species such as the corallivorous subset of parrotfish (Rotjan and Lewis, 2008). Indeed, while proponents of selectively protecting corallivorous parrotfishes argue that concerns about this practise are largely unwarranted in the context of overall coral cover it is appreciated that constraints to declining populations of the *Orbicella* complex are possible (Mumby, 2009). Nevertheless, for fisheries that target reef fish species, selectively protecting parrotfish would result in fishing effort being shifted to other species, some of whose value in the context of the reef ecology may be underestimated (e.g., Bellwood et al., 2006), thus inadvertently creating another crisis.

Owing mainly to limited human resources and the fact that a substantial proportion of landings are made at several tertiary sites that are not routinely monitored, landings from the island's reef fisheries, including parrotfishes, are known to be underreported. However, various researchers of the University of the West Indies have conducted detailed surveys and assessments of the island's main coral reef fisheries and reports of this work are sources of useful information for this paper.

Based on interviews of a total of 150 small-scale fishers in four separate studies conducted over the period 2009 to 2013, Gill et al. (2019) determined that of the four legal fishing methods used in the local reef fish fishery (hook and line, seine net, fish pots and spearfishing) the largest proportion (65%) of reef fish landings was taken in the seine net fishery followed by spearfishing (22%) with fish pot landings accounting for only 10% and line fishing a trifling 3%. As also noted by Gill et al. (*op. cit*) although the reef fishery is considered as minor in comparison to the other extant commercial Barbadian fisheries it is still important to coastal livelihoods, food security and has economic value at the national level and these fisheries serve as important social safety nets for several persons otherwise seasonally employed in other fisheries and the tourism sector, as well as retired persons. The hook and line fishery and the fish pot fishery are of especial importance to the group elderly "retired" fishers. The hook and line fishery will not be discussed here as parrotfish are not taken. For the other three reef fisheries, parrotfishes are the single most popular and thus commercially important species group taken.

In a survey of the Barbados seine net fishery conducted in 2010, Maraj et al. (2011) reported that the fishery at the time comprised 6 nets operated by around 100 fishers most of them well educated ranging in ages from 40 to 50 years old. In addition to fishing for the primary target species (jacks) in the fishery all but one of the groups reportedly also engaged in fishing reef fish popularly known as "chubbing". Mean seasonal estimates of landings for a season (June to October) ranged from 78 to 257 mt worth between US$257,000 and 848,000 for the catches of jacks and from 9 to 22 mt of reef fishes with an ex-vessel value of between US $48,500 and $123,500). Simpson et al. (2014) estimated that in 2013 there were 110 persons who were actively involved in the local spearfishery. Of this number around half were engaged in the activity on a commercial basis with catches dominated by parrotfish.

In 2011, Schuhmann et al. (2011) estimated that there were between 125-150 direct participants in the Barbados fish pot fishery at the time. Based on a 2010 interview-based survey of a total of 47 participants in the fishery, the authors found that although most of the participants had other jobs and thus sources of income, the vast majority (over 91%) indicated that the largest portion of their income was derived from some form of fishing and of this number of fishers, 61% reported that trap fishing was their main fishing activity. Of the albeit smaller subset of fishers willing to respond to the more sensitive question of income (n=24), 61% identified trap fishing as providing more than 50% of their income. Indeed, the authors concluded that overall the fish pot fishery was more profitable than previously believed and although participants earned much less from the fishery than the average per capita income for the island, a significant portion of their earnings were derived from trap fishing. Although parrotfish do not rank as the most expensive of the types of fish taken in the traps, they still rank as one of the most important of the species groups taken, particularly in the context of proportion of the total catch.

4. DISCUSSION

It is imperative that fishing pressure on coral reefs be maintained at sustainable levels, including being reduced as necessary, to maintain or rehabilitate reef fish assemblages and by extension coral reef health. However, the information presented here does not support parrotfishes being conferred biased protection over other demersal reef fish species. To this end a holistic management policy, associated strategies and supporting legislation are required, which would redound to the conservation of all demersal reef fish species and the coral reef ecosystem as a whole, while allowing stringently managed sustainable fishing of these important resources. The policy and strategies must importantly consider and be sensitive to the real social and economic impacts on the fishing community. In this context the strategies adopted should be those that strike a balance and give the most "bang for the buck" i.e., maximizing the conservation benefits while minimizing negative impacts on the fishing community.

Furthermore, where fishing pressure has to be reduced, circumscribed fishing opportunities should be distributed as equitably as possible ensuring that those persons who most rely on the fishery for their livelihoods and the more vulnerable participants are adequately accommodated. This includes developing strategies to mitigate the socioeconomic burden that will be imposed by the reduced catches of reef fish species including parrotfishes. In keeping with these criteria, the following holistic strategy was adopted and is supported through legislation initially in the form of the 2023 Fisheries Management Regulations that should be in force shortly.

Given the relatively small contribution of the demersal fish catch (7%) to the total revenue from seine net fishing, after consultation with the fishery stakeholders, it was agreed to prohibit "chubbing", the local name for fishing seine nets over reefs to harvest demersal reef fish including parrotfishes (chubs). This action immediately significantly reduces fishing pressure on all demersal reef fish stocks. In addition, it should be noted that at present only 4 seine nets are in use compared to 6 reported in 2010, Maraj et al. (2011). As such fishing pressure from this fishery on demersal fish stocks has already significantly decreased over this period.

Effective regulation of this fishery is currently practically impossible as the Fisheries Division has no records of who are involved or the nature of their involvement (commercial or recreational) in this fishery. In this context, the first regulatory step included is to mandate by law that persons need a license from the Fisheries Division to spearfish. In this context, two types of licenses, a commercial and a recreational license would be offered. Specific conditions will be attached to retaining both licenses, including the mandatory keeping of catch and effort records that must be systematically submitted to the Fisheries Division. In the case of the commercial license, fishers must land and have recorded a significant portion of their catches at either monitored landing sites or present sales receipts recording the species and quantities sold outside of the traditional market stream. Failure to do this will result in revocation of the license. Persons having a recreational fisher license will be prohibited from selling any portion of their catch. With no financial incentive it is unlikely that recreational fishers would seek to acquire large catches. While there is little that can realistically be done to compel participants in this fishery to submit all catch data, especially the recreational fishers, follow up enquiries aimed at monitoring activities in the fishery will be made once those involved are known via the registration/licensing system. This strategy will facilitate quantification of catches and lead to a better understanding of the fishery in general.

The mandatory licensing regime could be used to effectively reduce fishing effort through restricting the number of licenses, especially commercial, issued. It is recommended to initially grandfather all existing commercial spearfishers into the system and, based on the numbers, determine the need for capping participation at current levels or allowing limited entry in the future. The second option is complemental, whereby commercial fishers are allowed to sell a fixed quantity of reef fish i.e., setting a "bag limit" for sensitive species (e.g., parrotfish) while still mitigating the overall economic losses to commercial fishers. This would likely transfer increased fishing pressure to other species. However this can have its conservation benefits specifically where fishing effort is directed to the invasive lionfish (*Pterois volitans*) thus assisting in the control of the population of this voracious predator of several reef fish species including juvenile parrotfish (Green et al., 2011, Morris and Akins, 2009). Indeed, this has already been occurring in the fishery as lionfish now constitute the second most important fish group taken by local spearfishers, which in turn has effectively reduced fishing pressure on other reef fish groups, including parrotfishes (Vallès, et al., 2023). In this context, while there is already an established market for lionfish on the island, the market price of lionfish is only slightly greater than that of parrotfish. A widening of this price margin, such that it was significantly more profitable to catch lionfish, would be a big incentive for fishers to target these fish even more. Noting that some hotel and restaurant chains in the region are supporting the