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4.3.4 Assessing the Potential Benefits of Marine Protected Areas to Adjacent Fished Areas

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Executive Summary

I commenced this project in February 2005 and am currently in the middle of my first field season. Here I present data from the various pilot studies I have undertaken.

Currently I am assessing the feasibility of determining the potential reproductive output for coral trout (*Plectropomus leopardus*) and red-throat emperor (*Lethrinus miniatus*). The current status of the project suggests that a description of spawning aggregations and reproductive output from an aggregation within MPAs could be possible for *P. leopardus,* however, the reproductive potential for *L. miniatus* is unlikely to be established. Pilot work on the movement patterns of West Australian dhufish (*Glaucosoma hebraicum*) has had some issues with the post-operative survival of dhufish and modifications to the catch and holding procedures are currently being developed. If these are successful, then the movement patterns of dhufish can be tracked within MPAs.

Introduction

Marine Protected Areas (MPAs), often referred to as either sanctuaries, refugia, marine reserves or no – take zones, are used throughout the world to denote areas where the extraction of some or all marine organisms from an area is illegal (Newman et al. 2002, Gell and Roberts 2003, Halpern 2003). The advent of MPAs is a relatively recent management measure designed either to conserve marine biodiversity, or to serve as an additional tool in the management of fisheries stocks (Newman et al. 2002, Roberts et al. 2003).

As a fisheries management tool, MPAs create an area of increased abundance and biomass, that on average, double density, triple biomass, and increase organism size and diversity by 20 – 30% compared to adjacent unprotected areas (Gell and Roberts 2003, Halpern 2003) (Figure 4.3). Theoretically, the increased abundance and biomass of fish in MPAs provide benefits to the adjacent fishery, through the supply of larvae from increased reproductive output, and / or through spillover and the movement of post-settlement individuals of all ages from the closed area to fished grounds (Gell and Roberts 2003). Alternatively, MPAs may provide no potential benefits to the adjacent fished areas.

MPA planning and function is a contentious issue, both socially and politically. Direct evidence of export to adjacent fisheries from MPAs is crucial for their widespread understanding and acceptance. Currently there is little empirical evidence to support theoretical export functions of MPAs. In order to assess this gap in the understanding of the function of MPAs, we need to know the biology and movement patterns of key species as well as how species are affected by protection. As such the movement, biology, age and growth, as well as reproductive biology, will be compared with underwater visual census data to examine the potential export functions of MPAs.

Aims

Aim: To assess the potential benefits Marine Protected Areas to adjacent fished areas.

The specific aims are to:

1. Describe the age structure, growth rates and mortality of *Plectropomus leopardus* and *Lethrinus miniatus* in the Houtman Abrolhos Island region
2. Describe the reproductive biology of *Plectropomus leopardus* and *Lethrinus miniatus*;
3. Assess the potential reproductive output from Reef Observation Areas (ROAs) for *Plectropomus leopardus* and *Lethrinus miniatus*;
4. Investigate the movement patterns of commercially important reef fish species to relate size of home range to response to protection and potential for cross boundary movement in MPAs

Methods

Biology of *P. leopardus* and *L. miniatus*

Between 20 and 50 coral trout and red-throated emperor will be collected monthly to collect biological information. Sample collection has begun and will continue for 18 months. Samples are either whole or filleted fish. Most of the samples will be collected from fish markets with some additional research sampling for size not available in the commercial catch.

All fish will be measured (TL, FL, SL) and weighed when whole. Otoliths will be removed washed and stored in paper envelopes. Otoliths will be examined whole, and also embedded in resin and sectioned with a low speed saw to be examined microscopically. Growth zones will be counted for aging. Growth will be described through the von Bertalanffy growth equation, providing estimates of the asymptotic length (L_∞), growth coefficient (K) and theoretical age at length zero (t_o) (King 1995).The age structure of the commercial catch can then be examined as well as determining total mortality for each species.

The gonads of all fish will be weighed to the nearest 0.1g sexed and staged according to the criteria of Mackie and Lewis (2001). Gonads will then be fixed in 10% neutral buffered formalin for at least a week before being stored in 70% ethanol.

The peak spawning period for coral trout and red-throated emperor will be determined by examining the annual trends in monthly gonad stages, and average gonadosomatic index (GSI). Histological sections of ovaries will be used to determine the reproductive biology for each species i.e. examining sexual transition from female to male, and frequency of spawning in each spawning period.

Fecundity measures will be taken from a sub-sample of females collected from both inside and outside of ROAs at peak spawning period. Gonads from a wide size range of mature female fish will be weighed before being placed in Gilson's fluid to remove the connective tissue of the ovary. With mature oocytes separated from the tissues, the number of mature oocytes will be counted from three pre-weighed sub-samples. An estimate of the total number of mature eggs in the whole gonad can then be extrapolated. A relationship between fish size and fecundity can then be established through a regression analysis.

Reproductive data such as length – fecundity relationships, size and maturity and sex change will be used to assess the reproductive potential of these two species.

Reproductive Potential

To determine the reproductive potential from, *P. leopardus* and *L. miniatus*, reproductive data (see above) will be compared to length frequency data of both species inside and outside the ROAs. Initial surveys focused on locating spawning aggregations of *P. leopardus*, and preferred habitats of *L. miniatus* before broader surveying was undertaken.

Plectropomus leopardus Spawning Aggregations

To locate *P. leopardus* spawning aggregations, three 100x5m transects were used to record abundances and sizes of *P. leopardus* and other commercially important species. Sites were selected in areas where there was likely to be more water movement, as these have been shown to be areas where fish tend to aggregate for spawning (Colin et al. 2003). Small areas along or adjacent to the transect that appeared to have slightly higher numbers of *P. leopardus* were noted for later examination. As most spawning activity appears in *P. leopardus* on sunset (Samoilys 1997), those sites identified from the transects were examined at sunset to confirm if they were spawning aggregations.

Lethrinus miniatus Abundance

To assess the reproductive potential of ROAs and fished areas for *L. miniatus*, it was necessary to determine the major habitats that they occupy. To assess the distribution of *L. miniatus* in ROAs and adjacent habitats, three sites within three different habitats were surveyed for size and abundance of *L. miniatus*. These included reef slopes, inshore channels and deep drop offs. At each site, three transects of 100x5m were scored for abundances and sizes (5cm TL size classes) of *L. miniatus*.

Dhufish Movement / Acoustic tagging

Surgical Trials on three Species of Cultured fish

Initial surgical techniques were developed and refined through surgery on six individuals from three species of cultured fish; three pink snapper (*Pagrus auratus*), two mulloway (*Argyrosomus hololepidotus*) and a tarwhine (*Rabdosargus sarba*). Fish had been held in tanks at the Department of Fisheries, and were returned to the same 5000L tanks after surgery for monitoring. All fish were anaesthetised, underwent surgery and recovery. Only some were implanted with dummy acoustic tags or received OTC injections (see Table 4.1).

As the trials were successful and the surgical method was developed, we employed this technique in the field on dhufish (see below). Trials were conducted off Geographe Bay (Figure 4.5) and Fremantle (Figure 4.6). Dhufish were caught on hook and line at depths of less than 30m where possible, to reduce catch mortality (St John and Syers 2005).

On board handling protocol and Surgical Techniques

Once caught, fish were placed into a holding tank and transported to the release site if it was different to the initial capture site. Fish were then placed in a separate tank where they were anaesthetised using clove oil. A length measurement was taken prior to surgery commencing. A few lines of scales were removed from the exposed ventral side and a 3 cm incision running anteriorly was made starting at approximately 2 cm from the anus , and 2 cm laterally from the midventral line (Zeller 1999). Once the dummy tag was implanted, the wound was closed with monofilament, non-absorbable sutures and an antibiotic injection of oxytetracycline was administered intramuscularly. The fish was then transferred back into the same holding tank with air or oxygen bubbled underneath their gills and fresh seawater introduced periodically. Once the dhufish was showing signs of recovery (tail kicks or finning), a sling was used to transfer the fish from the tank to the sea cage. A wet towel was used with all handling and transfers to reduce stress and damage. The sea cage was then slowly lowered to the bottom.

Monitoring fish survival and behaviour

Divers monitored fish in the sea cages recording swimming and cage position, stress colours and other relevant behaviour. Although monitoring was planned for several time periods; immediately after release into the cage, on day one and on the day of release (either day two – four) this was not always possible due to weather and logistical constraints.

Study sites,

Houtman Abrolhos Islands

The Houtman Abrolhos Islands consists of around 122 low lying islands and associated reefs some 60 km offshore of Geraldton on the Western Australian mid west coast (Figure 4.3). These islands are concentrated into three major island groups, the Wallabi, Easter and Pelsaert groups. Each of these groups is separated by 6 – 10 km wide, 40m deep channels (Anon 2001). The islands are surrounded by the most southern coral reefs in the Indian Ocean

inhabited by tropical species of fish and invertebrates. This habitat is unique because tropical reefs co-occur with temperate algae species endemic to Western Australia (Anon 1998).

The work to date on reproductive potential has been conducted primarily in the Reef Observation Area (ROA) at the Easter Group of the Houtman Abrolhos Islands (Figure 4.3). The underwater visual surveys were conducted within a range of habitats around the Leo's ROA (Figure 4.4).

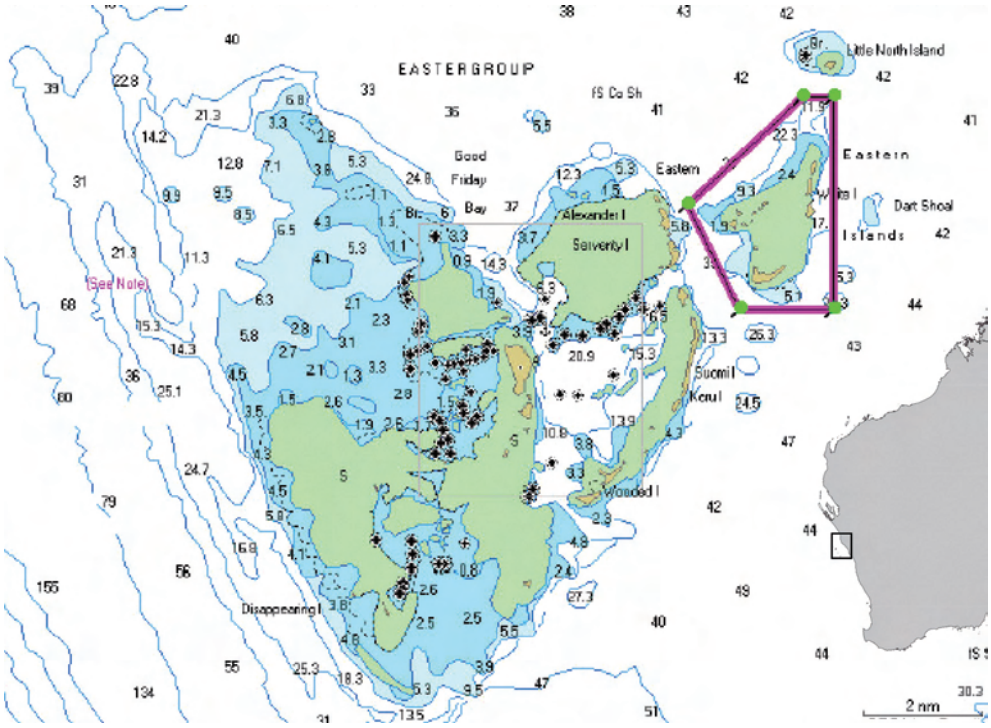

Figure 4.3: The Easter Group of the Houtman Abrolhos Islands featuring the Reef Observation Area (ROA) bordered in pink

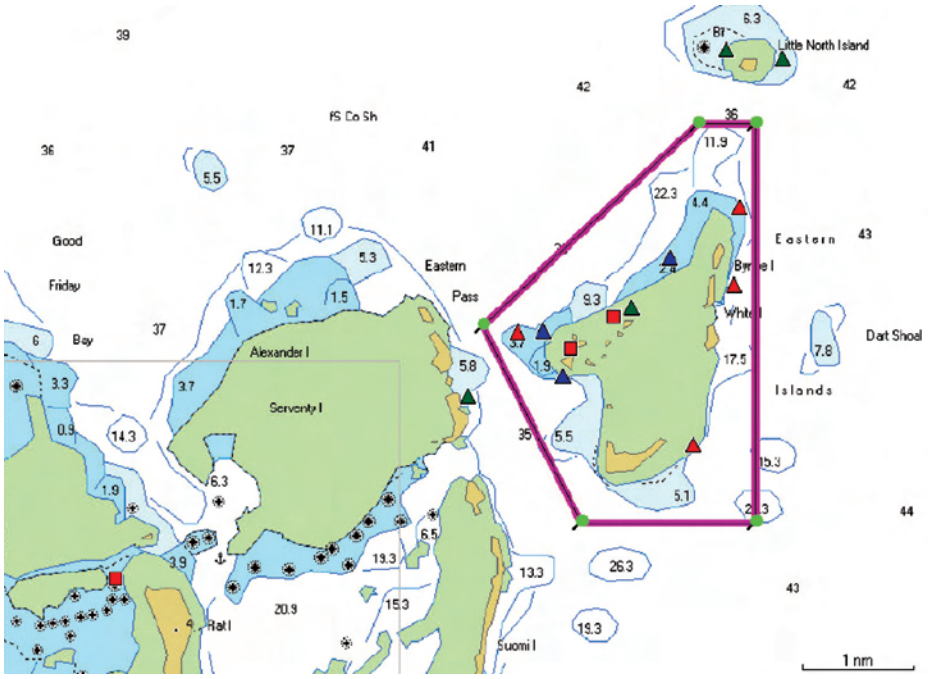

Figure 4.4: Underwater visual census of habitats around the Leo Island ROA at the Easter Group of the Houtman Abrolhos Islands. ▲ Coral Drop offs ▲ Deep Sites ■ Channels ▲ Snorkels

Dhufish Movement / Acoustics tagging

Initial trials of surgical techniques to implant acoustic tags into the WA dhufish were done near Meelup Bay, Geographe Bay (Figure 4.5) and the majority were done near Five Fathom Bank, Perth (Figure 4.6).

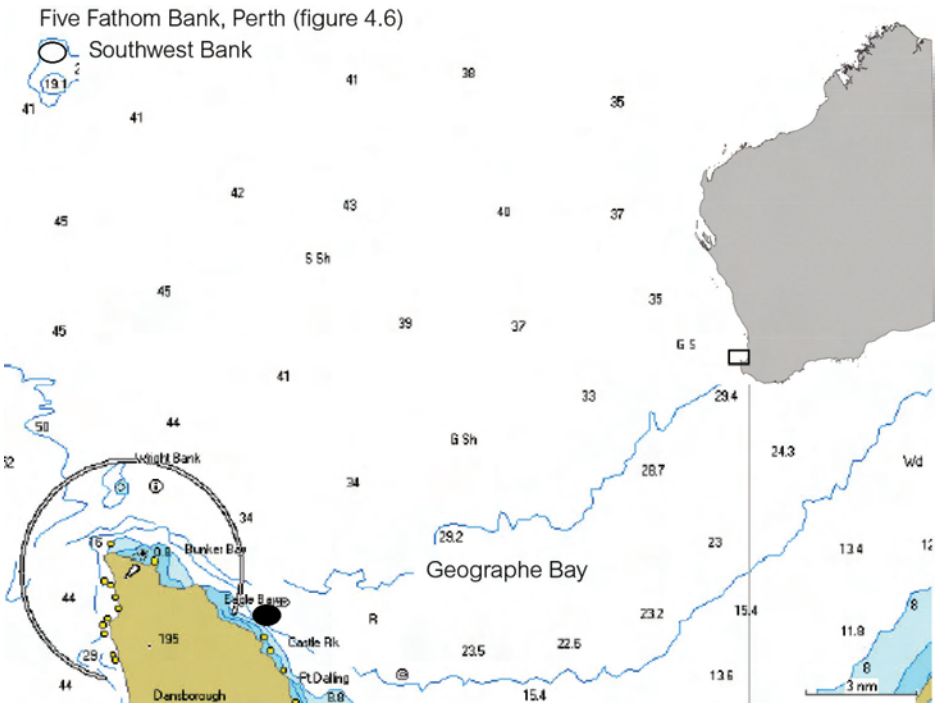

Figure 4.5: Capture location (open circle) and surgical and caging area (full circle) for initial trials on dhufish surgery in Geographe Bay, Western Australia

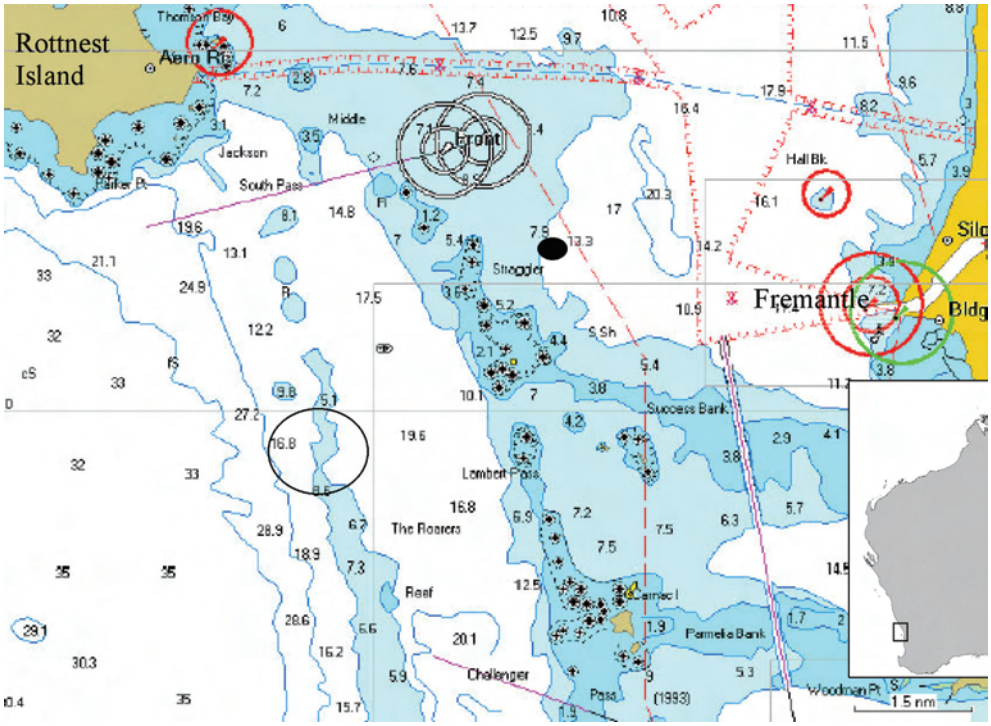

Figure 4.6: Sites were fish were caught (large open circle) for dhufish trials off Fremantle. Some fish were caged at the capture sites while others were caged in more sheltered waters (closed circle).

Results

Biology of *P. leopardus* and *L. miniatus*

259 *L. miniatus* and 100 *P. leopardus* have been processed with approximately 400 *L. miniatus* and 60 *P. leopardus* collected. However, aging and histological examination of gonads has not yet commenced.

Reproductive Potential

Plectropomus leopardus Spawning Aggregations

During the visual censuses two small areas had higher numbers of *P. leopardus* and were identified as potential aggregation sites. Both areas were drop offs on the eastern slopes of the ROA (Figure 4.4). On the 28th of February 2006 (the new moon), at 1645 – 1745, the first of these two sites was revisited and a spawning aggregation was discovered. A count of *P. leopardus* at the aggregation was done by two divers drifting side-by-side 35m through the aggregation counting every *P. leopardus* they could see (approximate visibility of 20m). 61 fish were counted. The drift was done once. Males were observed to be territorial and were displaying to males (presumably to defend their territory) as well as directly towards very gravid females.

Due to logistical constraints the site could only be snorkeled on again the next morning at 0830 and evening at 1630, and as such was unable to be quantified. Approximately 1/3 of the fish present the night before, mostly larger males with a few smaller females were still at the site. One day after the aggregation was first seen, only large males were present with two large females arriving toward the end of the snorkel.

Lethrinus miniatus Abundance

The abundance of *L. miniatus* numbers was low in all of the habitats surveyed. Of 28 transects surveyed, only six fish were recorded, averaging 0.2 fish per 500m^{-2}. *L. miniatus* were absent from the channel habitat, and were found in the deep and drop off habitats only, in low numbers (Figure 4.7). The size of the *L. miniatus* surveyed was 34.2 cmTL (±1.5SE; range 30 – 40 cmTL).

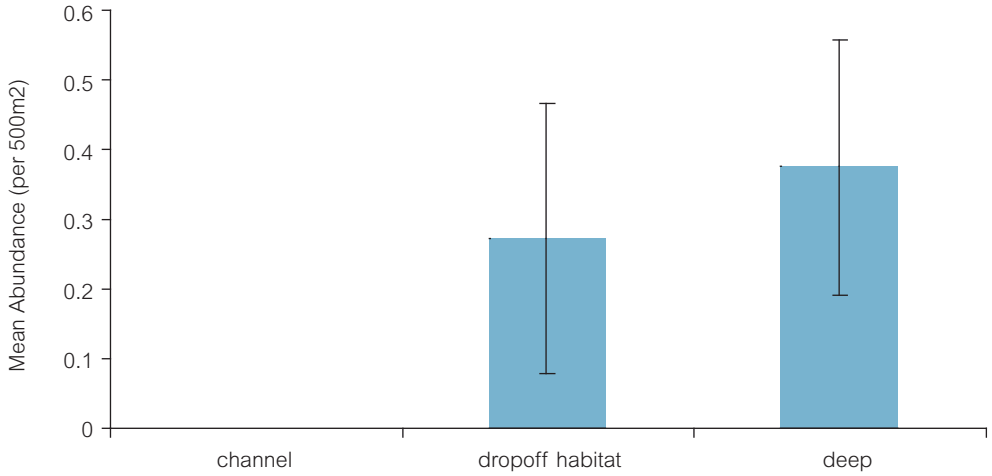

Figure 4.7: Abundance of *L. miniatus* in three habitats in the Leo ROA at the Houtman Abrolhos Islands (SE error bars).

Dhufish Movement / Acoustic Tagging

Surgical Trials on Cultured Species

Of the six cultured fish that underwent surgery half are still alive. Both of the mulloway and one pink snapper are still alive after 147-8 days. The tarwhine died after 78 days and two pink snapper died after 15 and 62 respectively.

Table 4.1. Details of surgery performed on each aquaculture reared individual

Date Operated On	Species	Dummy Tag	OTC	Died?	Days Survived
11/10/2005	Mulloway	No	No	Still Alive	148+
12/10/2005	Mulloway	Yes	Yes	Still Alive	147+
11/10/2005	Pink Snapper	No	No	12/12/2005	62
12/10/2005	Pink Snapper	Yes	Yes	Still Alive	147+
12/10/2005	Pink Snapper	Yes	Yes	27/10/2005	15
12/10/2005	Tarwhine	Yes	No	29/12/2005	78

Post mortems on the dead fish found that the first pink snapper that died after 15 days appeared to have an infection (skin was a red colour and swim bladder was very bloated, Figure 4.8a). Note that the body cavity was full of fat (Figure 4.8b), which is common for cultured fish (S. Kolkovski pers com.).

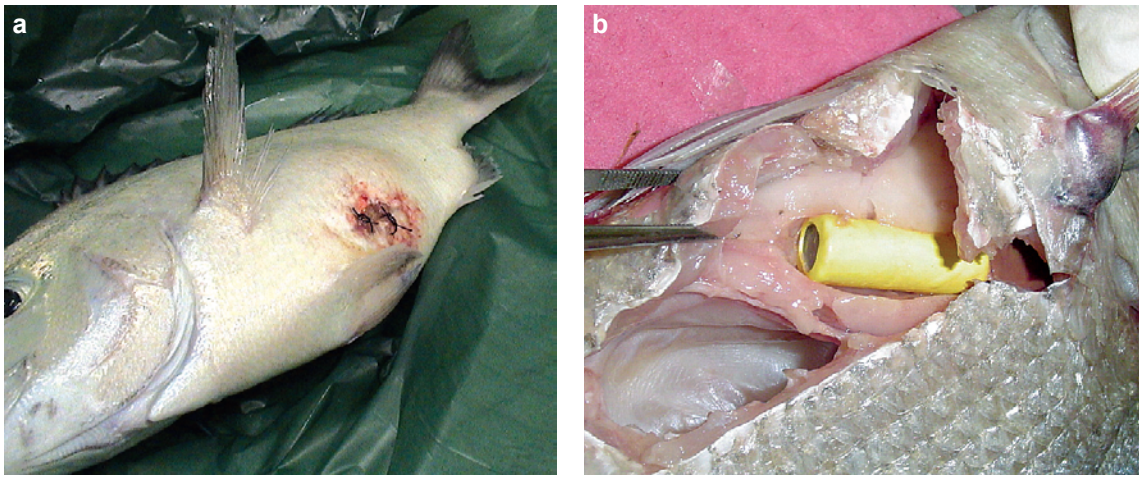

Figure 4.8: Post mortem photos of pink snapper that died after 15 days. a) showing bloated swim bladder and red skin from infection; b) position of the dummy tag in the body cavity and the large amount of fat reserves

The post mortem on the second pink snapper that died after 62 days found a different cause of death. The intestine appeared to be stitched (Figure 4.9a) and the fish had no fat reserves indicating that the stitch reduced the ability of the fish to feed and the fish died after utilising all of its existing fat stores.

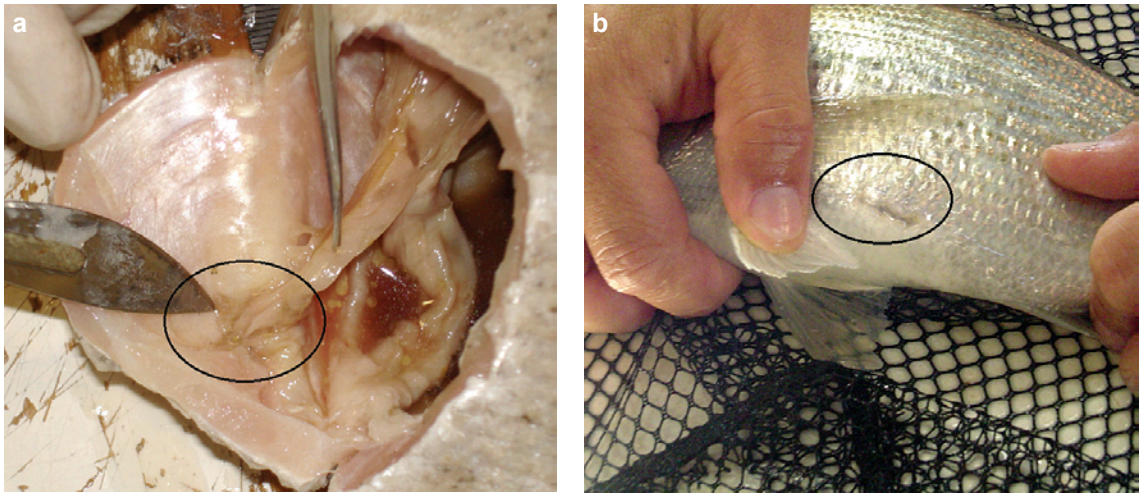

Figure 4.9: a) Intestine of pink snapper stitched to body wall; b) wound recovery in the Tarwhine (wound circled)

Of the remaining fish that died, there was no obvious cause for the death for the tarwhine after 78 days. The wound in the tarwhine showed good repair and was completely covered with a new layer of scales 40 days post surgery (Figure 4.9b). This death, therefore, may be explained by normal mortalities associated with rearing cultured fish rather than an artefact of the surgery.

Field Trials on Dhufish

Field surgery was attempted on nine dhufish. Of these, one was aborted due to the stitches pulling through the flesh on a very small fish (31cm TL). Three were in poor condition after capture and handling before surgery due to 1. being held too long in the holding tank while transporting from capture site to caging site, 2. being too small for the large tag (39cm TL) and 3. being not fully recovered (poor swimming on the surface). In these cases both surgery and/or recovery was continued to establish limits for survival, time held on boat, fish size, and degree of recovery.

Of the other five fish that were implanted with dummy tags, two survived surgery and were released either two or four days after surgery and three dhufish died with no obvious explanation. The fish that died all showed good initial recovery either on the surface or when initially dived on, however when they were to be released, (2, 3 and 4 days post surgery), were dead.

Because of survival problems in apparently healthy fish, three fish were used in control experiments to test the various stages of the process. To determine if catch mortality was responsible for some of the deaths, two fish were held on board for 6 and 18 minutes respectively, before being released back into the cage for 4 days and four hours respectively. Both fish are still alive, surviving caging, cage retrieval and transportation to the Department of Fisheries (DoF) tanks at Hillarys.

To determine the effects of the anaesthesia one fish was held on board for 6 minutes before being anaesthetised and placed in a holding tank for recovery. No surgery was done. This fish was released into a cage. On retrieval 4 days later, the fish had been stolen.

Discussion

Reproductive Potential

Plectropomus leopardus Spawning Aggregations

An aggregation was discovered off the northern tip of Bynoe Island within the Leo ROA and a preliminary survey was done, however, sizes of fish were not estimated. The aggregation appeared to be there only on the new moon night and was almost non existent the following night. Ideally a number of aggregations should be described to get a more accurate picture of spawning aggregations within ROAs at the Houtman Abrolhos Islands. Another avenue to be explored is the movement of eggs, or larvae from the aggregation site to outside the ROA as the aggregation is in an area of strong current movement, and near the northern edge of the ROA. Tracked over several days, this movement will demonstrate potential egg movement outside the ROA from an aggregation inside. The feasibility of such a project is currently being assessed.

Lethrinus miniatus Abundance

A large number of individuals is required to compare the abundance and size distribution of *L. miniatus* between areas open and closed to fishing and to compare reproductive differences between the two management areas. The pilot study on habitat preference revealed low numbers of *L. miniatus* in the habitats surveyed.

L. miniatus appear to be a deep water species and not abundant in shallow waters, although surveys were limited by depths at which SCUBA surveys could be conducted (approximately 18m). Fish processed for biological information were of a similar size of those counted in the transects. They were found to be either immature (n=12) or in a non reproductive state (n=1).

Results of the pilot study suggest that determining the reproductive potential of *L. miniatus* at the Abrolhos Islands is not possible using existing methods.

Dhufish Movement

Surgical Trials on cultured Species

Of the three cultured species that underwent surgical trials, mulloway may be best suited to coping with surgical tagging. However, all species seem to cope well with initial recovery from surgery when held in tanks and most survived for reasonable time periods in captivity. Egli and Babcock (2004) held wild caught pink snapper for an average of average 6 days (minimum of 24 hours) both pre and post surgery, before re-release at the capture location. There was no postoperative mortality during the holding time.

The results of surgical trials suggest that the surgical methods used on these individuals is a suitable technique which could be used on other wild caught fish, eg. dhufish.

Field Trials on Dhufish

The trials of the surgical methodology developed from the cultured fish were not as successful on the wild caught dhufish but there was no pattern that explained either all survivorship or mortality. It is likely that the high stress levels from capture, combined with surgery and recovery in a relatively exposed cage, may cause an accumulation of a number of sub-lethal stresses, which then culminate in the death of the fish.

Other options to reduce stress on fish are being explored, including holding them in either tanks or cages in the field before surgery is done. Initial trials show that fish survive capture and release into cages at the site and/or transport back to the mainland into holding tanks. The next stage is to ensure surgery techniques of wild caught dhufish kept in captivity are not fatal. As surgery of culture fish was mostly successful, this appears to be highly likely.

Acknowledgements

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Conference attendance and presentations

Conferences Attended:

International Marine Protected Areas Congress; Geelong 2005

Other Presentations:

Proposal Seminar, Department of Fisheries October 2005

Spawning Aggregation Workshop; Department of Fisheries W.A., September 2005

Proposal Seminar, Edith Cowan University, September 2005

AMSA Student Workshop; Rottnest Island, June 2005