Marine Management Organisation | Centre for Environment Fisheries & Aquaculture Science

Funded by UK Government

St Helena – Grouper (*Epinephelus adscenionis*)

CR071: Fisheries Advice - Management and Research Strategy

Blue Belt Programme

Date 31/07/2020

Report Reference CR071

Author(s): A. Riley, J. Ball, B. Cowburn, S. Wright

Document Control

Submitted to:	St Helena Government and Foreign and Commonwealth Office
Date submitted:	31/07/2020
Project lead:	PI: Chris Darby, Tammy Stamford PM: Victoria Young
Report compiled by:	A. Riley, J. Ball, B. Cowburn, S. Wright
Quality control by:	Tammy Stamford
Approved by and date:	Chris Darby 31/07/2020
Version:	1.8

Version Control History			
Author	Date	Comment	Version
A Riley	11/12/2019	Write draft	0.1
L Readdy	19/03/2020	Technical review	0.5
A Riley, S Wright	23/03/2020	Address comments	0.6
C Darby	04/05/2020	Comments	0.7
S Wright, A Riley	11/05/2020	Revisions made	0.8
C Darby	08/07/2020	Review	0.9
A Riley, S Wright	13/07/2020	Address comments, Final Draft	1.3
T Stamford	20/07/2020	QC	1.3
A Riley	20/07/2020	Address comments	1.4
T Stamford	30/07/2020	Final QC	1.6
C Darby	31/07/2020	Sign off	1.8

Executive Summary

Grouper (*Epinephelus adscensionis*) are one of the main demersal fish species exploited locally around St Helena Island. Since, the entirety of the St Helena EEZ was designated as an IUCN Category VI MPA in 2016, the MPA has been managed under the Marine Management Plan which has objectives to "sustainably manage marine resources, including fisheries", with "minimum impact on species abundance, diversity and habitats". Therefore, the principle aim of this report is to provide advice on sustainable fisheries strategies and management recommendations, as part of a fisheries management plan for the St Helena grouper fishery. Data and information have been drawn from:

1. Historical data and previous research (such as landings data, Underwater Visual Surveys and anecdotal information on grouper biology and ecology);
2. Data collected within St Helena's EEZ, under the current Blue Belt Programme and other local initiatives (including biological, fisheries, catch and tagging data).

Advice and recommendations for the grouper fishery within St Helena's EEZ are as follows:

- The grouper stock is considered to be sustainably fished.
- Although, historic total annual catches are considered to have been sustainable, it is recommended that any expansion to the current fishery is implemented gradually as a precautionary feedback management process, that includes observer monitoring and comprehensive data collection.
- Collection of additional data, particularly from logbooks, is recommended, such that more detailed analyses can be used to provide advice on development of a long-term management plan.
    - Logbooks can be used to record daily catch and effort data (including zero-catch days) to improve LPUE estimates.
    - Continuation of existing sampling and collection of new biological samples is recommended to inform future stock analyses.
    - Continuation of tagging studies to support analysis of growth, movement and assessment of biomass.
    - Continuation of underwater visual surveys (UVS) and benthic habitat and substrate mapping studies to identify grouper habitat. This could provide an approach to estimate stock abundance.
- To provide further information on rock fishing, it is recommended, in line with SHG (2013) recommendations, that a rock fishing survey, similar to the SHG (2013) survey, be conducted at regular, i.e. three or five-yearly, intervals, these could include a sample of fisher logged catch and effort data, which together with the survey data could be used to monitor fishing activity trends and catches. Additionally, future surveys could be expanded

to include fishers using boats to access rock fishing sites and to include other areas such as the rocks at West Rocks, the Wharf and Rupert's Bay and other easily accessible sites on the leeward side of the island.

- Analysis from underwater visual surveys (UVS) has provided abundance estimations and these show an increase in grouper abundance in the EEZ since 2013, which is also demonstrated by the landings per unit effort data. The continuation of regular surveying is recommended.
- Further research could include:
    - The use of reference non-fished areas is suggested to monitor the abundance response and to contrast with adjacent fished areas.
    - Repetition of Choat and Robertson's (2008) study conducted in 2006 to assess whether there has been a change in life history traits since the original survey.

Contents

1. Objectives

The Blue Belt Programme supports the delivery of the UK Government's commitment to enhance marine protection of over 4 million km^2 of marine environment across UK Overseas Territories (UKOTs). The programme currently includes the Pitcairn Islands, British Indian Ocean Territory, British Antarctic Territory, South Georgia and the South Sandwich Islands, and the Territory of Ascension, St Helena and Tristan da Cunha. The programme aims to assist and support the UKOTs with the protection of their marine environment and sustainable management of their marine resources and human activities.

This report has been produced as part of the Blue Belt Overseas Territory Work Plan for St Helena, which, among other tasks, aims to provide advice on sustainable fisheries strategies and management recommendations, as part of a fisheries management plan for the St Helena grouper (also known as Jack, rock hind) (*Epinephelus adscensionis*) fishery. Through a scoping and review study, and consultation with St Helena government and stakeholders, the information from the fishery has been collated and catch data and information on grouper biology and ecology are considered in relation to indicators of sustainability.

2. Introduction

In 2016, St Helena's waters were designated an IUCN Category VI sustainable use MPA (SHG, 2016a), and in line with this designation, local fisheries only operate the following gears: pole and line, hand line, rod and line and small drop nets. These methods help to minimise environmental and marine species impacts within the St Helena EEZ [EEZ spatially overlaps the MPA (Figure 1); Blue Belt, 2019a].

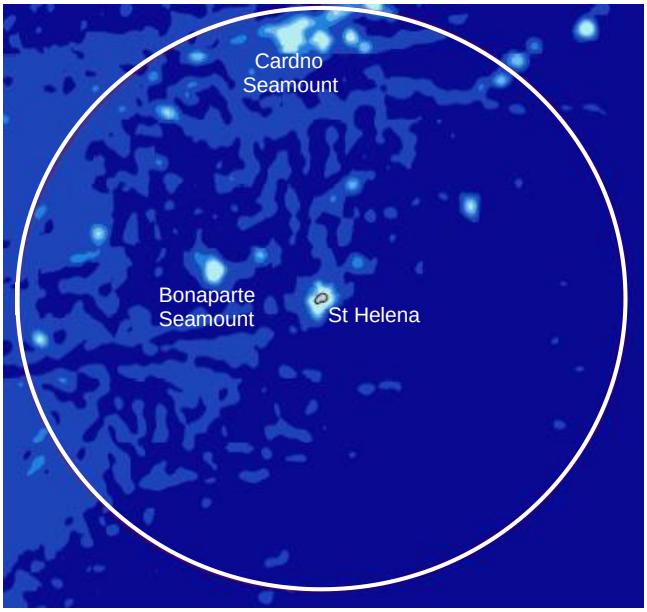

Figure 1. St Helena Island and Exclusive Economic Zone (EEZ) and MPA, (both 200 nm radius, white circle) and Bonaparte Seamount and Cardno Seamount fishing grounds within the EEZ.

2.1. Species distribution

Grouper are found in tropical and subtropical water from the south-west of Europe to South Africa (Froese and Pauly, 2018), extending to both sides of the Atlantic from Brazil to the USA in the Western Atlantic, and around St Helena, Ascension and São Tomé in the Eastern Atlantic (Figure 2).

Within St Helena's EEZ, the shallow shelf around St Helena island drops to 200 m depth within about 2 km of the shore on the leeward side of the Island but extends out about 6 km off the southern tip (Speery Ledge), before plunging thousands of metres into the ocean depths (Edwards, 1990; Figure 3). The total area of seabed available for shallow water marine life to colonise (here considered at less than 200 m deep) is around 156 km^2 (Edwards, 1990).

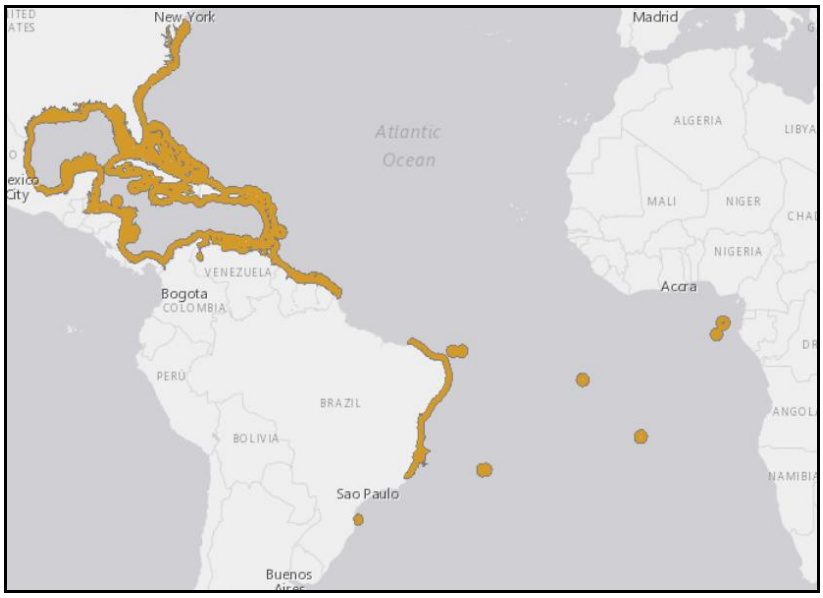

Figure 2. Distribution map of E. adscensionis within the tropical Atlantic. Reproduced from IUCN Red List.

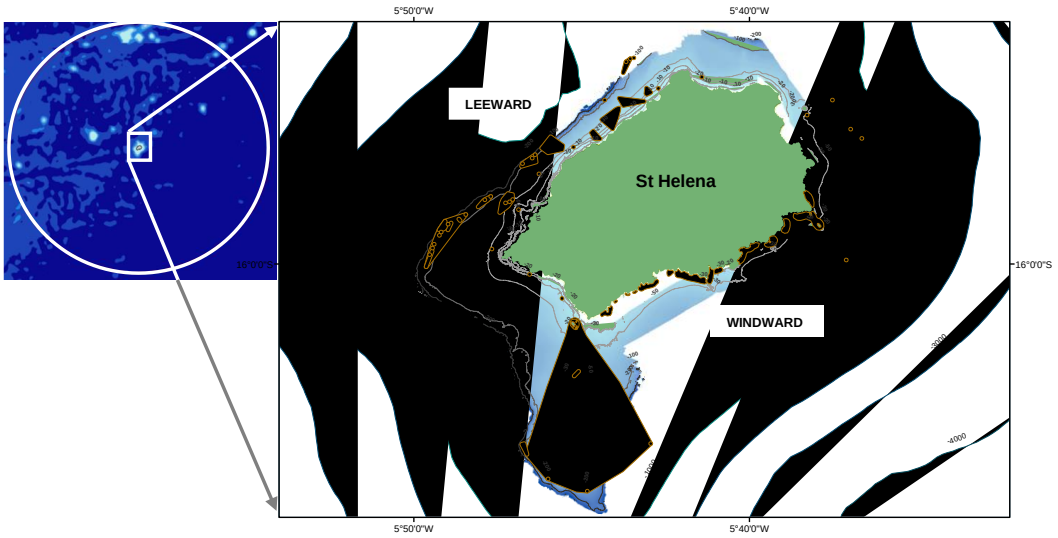

Figure 3. Fishing grounds (in brown) around St Helena Island. Positions are approximate and contours are in metres (Source: SHG). Inset: St Helena's Exclusive Economic Zone (EEZ) and MPA, both delineated by white circle.

2.2. Habitat and life history

E. adscensionis is a grouper from the subfamily Epinephelinae (family: Serranidae), which contains 163 species from 16 genera (Sadovy *et al*., 2013). It is one of 88 species, belonging to the genus *Epinephelus*, found globally, and one of the 12 species found in the Atlantic. Current understanding is that it is the only grouper species recorded in St Helena waters, whereas in other parts of its range, it is found in multi-species assemblages. To date, there have been no stock assessments specific to *E. adscensionis*.

E adscensionis are a demersal species found on rocky solid-substrate habitats in shallow waters; they are common in 2 m to 50 m and regularly caught in depths between 30 and 50 m.

Newly metamorphized juveniles of *Epinephelus* groupers tend to recruit to inshore sites such as mangroves, shallow bays and rockpools, whereas the largest individuals are found in the deeper water (Artero *et al*., 2015; Choat and Robertson, 2008; Lindeman *et al*., 2000; Marques and Ferreira, 2017). However, despite this general movement to deeper water with age, grouper populations tend to be well mixed with representatives of different size classes in most habitat zones (Choat and Robertson, 2008; Condini *et al*., 2015; John, 1999).

With a maximum length of 61 cm and average length of 35 cm, the St Helena grouper is a medium-sized species when compared to other *Epinephelus* spp*.,* which range in maximum length from 13-270 cm (Froese and Pauly, 2018).

Grouper species are benthic predators, targeting a wide range of prey including invertebrates such as molluscs, worms and brittle stars, but mostly their diet consists of crustaceans and fish (Gibran, 2007; John, 1999; Meyer and Dierking, 2011; Marques and Ferreira, 2017 Pinheiro *et al*., 2011; Heemstra and Randall, 1993). Studies of other grouper species show a continuum of feeding behaviours from patrolling a wide home range searching for prey to sit-and-wait ambush hunting (Gibran, 2007). All grouper feeding is diurnal, and some species are particularly active at twilight (Clua *et al*., 2015; Gibran, 2007).

3. Description of the St Helena grouper fishery

3.1. Commercial fishery

Grouper have been exploited around St Helena since the earliest human settlement and are one of the main demersal fish species landed, providing 50-70% of the catch in the last 5 years (which comprises almost 5% of the island's total annual catch). An average of approximately 9 tonnes per year of grouper has been landed over the last five years (2015-2019[1]), although,

[1] Note: data for 2019 are incomplete.

the annual landings varied between 0.35 tonnes in 2015 and nearly 19 tonnes landed in 2018[2]. Grouper are also caught from the island's shoreline through the recreational fishery known as 'rock fishing'.

Grouper are only caught inshore within St Helena's EEZ and are not thought to be found at the other key fishing grounds within the EEZ, specifically Bonaparte and Cardno seamounts. This is because the seamounts are probably too deep for the species life cycle. Historically, grouper formed about 90% of the local inshore fishery landings recorded as 'groundfish' or demersal fish (Edwards and Glass, 1987) and was a substantial component of the local fisheries, constituting almost 4% of the islands total annual fish catch. There were few large individuals (>50 cm) observed in shallow water (<20 m depth), but examples over 50 cm were often caught by fishermen in deeper water (Edwards and Glass, 1987).

In the early eighties, about 12.5 tonnes were landed annually. Since 1988, a commercial fishery catch limit of 36 tonnes per year has been applied. From unsubstantiated records the quota was exceeded in 1994, 1996 and 1997. However, landings were high in 1998, when records started, where 60 tonnes were caught, and in 2007 when 40 tonnes were caught; catches have since been lower (Figure 4). The average catch between 1980-1989 was just over 18 tonnes which doubled to nearly 36 tonnes between 1990-1999, but since then has halved with each decade from nearly 17 tonnes between 2000 and 2009 to just over 8 tonnes during the period 2010-2019 (Figure 4).

The inshore fishery currently involves six full-time fishing vessels (<10 m in length), which fish in total more than 150 days per year mainly on the leeward, north-northwest, side of the island (Figure 3). When the sea is calm and there is commercial demand, fishing vessels will fish the less accessible windward grounds on the south eastern side of the island. There the average size of groundfish species is generally greater and catch rates higher, due to the lower annual effort and catch removals (exploitation rate) (Edwards, 1990).

3.2. Grouper landings data

The number of vessels and fishing effort (in days) targeting grouper was estimated from the grouper landings data. A single day's fishing effort was assigned if grouper were landed by the vessel at the cold store. Estimates of fishing effort and catch are therefore likely to be an underestimate, as neither grouper landed outside the cold store, nor days when grouper were targeted but not caught, are included. Anecdotally, the cold store catch is considered to represent the majority of the landed catch and therefore the underestimation bias is considered to be low.

Between 1998 and 2015, there has been a declining trend in the number of days fished and the number of vessels targeting grouper, with a slight increase since 2016 to present day (Figure 4). Landings per unit effort (LPUE) were estimated from the number of days fished and the recorded quantity of grouper landed per vessel per year. Time series of LPUE provide

[2] Figures have been sourced from St Helena Government (SHG) Fisheries database - extracted January 2020; the total for 2019 is incomplete.

an index of changes in local biomass. Monitoring LPUE trends allows the impact of the fishery on the local resource to be evaluated, while more detailed assessment processes are developed.

The rationale behind LPUE analysis is that as the amount of effort exerted and catch increase, the removals from the local biomass will reach a rate at which a resource is fully exploited, known as the maximum sustainable yield (MSY). This refers to the highest catches that the local biomass can sustain in the long-term. Increases in catch (above MSY) cannot be supported over the long term by the local biomass and replacement by annual immigration/recruitment, and result in overfishing (over-exploitation). Monitoring LPUE rates as catches are increased provides an approximation of the region of sustainability, where catch levels are supported by the local biomass productivity.

The LPUE time series for the St Helena Grouper (Figure 4) exhibits variation around a relatively stable mean level. The average LPUE between 1998 and 2019 has been 98 kg (minimum = 3 kg and maximum 346 kg).

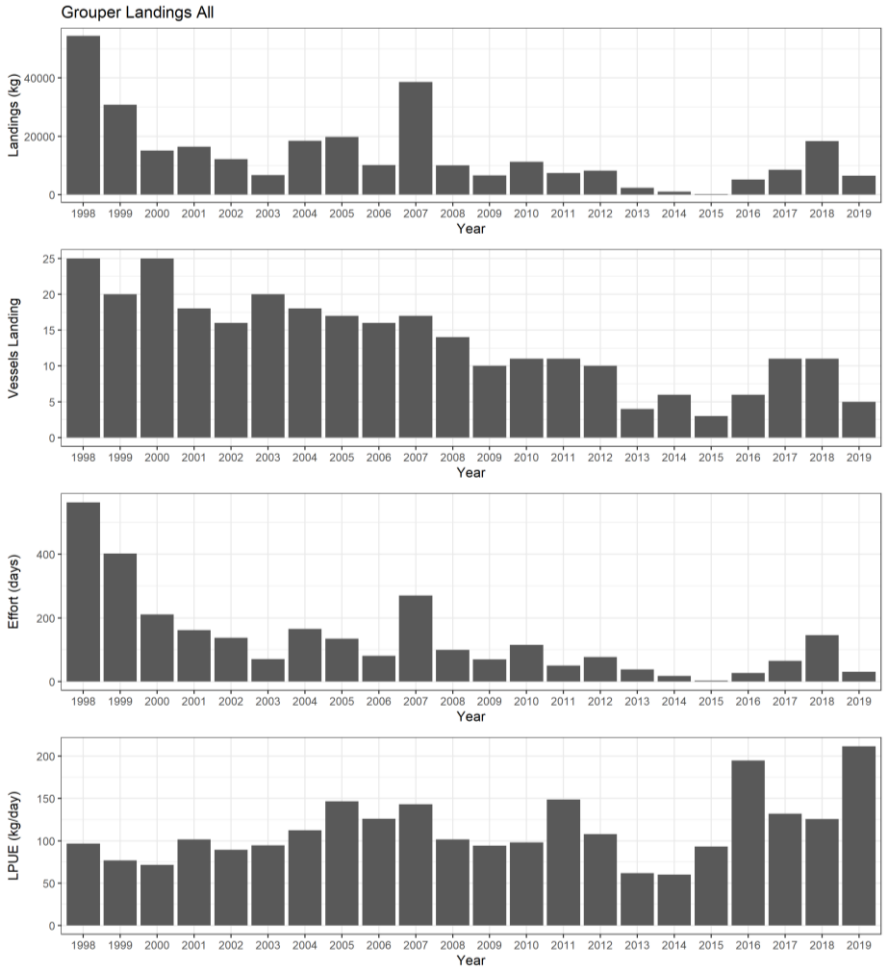

Figure 4. Historic catch of grouper, including landings of grouper, number of vessels fishing for grouper, effort in days fished and landings per unit effort (LPUE). (Note: catch for 2019 is incomplete).

The annual change in LPUE between 1998 and 2019 was assessed for individual vessels using a linear mixed effects model where the boat ID and number of crew were incorporated

as random effects. Between 1998 and 2019, LPUE has remained relatively stable, showing a small increase through time (AIC=319.95, P's for intercept = 0.1, slope =0.054, Figure 5). This is an indication that the historic effort exerted, and catch taken, by the fishery throughout the years for which data are available, do not appear to have reduced the local biomass of grouper. Some variation across time is recorded but that is likely to be a result of natural variation in the data and also spatial changes in the position of the fishery which have not been included in the analysis.

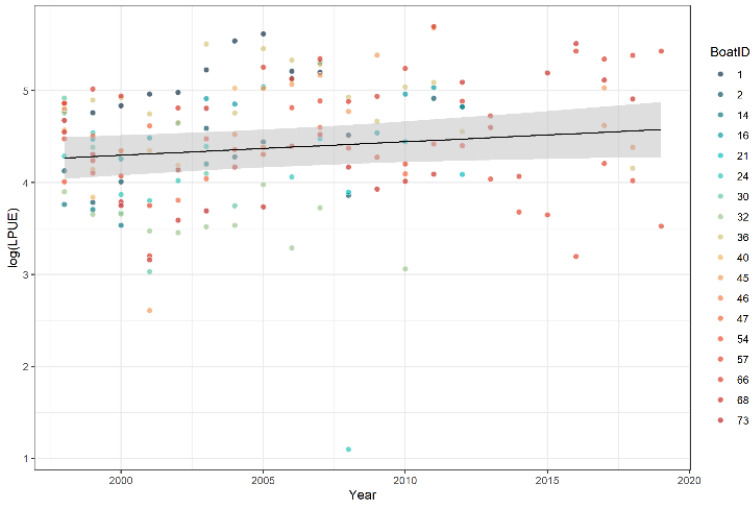

Figure 5. Landings per unit effort (LPUE) of grouper in relation to year of landing. (Note: catch for 2019 is incomplete).

Figure 6 illustrates the relationship between landings and effort by the grouper fishery. Landings of grouper have increased linearly with the effort deployed. There is no point at which grouper landings have started to plateau or decline at the highest effort levels. This indicates that, overall, the grouper biomass productivity has been able to sustain the historic catches recorded since 1998 (Figure 6), although the caveats on catch and effort recording apply.

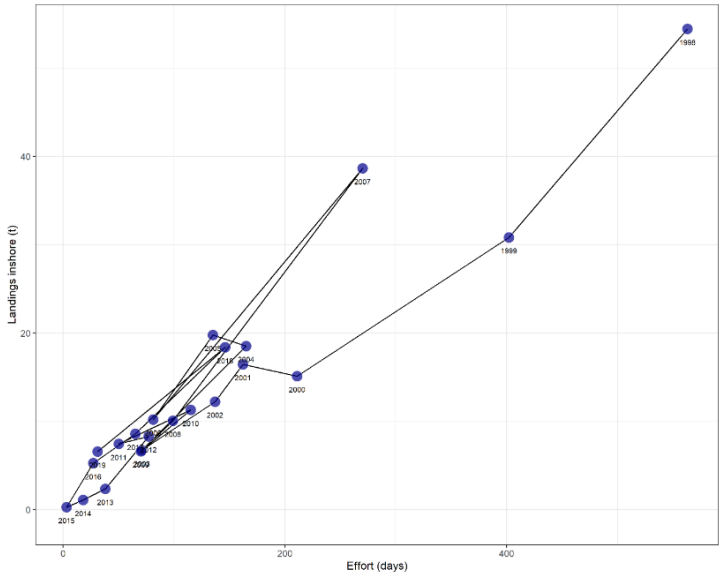

Figure 6. Historic catch of grouper, including landings of grouper, number of vessels fishing for grouper, effort in days fished and landings per unit effort (LPUE). (Note: catch for 2019 is incomplete).

3.3. Seasonal variability in landings

St Helena's main fishery targets primarily tuna species and other large pelagic species. The grouper fishery operates throughout the year but tends to be fished when tuna and other large pelagic species, are scarce (Edwards, 1990; source SHG). This trend is depicted when monthly landings of grouper are compared with landings of tuna (YFT (yellowfin), BET (bigeye), SKJ (skipjack), ALB (albacore)) by the inshore fleet (Figure 7).

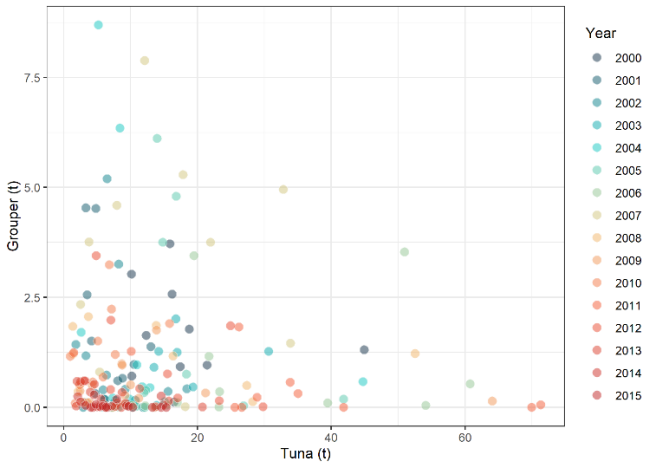

Figure 7. Monthly landings of tuna species inshore (skipjack, yellowfin, albacore and bigeye tuna) in relation to landings of grouper (E. adscensionis) in the same month.

Consequently, any seasonality in the grouper fishery can be masked by tuna availability (Figure 7), which can vary with season and between years. However, it has been noted by fishers that grouper are difficult to catch in winter months (SHG pers. Comm.), and lower catches are reported mainly between November and April; this may be a factor of spawning, which is thought to occur in the winter months (Edwards, 1990; source SHG). So there appears to be some consistent seasonality to grouper availability, with peak landings usually between May and October (Figure 8 and Figure 9).

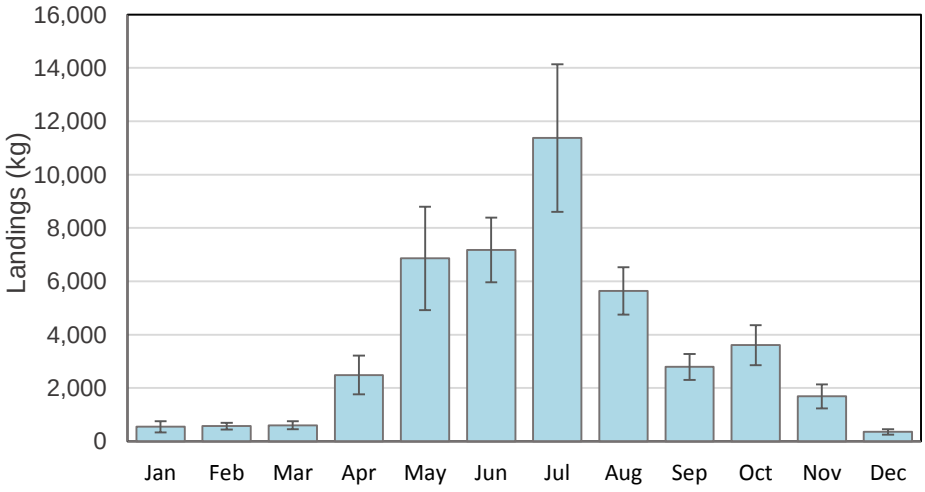

Figure 8. Average seasonal (monthly) landings of grouper 2015-2019.

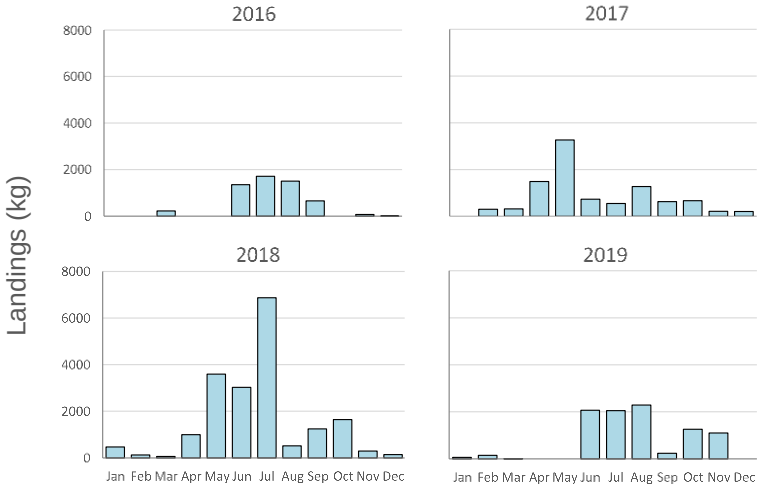

Figure 9. Annual landings by month 2016-2019 (Note: landings are incomplete for 2019).

3.4. Rock fishing

The tradition of rock fishing has taken place for 100's of years; the skills and locations have been passed down from generation to generation. Rock fishing usually involves a steep climb down cliffs to ledges from which fishing takes place. The activity can be hazardous, and the practice requires experience in climbing and a good local knowledge of the terrain. Rock fishing is now largely pursued for recreational fishing.

The extent of rock fishing exploitation on St Helena's grouper stock is not possible to estimate due to a lack of information on catch and fishing effort. However, a survey of 37 known rock fishers was conducted by St Helena Environmental Management Division (source: SHG), between 2012 to 2013. Historical observations relevant to grouper and rock fishing activity made by fishermen include:

- Catch of grouper is less at certain times of the year, but time of year was not specified.
- When fishermen gut and/or fillet their fish in a fishing area or throwaway leftover bait, this encourages other fish into the area to feed on the waste.
- Fishing paths have eroded.
- Grouper increased in 2011 compared to the three to four years previously. An interesting comment as there were mass deaths of grouper all around the Island in 2008, but the cause was not determined.
- High tide is better for fishing. The amount of moonlight affects fishing success.
- Historically there were so many people fishing that you would have to leave home early if you wanted to be the first person to fish at a particular site.
- Fish are smaller on the leeward side than on the windward side of the Island (which boats cannot readily access).

- Hook size is important when fishing for grouper.

When questioned on the future of rock fishing on St Helena, a high proportion (97%) of the fishermen surveyed had observed that fewer people were currently fishing. This was attributed to a number of reasons:

- It is more convenient to buy fish from the fish van. There is usually a variety of fish to choose from and fish are normally headed and gutted (so less preparation is required before cooking).
- People who previously fished from the rocks have aged and cannot walk the long distances to fish anymore; they have either stopped fishing or now fish from a boat.
- Most fishermen feel younger generations are not interested in fishing because it requires a long walk. Some fishermen also feel that the younger generations have other, less active, interests.
- Historically family sizes were larger and there was less disposable income, so people needed to fish either for income or for food. Now, families are generally smaller, and incomes have increased, therefore the need to rock fish is not as great as it would have been historically. Additionally, many people and families have left St Helena, so there are fewer people in a household or a district to fish.
- Some fishermen feel that a lot of the fishing paths have deteriorated or are deteriorating quite badly and as a result some sites have become or are becoming inaccessible.

Recommendations based on the results of the St Helena Environmental Management Division rock fishing survey are:

- An updated survey be conducted to ascertain if any of the current trends are changing, for example, different fishing gear or techniques, numbers of fishers.
- Surveys are conducted regularly, for example every five years, unless rock fishing is considered to be declining and catches, relatively low.
- The survey could be expanded to include boat access to rock fishing sites.
- The survey could include people who fish from the rocks at West Rocks, the Wharf and Rupert's Bay and other easily accessible sites on the leeward side of the island, as most fishermen interviewed concentrated their fishing efforts on the windward and south-western side of the island.
- A sample of fishers could be asked to log catch and effort over a year or another suitable time frame.

4. Abundance and biomass assessment

An estimation of grouper abundance was evaluated using underwater visual surveys (UVS), initiated to monitor inshore species as part of the Darwin Initiative study in 2013 (Brown, 2014), and conducted between 2013-2019 (source: SHG). Two observers count species present in 50 x 5 m (250 m^2) belt transects at survey sites, predominantly down to 24 m depth, around the island.

Grouper were seen in higher abundance in surveys with rock and boulder substrate (up to 2.8 individuals per 100m^2), on the windward side of the island (greater exposure to waves) and during the summer. It was a relatively wide-spread species present at all (100%) sites and recorded in the majority (64%) of surveys (Figure 10). The average density across all sites, was 1-2 individuals per 100 m^2. From the seasons available, an increase in abundance is observed from 2015 – 2018 (Figure 11).

It is recommended that regular UVS surveys continue to support the data analysis required for abundance and biomass trend estimation. There also needs to be consideration of how survey limitations, e.g. survey to depths of ≤24 m only, influence the resulting dataset and assessment outputs.

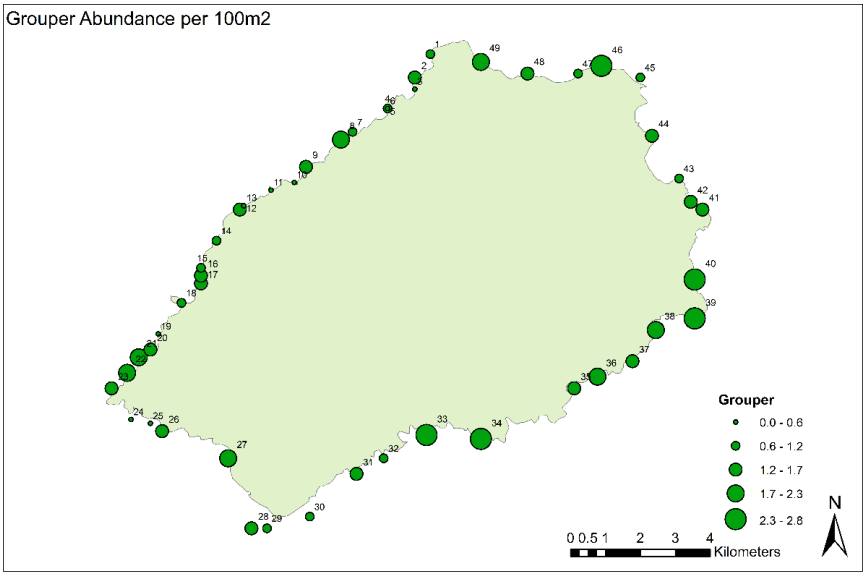

Figure 10. Grouper abundance per 100 m^2 from an underwater visual census (diving) survey observations carried out between 2013 and 2019.

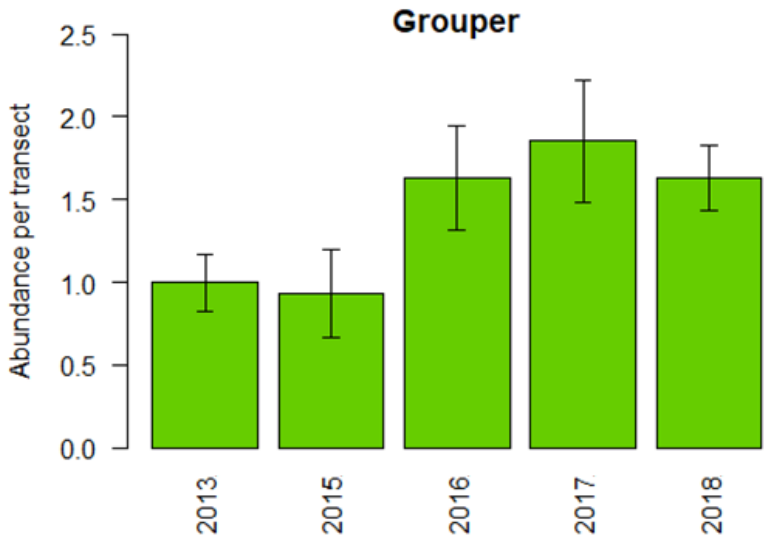

Figure 11. Grouper abundance per transect from UVC survey 2013-2018.

5. Tagging

Conventional tagging of grouper began in 2016 and, with the exception of 2017, has continued and is ongoing. Table 1 provides a summary of releases and recaptures by year. Figure 12 presents the release locations of grouper and Figure 13 presents known recovery locations. The numbers of tags released in 2018 and 2019 are starting to produce the recoveries needed for analysis of growth, movement and assessment of biomass. Consequently, this level of tagging is encouraged for future years while the approach is evaluated.

Table 1. Tag release, recaptures and recapture rate of St Helena grouper.

Year	Released (n)	Recapture				Recovered (n)	Tagging recovery rate %
		2016	2017	2018	2019		
2016	9	0	1	0	0	1	11
2017	0	0	0	0	0	0	0
2018	615	0	0	17	21	38	6
2019	475	0	0	0	7	7	2
Total	**1099**	**0**	**1**	**17**	**28**	**46**	**4**

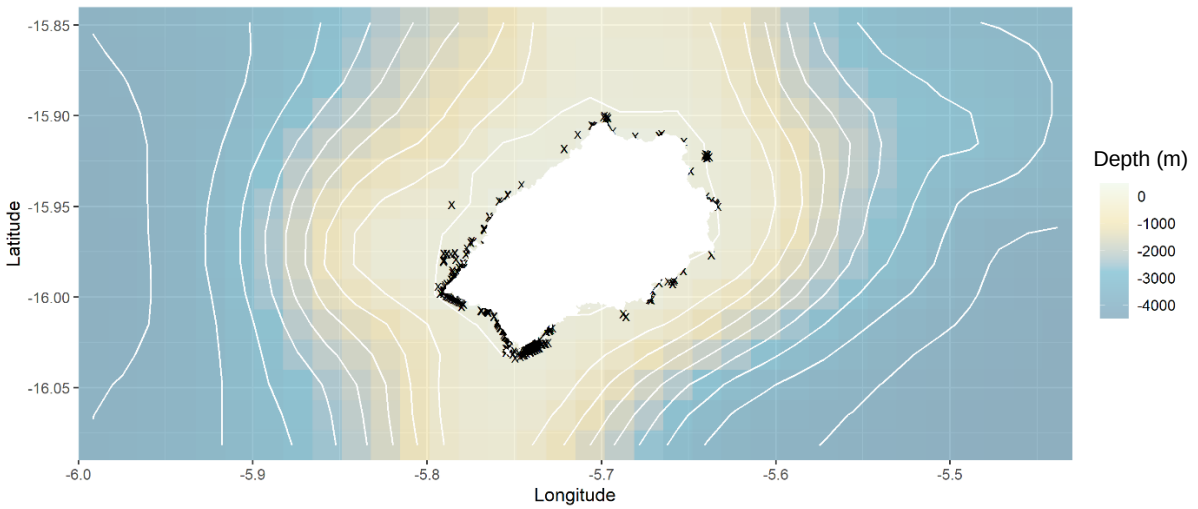

Figure 12. Tag releases of St Helena grouper from 2016 to 2019. (Note: no tagged fish were released in 2017) (Source: SHG).

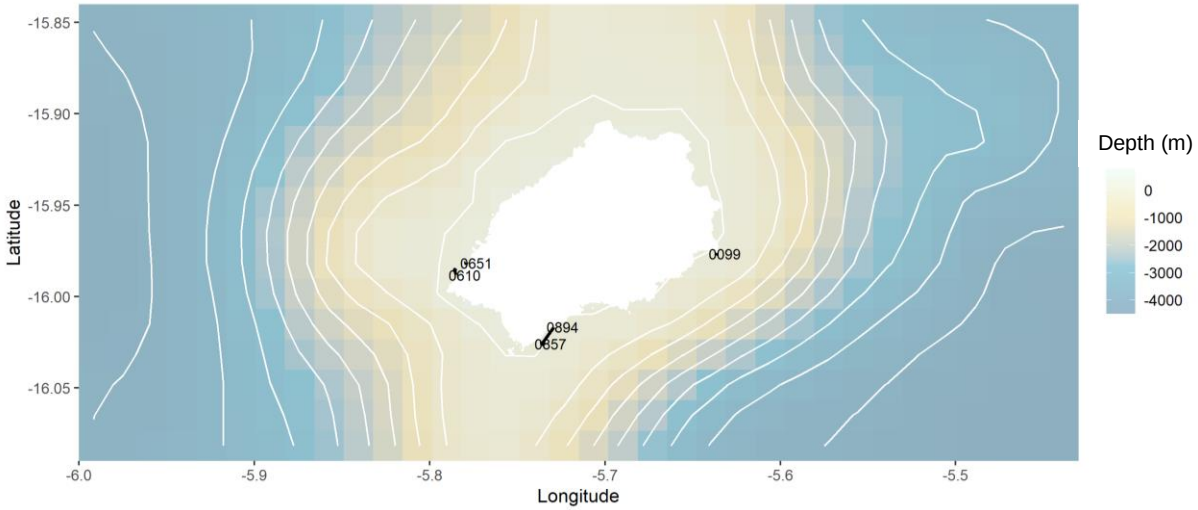

Figure 13. Tag recaptures of St Helena grouper from 2016 to 2019 (TagID no. indicated in figure). (Note: Only 5 tags were returned with catch location. No tagged fish were released or recaptured in 2017) (Source: SHG).

Conventional tag recovery is reliant on the fishery catching tagged fish and returning fish capture location and biological measurements (length, weight, otoliths, health condition). Tag recovery rates for St Helena grouper range from 2% to 11%, with an average of 4%. Apart from a low exploitation rate of the stock, which the rates of return imply, a number of factors could contribute to low tag recovery rates in the landed fish. These factors are listed below, alongside suggestions to ensure reliable estimates of the rate of tag recovery:

i. Non-return of tag from fishery – Improved communication and education of benefits.

ii. Potential tags lost following release (tag retention) – Double tagging is carried out and is designed to provide the information required to evaluate this.

iii. Tagged fish are moving to non-fished areas – Survey of grouper around island in fished and non-fished areas. From the majority of tag returns so far, fish have remained close to their release areas (Figure 14).

iv. Mortality from fishing and tagging procedures – Ensure consistent tagging procedures are carried out on healthy fish and conduct experimental studies.

Tagging can provide the distance between release and recapture and does not provide any information about fish movements in between the events. From five tag recoveries (Figure 14), the longest time at liberty was over 500 days with an overall movement of <200 m. In contrast, the longest distance moved was over 1,200 m, covered by a fish over the shortest time at liberty, <15 days. Two tag recoveries indicated no or little movement. The majority of fish observed have not discernibly moved, which would indicate that point (iii), above, may not be a factor in the low tag recovery rates.

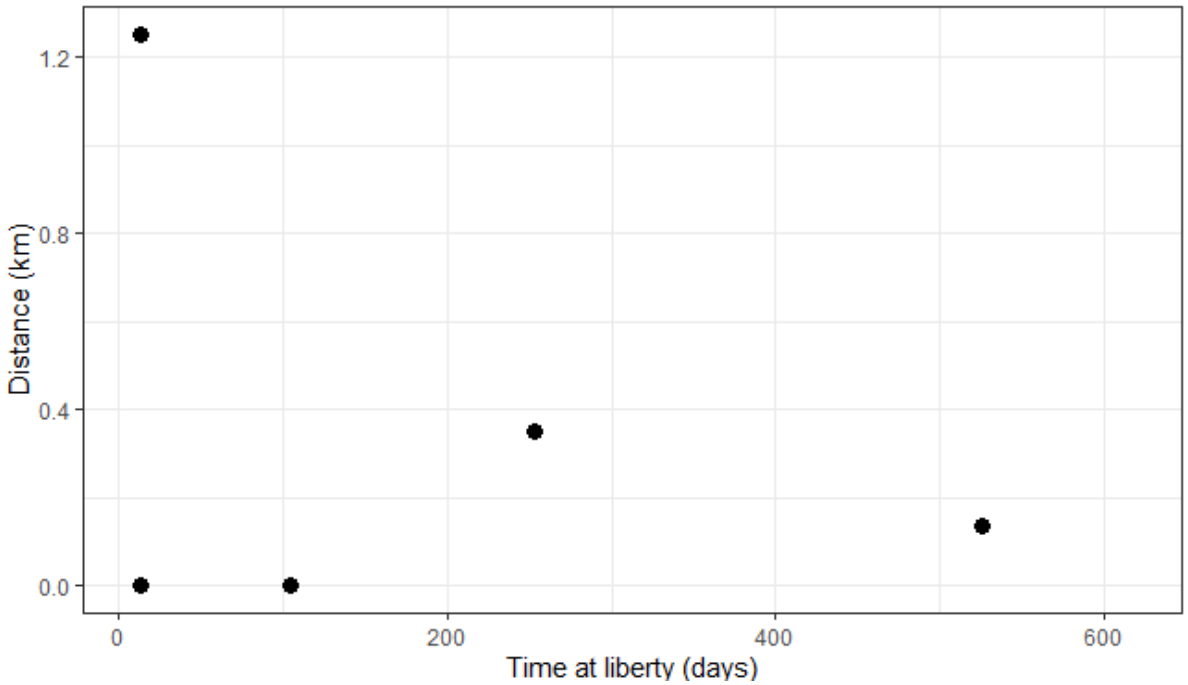

Figure 14. Time at liberty from 5 tag recoveries and distance form release location.

Growth rates were estimated from the 29 tagged grouper which have been recovered (with a length recorded) to date. Their average growth rate is 6.64 cm per year; further recoveries are required to assess how growth rates change with size.

Based on the total weight (proportional to number) of the fish with tags that were reported at the cold store, compared to individuals recovered without tags (Figure 15), a low population exploitation rate would be expected. However, this is caveated by the tagging uncertainties discussed previously.

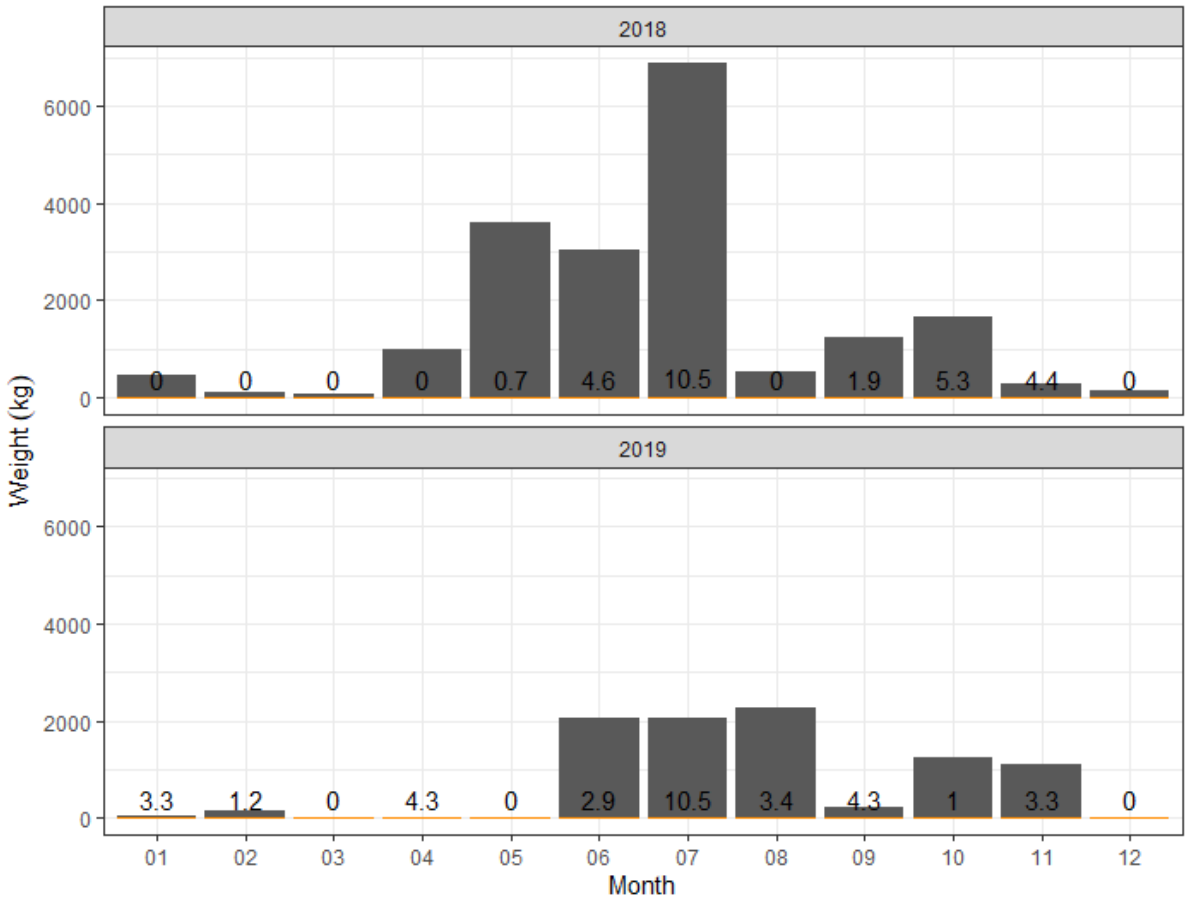

Figure 15. Weight of grouper landed at the cold store (grey) compared to weight of grouper landed with tags (orange) and reported kg of tagged fish for each month (displayed over each bar).

Further investigation into tagging and recovery procedure is necessary to enable advice on the application of improved practices. The main benefits of improved recovery rates would be the potential for local biomass estimation i.e. by using the Chapman assessment method (CCAMLR, 2014; Blue Belt, 2020), however, this approach will need to be tailored to take into account the limited dispersal. Tagging conducted across all fishing grounds routinely, with tags dispersing into the population over time will reduce the uncertainty of estimated trends in local biomass and the impact of the fishery.

The low or lack of dispersal away from the tagging locations indicates a potential for local depletion. Commercial fishing tends to occur where catch rates are optimum and when the catches have reduced the local numbers to below a worthwhile catch per unit effort, or targeted size distribution, the vessels move to fresh areas. Limited movement of fish from surrounding areas, into an area that has been fished will result in slower recovery after fishing. Logbooks collating effort and total catch would enable collection of information on the rate of removals, depletion and potentially recovery after fishing events.

At the same time, the relatively limited dispersal of tagged fish also indicates that spatial management of grouper using closed areas is likely to be effective, as fish will be unlikely to move out from a closed area and be exploited. In addition, conducting a tagging experiment, concentrated in one area, such as a preferred fishing ground, where it is known that effort will be regularly deployed, would provide a useful test area for evaluating tagging efficacy.

6. Biological sampling

Between January and November 2019 biological sampling was conducted on 217 grouper. Data generated from analysis of these samples were used to assess whether there was an ontogenetic change in size with depth and the gonadosomatic index (GSI) of the population.

Initial results followed the known increase in grouper size with depth (Figure 16). Whilst there were still individuals >40 cm observed in shallow waters (<10 m), and at depths >20 m, sizes appear similar, with most fish around 45 cm.

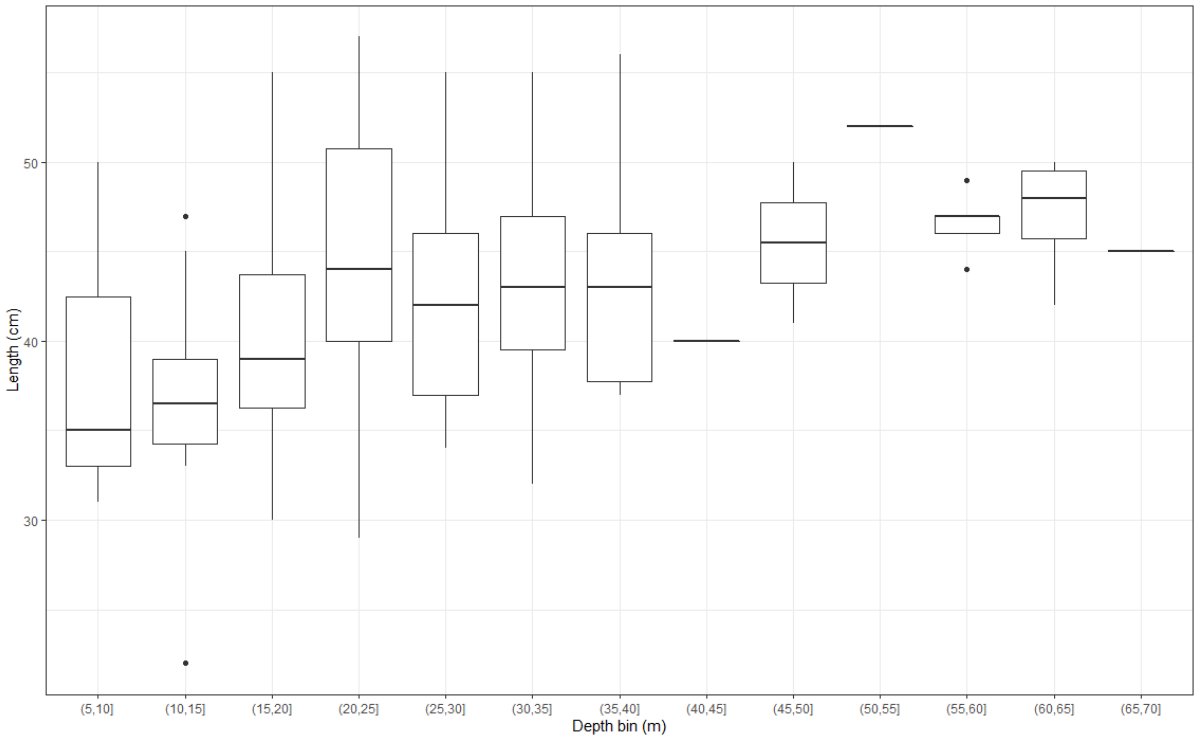

Figure 16. Length of grouper in relation to depth where they were caught for biologically sampled individuals.

The GSI was estimated using fish greater than 35 cm length to ensure that only mature fish were used to identify trends by month (Figure 17). The lowest GSI, indicating low or no spawning, was observed between June and September, with an increase in November and the highest values observed in January (indicating a pre-spawning and spawning period). Gonads were described as ribbonlike in all months sampled except for January, when 32 individuals were sampled with 27 noted as immature, four as developing or maturing and one as mature (see gonad development description in Choat and Robertson, 2008). Additional sampling is required, but initial results from the GSI analysis indicate that the spawning period encompasses January.

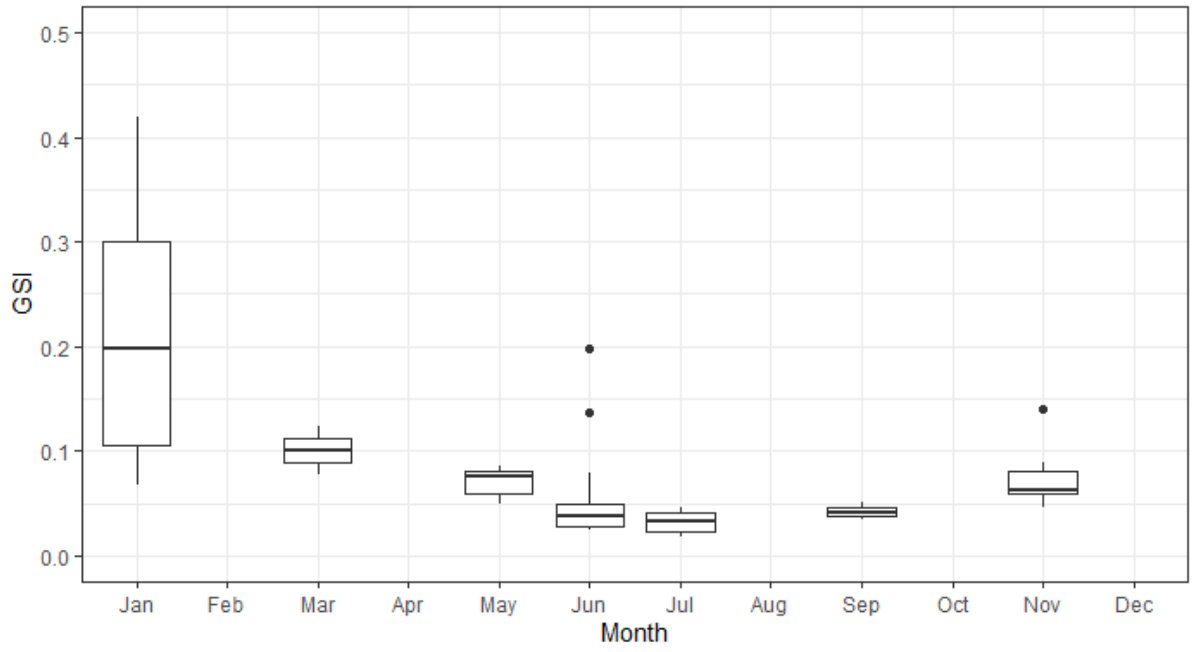

Figure 17. Gonadosomatic Index (GSI) in relation to month sampled (biological samples) for grouper.

7. Stock assessment development

Stock assessments for grouper are challenging as the data required are often very limited. Many grouper species are protogynous hermaphrodites and sex change is almost entirely ignored by most stock assessment models (Heppell *et al*., 2006; Provost and Jensen, 2012). Little is known about how various reproductive strategies affect stock dynamics, but Alonzo *et al*., (2008) demonstrates that ignoring sex change can lead to an overestimate of spawning biomass and very different conclusions regarding the effect of exploitation. Assessment of protogynous stocks also requires knowledge of the effect of male depletion on spawning potential and the factors that determine sex change (Alonzo *et al*., 2008). Data gaps (e.g. time series of the sex ratio of landings) and limited understanding of the social and environmental cues involved with sex change hinder efforts to account for sex change in stock assessment and management (Provost and Jensen, 2012). High fishing mortality on grouper species could lead to a female- or male-skewed sex ratio, and a truncated age distribution, which raises some concern about the overall fitness of a population (Alonzo *et al*., 2008). Choat and Robertson (2008) suggested that some signs of this may have been evident in their study on the St Helena grouper population.

A few stock assessments have been carried out, for example, Ehrhardt and Deleveaux (2007), conducted a stock assessment using national landings data to derive the frequency of different size classes for *E. striatus* in the Bahamas. These were then used to gain an understanding of fishing pressure, population structure and productivity, whilst recognising that there was considerable unreported catch through informal fishing and sales. The lack of sex ratio data was not considered an issue as available evidence indicates that *E. striatus* is primarily gonochoristic (separate sexes) (Sadovy and Colin, 1995) and therefore traditional approaches

to assessment can be used. In Mauritania, fishing pressure on *E. aeneus* was estimated by extrapolating the CPUE recorded by on-board observers to the size of the fleet (Meissa *et al*., 2013). In this example, a model incorporating seasonal upwelling was used to estimate the productivity of the stock, recognising the importance of this oceanographic process in the target species' biology. To estimate the size of remaining stock in the wild, Ehrhardt and Deleveaux (2007) used hydroacoustic methods to estimate the population, while Meissa *et al*., (2013) used data from scientific trawls. Sadovy (1990) recognises that for many grouper fisheries around the world, not enough data exist to carry out a full stock assessment. In these cases, Sadovy (1990) proposes that monitoring data from CPUE, landings and/or dive surveys can be used to detect important changes in the grouper population and inform the management needs.

In an initial approach to analyse the St Helena grouper, the SPiCT model (Pedersen and Berg, 2017) and Management Strategy Evaluation (MSE) were investigated, but the data needed for them proved limiting. Further assessment approaches are also being considered and include sex disaggregated length-based indicators (LBI's) and length cohort analysis. Due to lack of knowledge, proxy stock parameters required for these methods have been derived from previous studies about the stock and species biology. The assessment approach will, therefore, be developed as improvements in data collection are continued and implemented as recommended. An annual review should be undertaken to ensure new data and information collected are analysed, which can inform future assessment approaches (as part of an iterative process) and are subsequently fed directly into the selected assessment. Data limited approaches have been used, for example Porch *et al*., (2006) applied a model-based framework for estimating reference points, stock status, and recovery times in situations where catch data and other measures of absolute abundance are unavailable, to *E. itajara* off southern Florida.

The timeseries of data collected on grouper by the St Helena fishery and the consistent series of SHG funded underwater visual surveys, will be key to obtaining the biological information required for evaluation of the stock dynamics and response to exploitation.

8. Grouper management

8.1. Grouper fisheries, ecology and biology

Knowledge and understanding of grouper species and populations is varied but is generally scant with few studies. For example, 50 studies have been published on grouper movement and ecology, with the majority conducted in the north Atlantic and no currently published studies in the south Atlantic or central Pacific.

Grouper tend to be highly prized as food-fish, creating a high demand which has led to unsustainable fisheries in many areas (Coleman *et al*., 2000; Morris *et al*., 2000). Increasing exploitation has been associated with sharp declines in grouper populations and, in some cases, the local collapse of a fishery (Morris *et al*., 2000). Various aspects of groupers' biology

make them vulnerable to overfishing, including slow growth and a K-selected life cycle, i.e. larger sized fish, that are long-lived, produce low numbers of offspring, exhibit sequential hermaphroditism (sex reversal) and form predictable spawning aggregations (Coleman *et al*., 2000). Species such as the Nassau grouper (*E. striatus*) show an ontogenetic shift in habitat preference, from inshore reefs to progressively deeper water banks and offshore reefs (Colin *et al*., 1997; Tucker *et al*., 1993). This highlights the potential benefits of protection encompassing several habitat types to support a number of life stages. Additionally, species that form large transitional spawning aggregations are particularly vulnerable, as fisherman can remove the entire breeding population representing a large area in a very short time (Russell *et al*., 2012).

The largest sized grouper are generally targeted, but as many species are hermaphrodite with a larger male phase, removal of the largest individuals can severely skew the sex ratio, drastically reducing the effective population size of the species (Coleman *et al*., 2000; Morris *et al*., 2000; Nemeth, 2005; Sadovy *et al*., 2013). Nemeth (2005) highlights the vulnerability of grouper populations from the US Virgin Islands, where overfishing of large spawning aggregations of *E. striatus*, caused the fishery to collapse in the late 1970s. Following this, fishermen focussed primarily on the smaller species *E. guttatus* during the 1980s, which led to a severe decline in average size and loss of large size classes. 10 years after the fishery began, the population exhibited a heavily skewed sex ratio of 15 (gravid) females to 1 male, suggesting a shortage of males in the population and an increased potential for spawning failure (Beets and Friedlander, 1992; Nemeth, 2005).

8.2. Management challenges

Management and conservation measures for groupers primarily utilise fishing and trade restrictions and spatial protection. Sustainable landings are achieved through limiting numbers of licenses, gear limitations and catch quotas (Russell *et al*., 2012). Fully protected, or closed areas, for example, Marine Protected Areas (MPAs) have been suggested as potentially useful tools, due to the groupers' high site fidelity and high fecundity (Russell *et al*., 2012). By having specific home sites and typically small home ranges of 1-2 km, groupers can be protected by a closed area without them needing to enter unprotected habitat (Kaunda-Arara and Rose, 2004; Koeck *et al*., 2014, Sadovy *et al*.,2013). For St Helena, more information is needed to understand both the size of grouper territories / home ranges and whether they undergo movement between different habitats as they mature, in order to recommend management strategies.

Some observations have indicated localised aggregating or territorial breeding behaviour in *E. adscensionis,* such behaviour makes it less vulnerable compared to species that form a few large transitional aggregations (Russell *et al*., 2012). This species of grouper is also considered less threatened because of its relatively wide geographical range (Morris *et al*., 2000), which extends to both sides of the Atlantic. Where a particular aggregation is of conservation concern, fisheries closures may be applied temporarily during the breeding season (Russell *et al*., 2012). The *E. guttatus* population in the US Virgin Isles, was initially protected in 1990 using a temporary closure of its breeding grounds, which later became a

fully protected MPA (Nemeth, 2005). Towards the end of the decade, the average size of *E. guttatus* had increased to 395 mm (from 295 mm in the late 1980's) and the sex ratio had shifted from 15 females to 1 male to 4 females per male, along with an increase in average size (Beets and Friedlander, 1999). Further evidence supporting protected areas as an effective management measure is demonstrated by the recovery of an overfished *E. adscensionis* population (and several other grouper species) in Brazil (Anderson *et al*., 2014).

Through surveys of fishers and review of reef fisheries along the Brazilian coast, Begossi *et al.,* (2012) highlight the dilemma confronted by management of small reef fisheries regarding whether to conserve fish stocks or to catch fish to fulfil immediate economic needs. They suggest a co-management approach, with participation of fishers in such processes as where and when fish are caught, which could also contribute to monitoring fish stocks through fisher observation. Although management measures such as size limits, catch limits or gear limits, are applied by some countries i.e. Bermuda[3], no studies were found measuring the effectiveness of these management strategies.

While grouper species are broadly similar in terms of biology, ecology and preferred habitat, important differences in species-specific traits exist (Gibran, 2007), which influence the relative sustainability of harvesting particular species (Morris *et al*., 2000). In particular, growth rate and reproductive mode are major determinants, with large slow-growing species that breed annually in the same temporally and spatially restricted spawning aggregations (e.g. *E. striatus*) being more vulnerable, compared to smaller faster-growing species where breeding is spread over time and space.

9. Discussion

The analyses and results presented in this report have been made possible by the collection and collation of data from biological, fisheries, tagging and Underwater Visual Surveys within St Helena's EEZ. This information results from successful collaborations between the cold store, fishing industry, and St Helena government, over a substantial time series.

Preliminary assessments using two approaches have been trialled, but currently due to species knowledge gaps and data limitations, the development of these approaches and or suitable emerging approaches is ongoing.

The outcome of the rock fishing survey (SHG, 2013) recommends that the survey be expanded to include fishers using boats to access to rock fishing sites and those fishing from other areas such as the rocks at West Rocks, the Wharf and Rupert's Bay and other easily accessible sites on the leeward side of the island. The survey recommended that a similar survey be conducted at some point in the future to ascertain if any of the current trends are changing, for example, use of different fishing gear or techniques, if catches or numbers of fishermen are increasing or decreasing. In line with these recommendations, data could be collected through regular surveying, for example every three or five years. Additionally, a

[3] https://www.gov.bm/articles/amendments-made-fisheries-regulations-2017.

sample of fishers could be asked to log their catch and effort over a year or another suitable time frame, which could provide the information to monitor fishing activity levels and provide data on the catch.

Analysis from underwater visual surveys (UVS) has demonstrated its utility to provide a time series of abundance estimates by area which show an increase in grouper abundance between 2015-2018, which is further corroborated by the increase in annual LPUE shown in Figure 5. Continuing, regular UVS surveys to monitor the inshore population is recommended. Additional sampling or survey of deeper sites is encouraged to allow fuller understanding of abundance and density of grouper in these areas and that could allow an assessment of the current survey limitations (i.e. carried out to depths of ≤24 m only), and effects on the abundance estimate calculation. A combination of the survey abundance estimates with improved benthic characterisation could provide an approach for biomass estimation.

The monitoring of landings per unit effort (LPUE) data has allowed an evaluation of the impact of the fishery on the local resource, whilst more detailed assessment processes are developed. Between 1998 and 2019, LPUE has remained relatively stable indicating that historic catches have not impacted the population during the time period for which LPUE is available. The tagging returns to date, which are low in proportion to untagged fish, could also be as a result of and therefore, indicate that current exploitation rates are low.

The grouper stock is therefore considered sustainably fished at current annual catches. It is recommended that any expansion to the current fishery is implemented gradually as a precautionary feedback management process, that includes observer monitoring and comprehensive data collection.

10. Recommendations

10.1. Data collection

Key management issues and knowledge gaps were identified in the scoping phase (Blue Belt Report, 2019b) and are being addressed as part of the ongoing work for this species. Programmes of work linked to data collection that are either ongoing, have been conducted and could be revised, or are suggested as additional work, are provided in Table 2.

Table 2. Continued data collection requirements and future research plans for the grouper population and its fishery.

Description	Duration	Data collection requirements
St Helena Government: SHG_Fisheries_Database_201912.mdb (SHG)	Records, updated annually	Improved through logbook records and daily records of catch and effort (including days with no catch). Biological records collected through the cold store.
SHG Rock fishing survey	Every few years i.e. 3 or 5	Further collation of rock fishing information through an updated regular survey

Underwater Visual Survey		Annually	Develop a reporting format and link to future progress in assessment and monitoring
Benthic Mapping (source: UKHO) - high resolution benthic habitat and bathymetry mapping		2020	Use of available data with, if possible, under water visual survey to identify grouper habitat.
Choat and Robertson, (2008) survey		As soon as practically possible	Repeat after improvement of experimental design, possibly incorporating methods used in Nolan, *et al*., 2017
SHG Biological sampling:	Length, weight	Ongoing	As current collection
	Gonads for Gonadosomatic index (GSI**)**	Ongoing	Review data for complete annual cycle and continue until sufficient data collected
	Otolith collection (aging)	Ongoing	Improved/validated age readings
	Tagging	Ongoing	Regular review of recoveries and status
Data management		Ongoing	Write and implement a data management and storage SOP (updated as required)

10.1.1. Logbooks

Number or weight of catches by species, fishing line, vessel, and location are recommended to be recorded by trip (date and vessel) in logbooks and include tag recaptures (with tag number, date and location of capture) and fishing effort - number of hours fished and the number of lines per vessel including fishing effort with zero catch. Monitoring of catches is recommended to be carried out at landing. Development of an electronic data capture system would enable catches in real time and could support the monitoring of landings.

10.1.2. Observers

Observers have successfully been deployed in St Helena fisheries to collect biological information, size distributions, otoliths and spatial information. It is recommended that an observer programme is considered for this fishery.

10.1.3. Ongoing tagging

A tagging target of every tenth fish caught, depending on fish health following capture, is suggested, recording tag number, date of release, release location and fish measurements. Recaptures should be reported with tag number, length, otoliths and capture date and location. Improved tag return data will enable a more robust method of assessment to be used and will allow a better evaluation of grouper stock status and stock sustainability.

10.1.4. Biological sampling

It is recommended that the sampling programme is maintained to collect otoliths and other biological information for use in stock assessments. The recommended sampling rate is 1 in every 10 captures on observer covered fishing trips, with fish being labelled with fishing trip ID, capture date and location, straight after capture, and biological sampling conducted on return to the cold store.

10.1.5. Minimum landing size

A minimum landing size of 35 cm was recommended by Choat and Robertson in their 2008 report and is being applied to the fishery. In shallow water this may be effective, but there are concerns that an MLS in deeper waters may result in fish with barotrauma having reduced survival; and therefore, the effectiveness of this measure needs further investigation, such as monitoring and recording the condition of <35 cm fish before released.

10.2. Future research

10.2.1. Repeat of Choat and Robertson (2008) study in St Helena to compare findings in 2006

Evidence from studies on various grouper species show that these species can be overfished based on life-history and distribution. Results from the study carried out by Choat and Robertson (2008) in 2006, emphasised changes to life history traits in the St Helena grouper population, which indicated possible over exploitation from fishing. Repeating this study would allow the status of these traits to be monitored. A repeat of this survey and an updated survey design of Choat and Robertson's (2008) study, which possibly incorporates some methodology from Nolan *et al*., (2017) is recommended. This will enable the collection and update of key biological parameters for the St Helena grouper population, which can be used to compare with parameters from 2006.

10.2.2. Reference areas

Areas that are not fished could be monitored in conjunction with fished areas by i.e. UVS, these are referred to as reference areas. This would allow comparative studies between fished and non-fished areas. Data collected through these surveys could also be used to look at changes attributable to non-fishery related impacts, for example effects of climate change and island outflows. The reference areas could be established in places that are easy to monitor, that would provide resilient spatial management and be visible to the public eye (Choat and Robertson, 2008). The data collected could allow analysis in respect to the use and effectiveness of closed area management in St Helena waters. Additionally, potential closed area management could be considered on the windward side of the island in areas of grouper habitat, as there is some natural protection due to prevailing weather conditions. As a consequence, commercial fishing on this side of the island is limited by the sea conditions and is also limited by vessel size and capability i.e. engine power, health and safety issues etc.

11. Acknowledgements

This work was funded by the UK Government through the Blue Belt Programme (https://www.gov.uk/government/publications/the-blue-belt-programme). Additional data was also provided from historic Darwin projects and the authors sincerely thank Dr J. H. Choat for

providing data from the grouper study in 2006. Authors sincerely thank the St Helena Government team (Darren Duncan, Gerald Benjamin, Elizabeth Clingham, Rhys Hobbs, Joachim Naulaerts, Martin Cranfield, Leeann Henry), St Helena Fisheries Corporation, St Helena Fishers and St Helena Commercial Fishermen's Association for their fundamental role and foresight in sample collection, tagging release and recapture and continued discussions throughout the programme.

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