REEF FISH TAGGING PROGRAMME – BAA ATOLL PILOT PROJECT

BY

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ABSTRACT

Biology of reef fish species renders them easy to over exploit, with increasing fishing effort and unsustainable catch quantities. With the increasing demand for reef fish in the Maldives it is of essence that these populations be sustainably utilized to avoid overexploitation. However, proper management will only come through well-informed management decisions regarding their biology and behavior. The pilot reef fish tagging project was conducted in Baa Atoll, in collaboration with the Atoll Ecosystem Conservation Project. Conventional tagging using dart tags was carried out to study movement patterns of various reef fish species exploited in the multispecies fishery. Individuals of the most commonly exploited reef fish species were tagged and released on two survey trips from B. Kudarikilu. The pilot project had a recovery rate of 10.8% over a period of 1 year, which, while on the low side, is significant, in comparison to previous conventional tagging studies done in other parts of the world. Results from the study show that the most commonly exploited species, *A. virescens* (Green jobfish), travel relatively long distances, although on average they remain within the atoll or within a range of approximately 4 km. One of the main limitations of this project was the lack of awareness amongst all stakeholders involved. Nevertheless, despite some data limitations, it can be concluded that commercial reef fish species of the Maldives have a limited "home range" confirming previous knowledge on the targeted species. In terms of conservation and management recommendations, the results imply that in the Maldives, where human communities are separated by atolls and islands, due to geographic reasons, it would make sense to consider whole atolls as conservation units. We recommend similar tagging studies to be carried out on individual species of importance to study their biology and behavior. Further work should take advantage of the lessons learn from this pilot study.

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INTRODUCTION

Many reef fish are known to mature late, have long lives and low population turnover rates. It is also known that many species of reef fish aggregate to either feed or spawn. Many reef fish species are believed to be ‘residents’ i.e. generally stay near their place of first recruitment. Conversely, some species of groupers travel long distances to and from aggregations during spawning periods (Bolden, 2000). Aggregations sites which are well known and regularly targeted by experienced fishermen, have disappeared or shown a decrease in individuals per aggregation, due to intense fishing (Sadovy and Domeier, 2005). Clearly, biology and migration patterns of reef fish are critical information to ensure management plans can be developed to prevent overexploitation of these resources.

Various methods of tagging and mark recapture techniques, ranging from the conventional dart tags, to acoustic tagging, to chemical tags and Pop-up Satellite Archive Tags (PATS) are used throughout the world to study the behavior and biology of fauna both marine and terrestrial. Tagging studies which investigate population sizes, migration patterns, and growth rates are quite common for tuna populations of bigeye, yellowfin, skipjack and bluefin tuna, throughout the world. Same has previously been conducted in the Maldives with remarkable results (Yesaki and Waheed, 1992; Waheed and Anderson, 1994). However, relatively few studies have used tagging methods to study the behavior and ecology of reef fish species (but see Burns, 2009 for a grouper-snapper tagging study in Florida, the tagging study of *Amphiprion percula* and *Chaetodon vagabundus* by Almany et al. (2007) and the acoustic tagging of *Epinephelus maculatus, Plectropomus leopardus, Chlorurus microrhinos,* and *Scarus ghobban* by Chateau and Wantiez (2009) in New Caledonia.

A review of the reef fishery carried out by the Marine Research Centre showed that the reef fish consumption by resorts per tourist per night has decreased over the last 15 years. However, total reef fish purchase by resorts had increased three-fold, with an estimated quantity of 7000 metric tonnes of reef fish being purchased per year (Sattar 2008, Sattar et al., this issue). The review also estimated a total catch of 16,000 metric tonnes per year from the whole Maldives. Given the importance of this fishery to the Maldivian tourism industry and hence the economy, it is important to study fish behavior to gain as much insight as possible for sound management decisions.

Baa atoll is one of the most central atolls in the Maldives, both in terms of geography and economy. The atoll is well known for its world famous dive sites, beautiful coral reefs, marine biodiversity and the many tourist resorts scattered throughout the atoll, with more under construction. Given the spread of tourism within the atoll, reef resources are in high demand and the people of the atoll depend on reef fish as a direct source of income and to a lesser extent, as a source of food. Baa Atoll was chosen for this pilot tagging project, because of its central location and the importance placed by the community on reef resources as a source of their income.

Baa atoll has 13 inhabited islands, out of which 11 islands are reported to carry out reef fishing (including grouper fishery). At the time of the tagging project presented here, a total of 45 fishing vessels were active. The atoll has an estimated total surface area of 1240 km^2 (Naseer and Hatcher, 2004). An annual catch of 780 tonnes was previously estimated from Baa Atoll based on this surface area (Sattar, 2008). Yield per km^2 derived from these values comes to 0.63 tonnes considering the entire reef and lagoons, or 2.6 if we consider only the surface of productive fished reef flats, slopes and passes where most of the fishing occurs (Sattar et al., this issue). The reef fishery within the atoll caters for the various resorts in the Atoll as well as the export industry, whereas the grouper fishery solely targets the grouper export industry.

This paper reports on a conventional tagging study of reef fish. The objectives were to characterize the movements and distribution of reef fish within Baa Atoll. Results from this project, together with fishermen interviews in order to identify reef fish aggregations, will enable us to identify areas of importance to aid reef fishery management on the long term, specifically by identifying areas which could be made into time-area closures during spawning periods.

METHODOLOGY

Tagging was carried out in two phases; two weeks in August 2008, followed by two weeks in February 2009. Tagging was conducted during daily commercial fishing trips (n=28). Fishermen of B. Kudarikilu (outlined blue circle in Figure 2) were the focus. Although the initial plan was to tag equal numbers of the most commonly exploited species such as *Aprion virescens, Caranx melampygus, Lutjanus bohar, Lethrinus microdon* and *Lethrinus olivaceus,* this proved difficult. These species were not caught in equal quantities. Tagging effort was hence carried out according to the successful catch and release rates achieved for the most commonly caught species.

Fishing was carried out using either handlines or drop lines. In contrast with handlines, drop lines are weighted with a lead sink at the end, which enables the lines to drop down to depths. Individuals which were in good health when hauled on board were tagged and released. Individuals to be tagged were laid on a tagging bed with a measuring tape pasted on it for rapid length measurement. The fish were tagged about half-inch below the base of their dorsal fin, using conventional yellow dart tags (Fig. 1). Detailed information for all tagged individuals (tag number, species, length, weight, date and location of release) were recorded as soon as each individual was tagged.

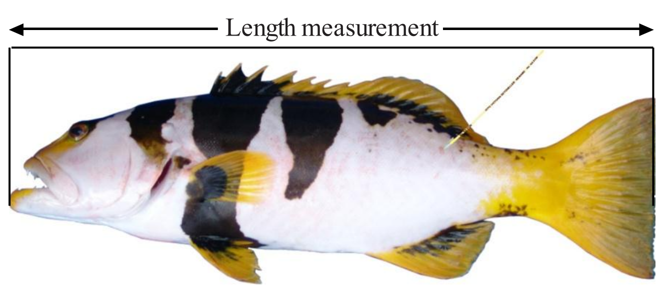

Figure 1. Illustration of the position of tagging

Precautions were taken to handle the fish very carefully so as to minimize stress while tagging and thus increase the chances of post-tagging survival. The eyes of the fish were covered, while tagging was carried out, since this had a calming effect on the individual. Once tagged, the fish was gently released back into the water, head-first. Tagging was mainly carried out on individuals which were larger than 30 cm, to ensure a higher survival after release.

A total of 408 individuals, mainly *A. virescens* and *C. melampygus* were tagged and released from different locations in Baa and Raa Atoll, as depicted in Figure 2. Released individuals were paid at a rate of MRF 15 per kilo (approx. US$ 1.2/kilo). Tag releases with inaccurately noted GPS positions have been eliminated from Figure 2.

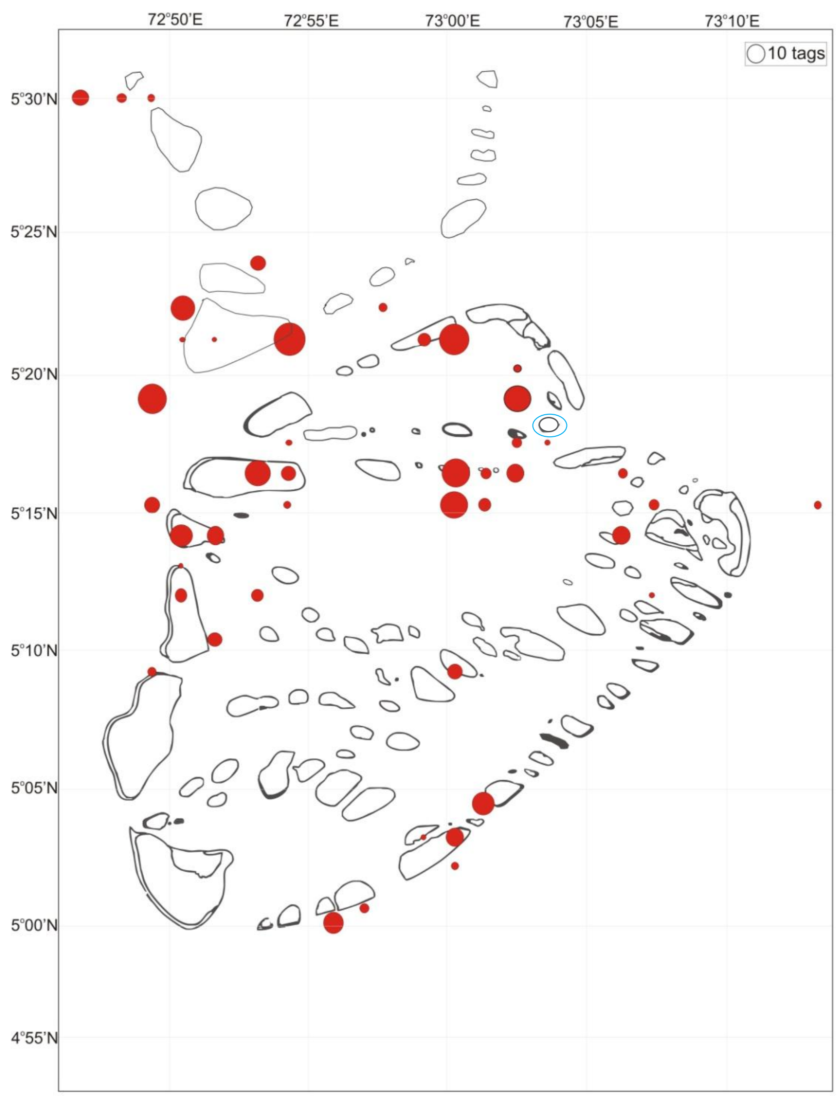

Figure 2. Locations of tag releases for 408 fishes. (Point of release is shown as the central point of the circles. The area of the circle is proportional to the number of tags released (see legend on the upper right corner, for 10 tags). If tags have been released from points very close to each other, these have been aggregated into one point.

This project was publicized throughout the entire Baa Atoll with the aid of posters. They provided clear instructions on how and where to return recaptured tags. Recaptured tags were to be returned to the Marine Research Centre with a completed “Tag recovery form”. Fishermen were informed on how to measure the length of the recaptured individual and were also provided with measuring tapes for this purpose. A reward of MRF 150 (approximately US$ 12) was given for every tag recovered/returned with complete information. Tag recapture data was collected till September 2009.

RESULTS

Species Composition of Total Catch and Tagged Individuals

A total of 1345 individuals were sampled during the survey. Table 1 shows the species distribution of catch as well as the percent of total catch tagged for each species tagged. Most data shown further in this paper will come from the species caught in higher numbers such as *A. virescens* and *C. melampygus*. Species such as *Elagatis bipinnulata* and *Gymnosarda unicolor* were captured but not tagged since they are not true reef species.

Size Composition of *A. virescens* and *C. melampygus*

Figures 3 and 4 show the length distributions of the tagged individuals and the total catch for *A. virescens* and *C. melampygus* respectively. Mean lengths of total catch and tagged individuals were very close for both species. Figures show that mean lengths and length distributions for both categories were almost similar. This indicates that tagged individuals represent well the population of individuals caught for each species. It also shows that the tagging effort captured size classes frequently caught and not the largest or smallest size classes.

Tag Recoveries

A total of 44 individuals (details summarized in Table 2) were recaptured and reported, giving a recovery rate of 10.8%. This is relatively low, when taking into consideration the hypothesis that reef fish do not travel large distances and mainly remain within their atolls. Furthermore there is a relatively high fishing intensity within the atoll i.e. regular daily fishing by few village islands, plus recreational fishing by locals and tourists. We believe that a large number of individuals that were recaptured went unreported, according to conversations with recreational fishing vessels from resorts and other fishermen. This is indicative of the importance of increasing awareness and creating greater publicity before similar research projects are launched. Also contributing to low recaptures could be tag shedding by fishes or the movement of some of the tagged individuals away from the atoll or fishing areas.

Table 1. Species distribution of total catch and tagged individuals in percentage.

Scientific Name	English Name	Dhivehi Name	Tagged % of total catch	Total catch percent
Aethaloperca rogaa	Redmouth Grouper	Ginimas faana	0.07	0.82
Aphareus furca	Smalltoothed jobfish	Keyolhu rovvi	0.00	0.22
Aprion virescens	Green jobfish	Giulhu	10.63	25.20
Carangoides caeruleopinnatus	Coastal trevally	Vahboa handhi	0.15	0.22
Carangoides ferdau	Blue trevally	Dhabaru handhi	0.07	0.07
Carangoides orthogrammus	Island trevally	Thumba handhi	1.26	5.35
Caranx ignobilis	Giant trevally	Muda handhi	0.22	0.52
Caranx lugubris	Black trevally	Kalha handhi	0.07	0.07
Caranx melampygus	Bluefin trevally	Fani handhi	8.77	13.75
Caranx sexfasciatus	Bigeye trevally	Haluvimas	0.74	0.74
Cephalopholis miniata	Coral hind	Koveli faana	0.00	0.37
Cephalopholis sonnerrati	Tomato hind	Veli faana	0.00	0.07
Coryphaena equiselis	Pompano dolphinfish	Aila	0.00	0.07
Elagatis bipinnulata	Rainbow runner	Maaniyamas	0.00	26.54
Epinephelus flavocaeruleus	Blue and Yellow grouper	Dhon noo faana	0.07	0.22
Epinephelus fuscoguttatus	Brown marbled grouper	Kas faana	0.15	0.15
Epinephelus polyphekadion	Camouflage grouper	Kula faana	0.00	0.07
Fistularia spp.	Cornetfish	Tholhi	0.00	2.75
Gnathodon speciosus	Golden trevally	Libaas handhi	0.00	0.15
Gymnosarda unicolor	Dogtooth tuna	Voshimas	0.00	5.95
Katsuwonus pelamis	Large skipjack tuna	Godhaa	0.00	0.07
Lethrinid spp. (to be identified)	Maldivian emperor	Laaboa kalhihi	0.30	0.30
Lethrinus conchyliatus	Redaxil emperor	Thun raiy filolhu	0.52	0.59
Lethrinus microdon	Small tooth emperor	Thundhigu filolhu	0.89	1.49
Lethrinus nebulosus	Spangled emperor	Filolhu	0.15	0.15
Lethrinus olivaceus	Longnose emperor	Filolhu	2.08	3.27
Lethrinus rubrioperculatus	Spotcheek emperor	Kalhihi	0.30	0.30
Lethrinus xanthochilus	Yellowlipped emperor	Thun reendhoo filolhu	0.59	0.89
Lutjanus bohar	Red snapper	Raiymas	2.30	3.72
Lutjanus gibbus	Humpback snapper	Ginimas	0.15	0.45
Macolor macularis	Midnight snapper	Kalhu foniyamas	0.00	0.30
Macolor niger	Black and white snapper	Foniyamas	0.45	0.45
Plectropomus areolatus	Squaretail coral grouper	Olhu faana	0.07	0.30
Plectropomus laevis	Black-saddled coral grouper	Kula olhu faana	0.07	0.52
Plectropomus pessuliferus	Roving coral grouper	Dhon olhu faana	0.15	0.37
Sphyraena forsteri	Bigeye barracuda	Faru tholhi	0.00	0.74
Thunnus albacares	Yellowfin tuna	Reendhoo uraha kanneli	0.00	1.64
Variola albimarginata	Whitedged lyretail	Kanduraiy haa	0.00	0.07
Variola louti	Moontail sea bass	Kanduhaa	0.07	1.04

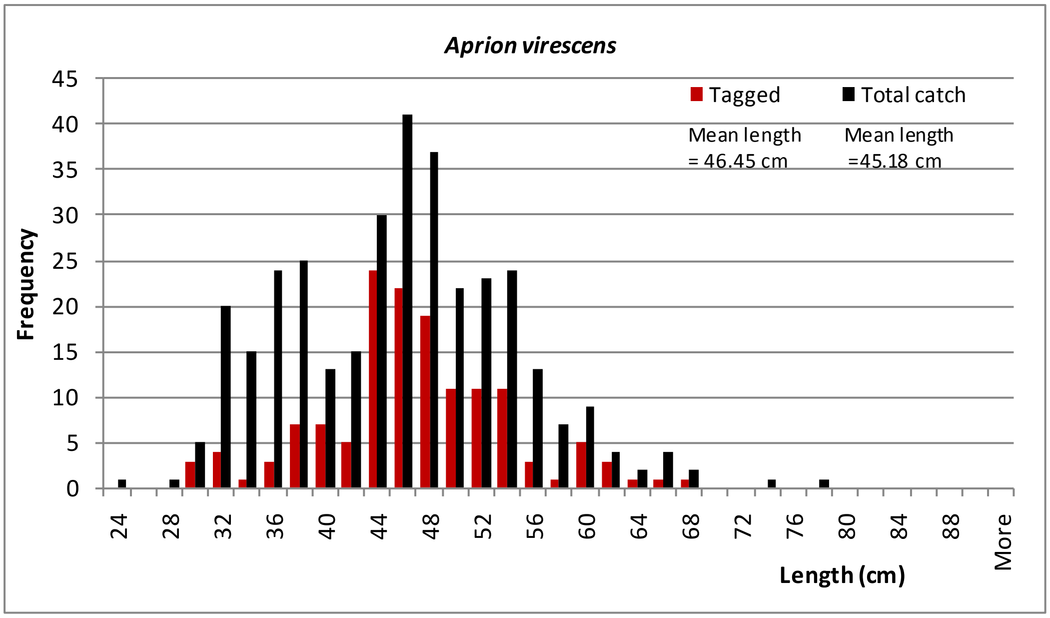

Figure 3. Length frequency distributions of all caught and tagged individuals of *A. virescens.*

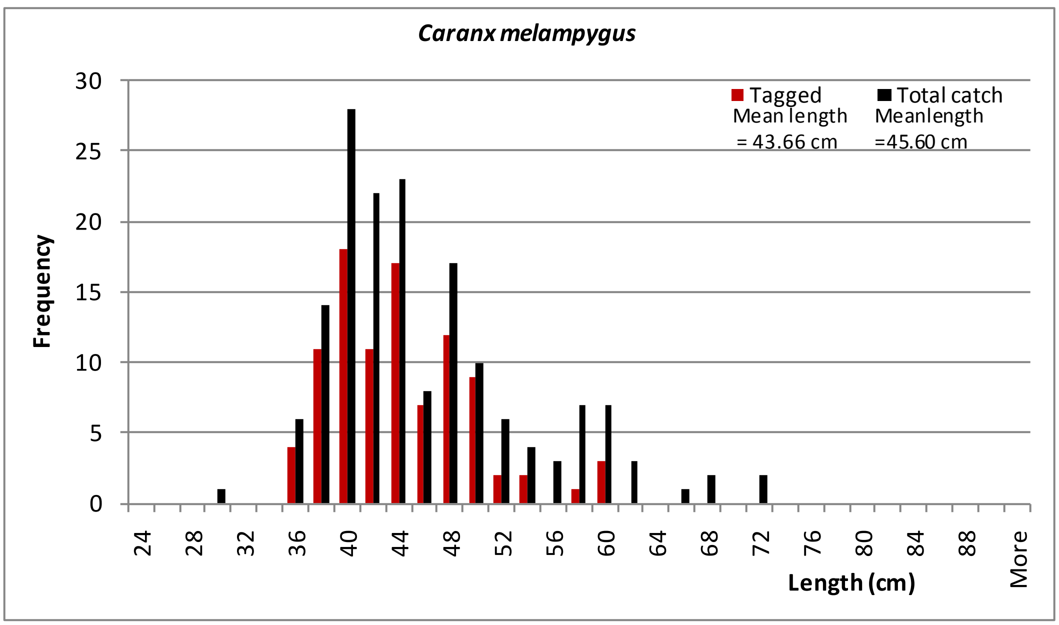

Figure 4. Length frequency distributions of all caught and tagged individuals of *C. melampygus.*

Tag Recoveries

A total of 44 individuals (details summarized in Table 2) were recaptured and reported, giving a recovery rate of 10.8%. This is relatively low, when taking into consideration the hypothesis that reef fish do not travel large distances and mainly remain within their atolls. Furthermore there is a relatively high fishing intensity within the atoll i.e. regular daily fishing by few village islands, plus recreational fishing by locals and tourists. We believe that a large number of individuals that were recaptured went unreported, according to conversations with recreational fishing vessels from resorts and other fishermen. This is indicative of the importance of increasing awareness and creating greater publicity before similar research projects are launched. Also contributing to low recaptures could be tag shedding by fishes or the movement of some of the tagged individuals away from the atoll or fishing areas.

Table 2. Summary data of recaptured individuals (numbers in brackets indicate range).

Species	No. recaptured	Mean size of tagged inds.(cm)	Mean time at liberty (days)	Mean distance travelled (km)
A. virescens	27	50 (35 - 65)	74 (2 - 385)	4 (0 - 22)
C. melampygus	5	45 (42 - 53)	46 (7 - 93)	5 (0.7 - 17)
C. sexfasciatus	2	60 (58 - 62)	13 (10 - 17)	1 (0 - 3)
L. bohar	5	35 (27 - 45)	48 (11 - 109)	2 (0 - 9)
L. olivaceus	2	44 (40 - 49)	100 (90 - 110)	0.5 (0.4 - 0.6)
L. xanthochilus	1	47	2	0.9
M. niger	1	56	36	0.9
P. laevis	1	36	20	1.9

On a species level, 27 individuals of *A. virescens* were recovered (Table 2), yielding a recovery rate of 18.9% for this species. In comparison to the success rates observed in 12 years in the reef fish tagging study carried out in Florida, our rates appeared quite significant for a 1 year period. Figure 5 shows the release and recovery points for all the recovered tags which have been returned with complete information. The red points indicate location of release and the blue points refer to the recovery locations. Arrows connect the release and recovery points for each tag with the arrowhead showing the direction of movement. A close up of the area where most tags were recovered from is shown in Figure 6.

Distance Travelled

Figure 7 shows the frequency distribution of distance travelled by all recaptured reef fish in Table 1, and specifically for *A. virescens*, between the time of release and recapture. Although distance between the points of release and recovery can be calculated, conventional tagging does not enable the delineation of the actual path of movement. Thus the distance travelled calculated denotes the least distance travelled by individuals during their time at liberty. The least distance travelled was calculated using a modification of Vincenty formula for calculating distance between two latitude longitude points (http://bluemm.blogspot.com/2007/01/excel-formula-to-calculate-distance.html, website accessed September 2009) which was further verified using GPS visualizer (http://www.gpsvisualizer.com/, website accessed August 2009), an online utility which creates maps and profiles using GPS data.

These results support the assumption that the majority of individuals tagged did not travel large distances. Instead, they remained within the same reef area. Mean distance travelled by *A. virescens* and *C. melampygus* was approximately 4 and 6 km respectively. A detailed look at distances travelled by *A. virescens*, shows that although 42% were recovered from a distance of 1 km or less from the point of release, 30% were recovered from distances greater than 5 km from the point of release. Furthermore, one individual of this species was recovered from a distance of 22 km from the point of release and was noted to have crossed the ocean between Baa and Raa atolls. Travel to such large distances by some individuals is indicative of the fact that some of the un-recaptured tagged individuals might have moved to other nearby atolls.

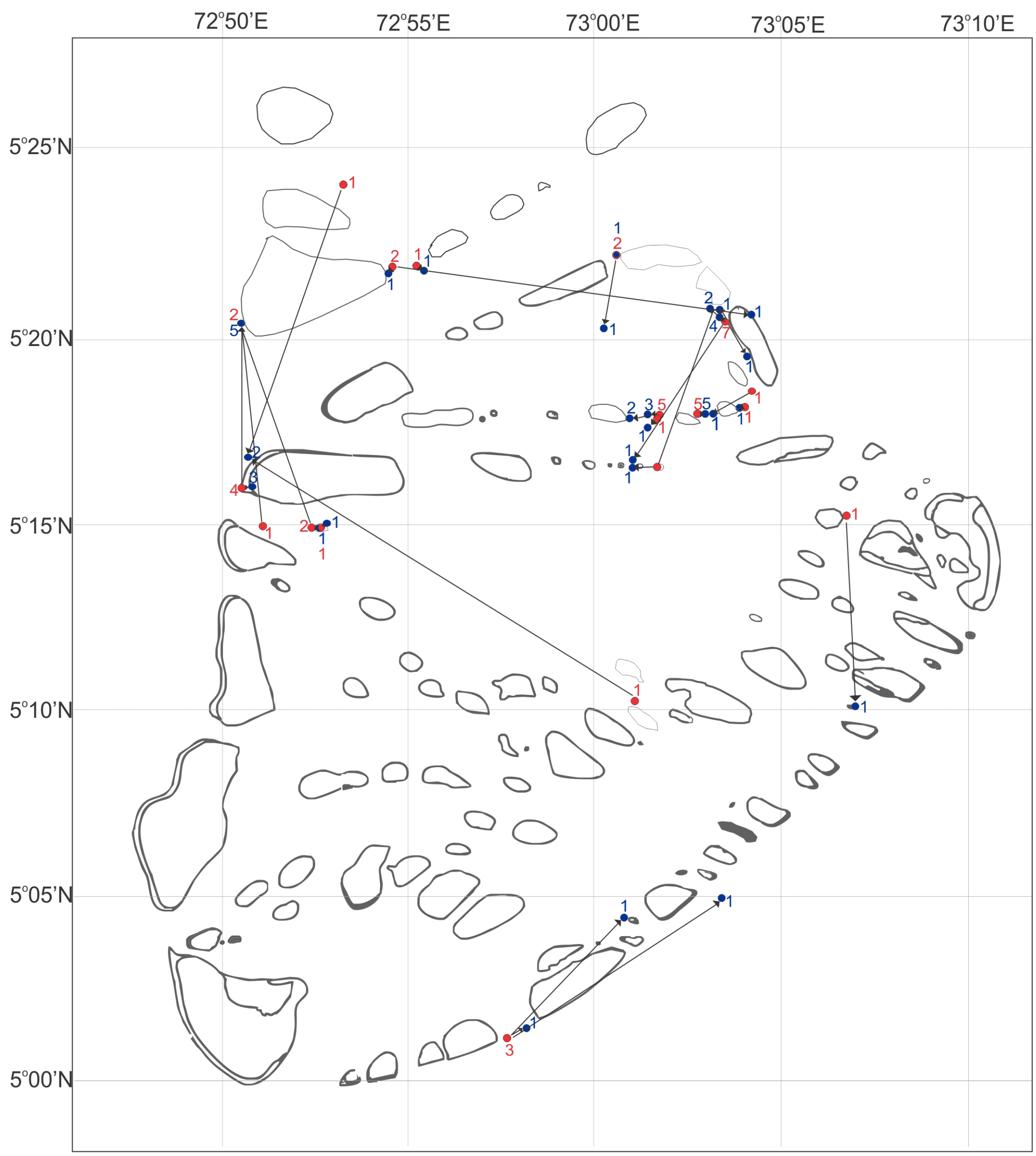

Figure 5. Points of release (red) and recovery (blue) of all recovered and returned tags. The arrowheads show the direction of movement. Numbers indicate number of tags released (red) and/or recovered (blue) for each point

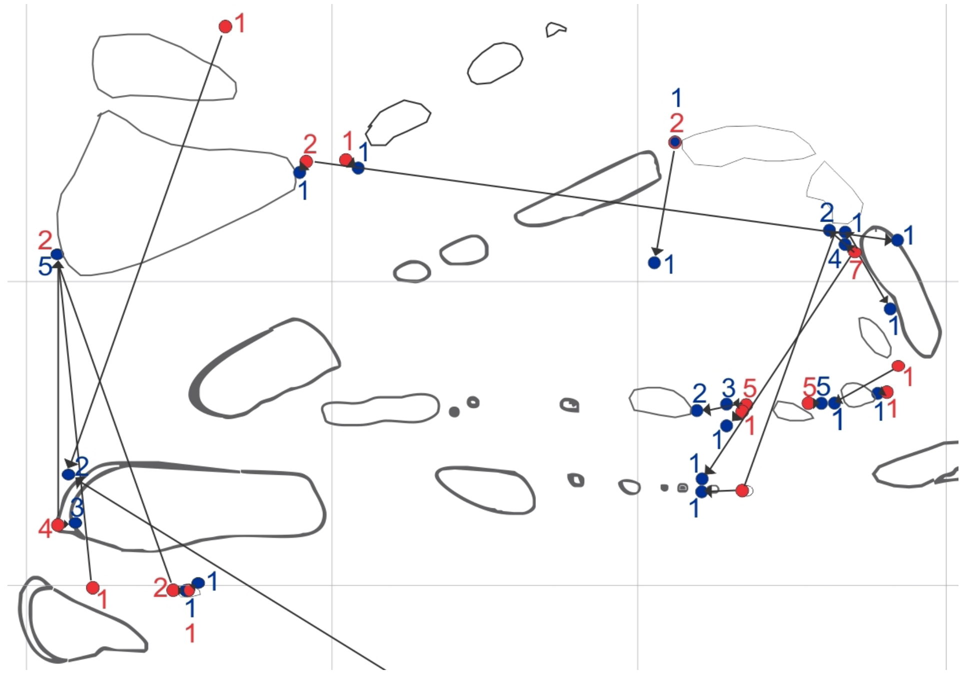

Figure 6. Close-up of area where most tags were recovered. Arrows indicate direction of movement and numbers indicate number of tags released (red) and/or recovered (blue) for each point.

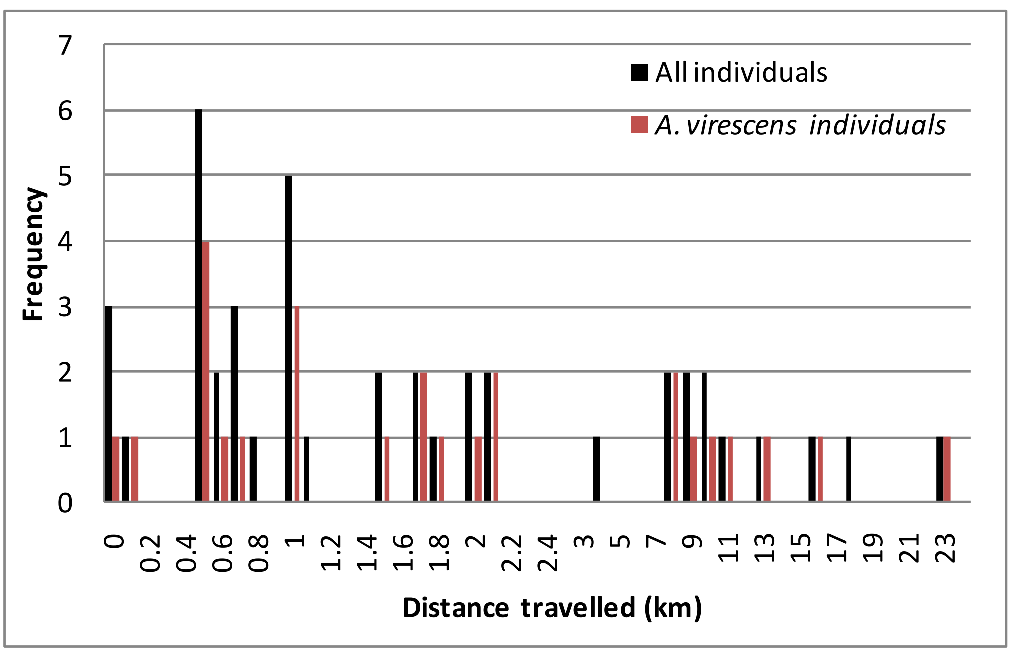

Figure 7. Least distance travelled by all species individuals (black) and individuals of *A. virescens* (red) recovered and reported. Note: X-axis not continuous.

Time at Liberty

Time at liberty (length of time between release and recapture of individuals) varied for different species, ranging from 2 to 385 days. Average time at liberty for all species was 63 days.

Since most individuals were recaptured from locations close to their release points, it is likely that majority would have been caught within a short time frame of being released. With respect to this, there were two obvious peaks in recaptures both during the first week of release and again 3 months of release. This is indicative of potential movement of the individuals during their time at liberty, though we cannot determine the exact total distances travelled. Although we could expect a directly proportional relationship between time at liberty and distance travelled, Figure 8 negates this assumption. Further, the individual of *A. virescens* which was recovered 385 days after release was recovered only approximately 2 km from the point of release, in the same reef area. On the other hand, another individual of *A. virescens* recovered 107 days after release, was 22 km away from the point of release, indicating significant movement during its time at liberty.

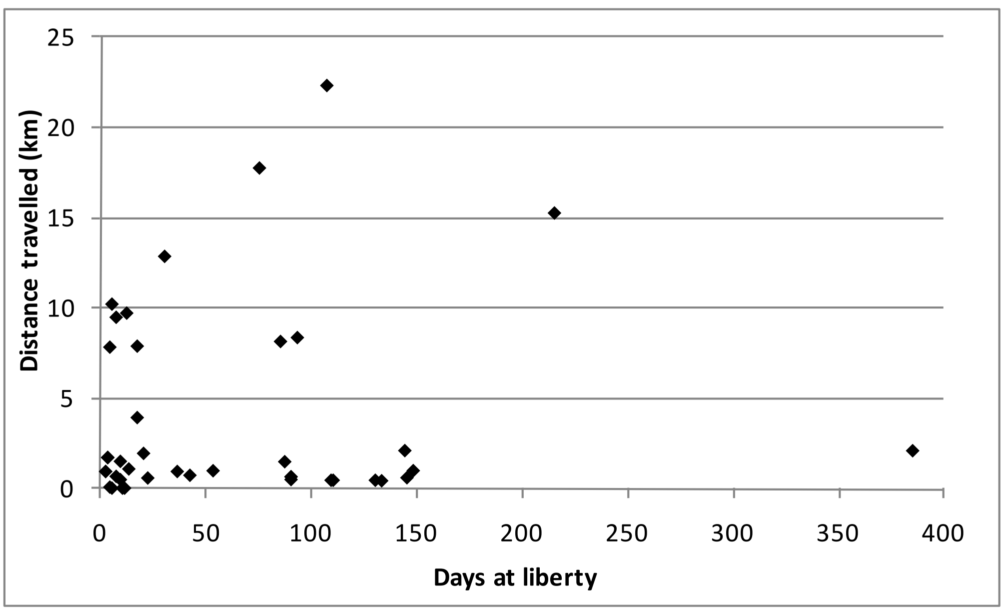

Figure 8. Correlation between time at liberty and distance travelled by all recaptured individuals.

DISCUSSION AND CONCLUSION

The most commonly tagged species, in proportion to catch quantities, were *A. virescens* and *C. melampygus*. The decision to tag individuals larger than 30 cm eliminates the smaller individuals which are more susceptible to predation. Additionally, tagging of larger individuals was minimized to reduce loss of tags due to natural mortality. These precautions ensured that there would be a good return of tags, by tagging size classes vulnerable to fishery.

Thanks to these precautions, the level of tag recovery achieved for Baa was fairly successful with an average recovery rate of 10.8% for all species and 18.9% for *A. virescens* over a 1 year period. In comparison, reef fish tagging study conducted in Florida reported a 7.7% return rate for the Red grouper, *Epinephelus morio* (Burns, 2009), and species-specific recovery rates of 50% for some species, but over a 12-year period (http://isurus.mote.org/research/cfe/fish-bio/tagging-reef_fish.htm, website first accessed March 2008).

There are several reasons that could explain a low recovery rate: lack of awareness amongst stakeholders, natural mortality, discarded/unreported tags, low exploitation rates, tags not being seen by the fishermen and tag shedding. From these, we suggest that the most plausible reason in the Baa pilot study is the lack of awareness amongst the fishermen (especially those of neighbouring atolls) and other stakeholders with respect to the aims and importance of the project. It is recommended that future tagging studies address these issues and also consider studying tag shedding rates which are useful in estimating accurate recovery rates.

Results from this pilot project, indicates that reef fish species such as *A. virescens* and *C. melampygus* were mainly resident and did not seem to travel far from their home reefs. Although the majority of tags were recovered from locations close to where they were released, a small number of tags were recovered from distances as far as 22 km away from their release locations. Of course, we are not able to infer the path of movement between release and recapture, thus we cannot conclude that an individual recaptured from the same area of release, had not moved from the reef for the duration of its time at liberty, to go to spawn or feed elsewhere. The correlation between distance travelled and time at liberty did not suggest an increase in distance travelled with increasing time at liberty. Other technology, like deployment of networks of acoustic sensors would be needed to qualify the paths followed by the tagged individuals (Chateau and Wantiez, 2009).

High rates of recovery in similar locations could suggest that these sites act as concentrations areas, for spawning or feeding. Here, this trend is not obvious, and more tagging would be needed. Figures 5 and 6 may suggest accumulations of individuals next to some passes, but this can not be established with certainty despite the fact that these sites are consistent with reported spawning aggregation sites by fishermen from Baa atoll and other atolls during the Reef fish Aggregation Identification interviews carried out by IUCN in 2007/2008 (Tamelander et al., 2008). It is recommended that immediate action be taken to confirm the likely spawning aggregations identified by fishermen surveys and this project, with in-water surveys. This would enable establishment of MPAs on critical areas for species resilience. Continuous high fishing pressure on these sites is a threat to the populations which aggregate at these sites. High fishing pressure on spawning/feeding aggregations impact both number of aggregations and number of individuals per aggregation (Sadovy and Domeier, 2005). While there has been no formal spawning aggregation research done in Maldives, fishermen have reported seeing fewer individuals at aggregation sites, during the spawning period, in comparison to previous years. Therefore identification and verification of these areas and as well as their potential use would offer the foundation for sound management decisions (quotas, seasonal/temporal closures, Marine Protected Areas). Effective implementation and benefits of these MPAs would be strengthened by increased awareness of the issues among both stake holders and the public at large.

Taking into account all the limitations of this project, it can be concluded that commercial reef fish species of the Maldives have a short “home range”. This could imply that in a country such as the Maldives, where the geographic formation is such that communities are divided by atolls and islands, conservation of our resources can also be carried out by delineating whole atolls as conservation units on their own. However, we have to take into consideration, the dispersal of planktonic larvae and ‘source-sink’ connections between atolls.

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