FINAL REPORT

NOAA General Coral Reef Conservation Program

Grant No. NA04NMF4630342: "A pilot stock enhancement project for grouper in Palau"

Principal Investigator: Mark H. Tupper, Ph.D.

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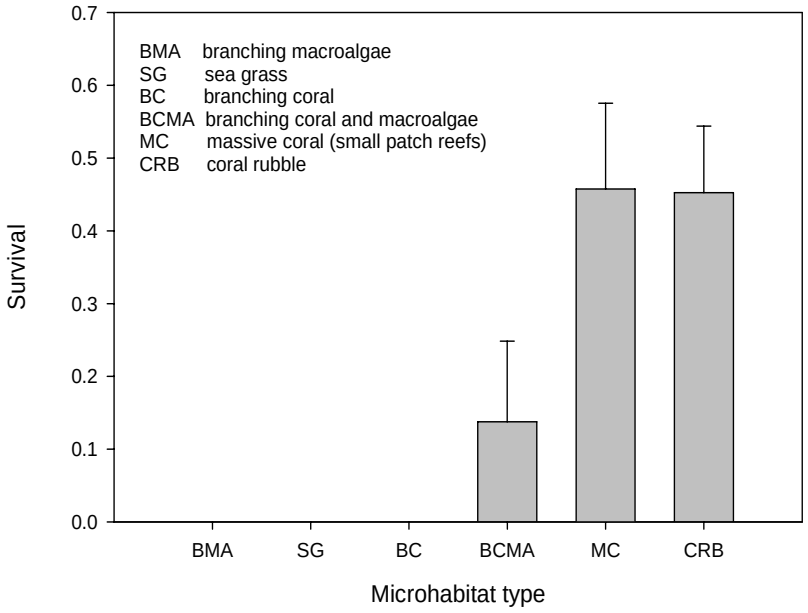
Introduction

The greatest impediment to creating meaningful fishery management plans in the Pacific Islands is the lack of biological knowledge about the species to be managed. Essential spawning and nursery habitat for Pacific reef fishes is virtually unknown. In order to effectively manage these fishes, information is needed on their habitat associations and the extent and location of essential habitat. This is particularly true if management is to involve the use of MPAs or other ecosystem-based approaches, or if managers are to attempt stock enhancement of reef fishes through release of hatchery-reared juveniles. Previous projects involving release of cultured Nassau grouper (*Epinephelus striatus*) in the Caribbean were deemed failures (Roberts et al. 1995). In Palau, the Bureau of Marine Resources (BMR) has successfully reared several hundred thousand juvenile (age 0) brown-marbled groupers (*Epinephelus fuscoguttatus*). The BMR wanted to use these juveniles to begin a stock enhancement program in Palau, but they lack (1) the technology to mark small juveniles (25-35 mm TL), and (2) information on the locations and characteristics of appropriate nursery habitats into which the fish should be released. Recently, research funded by NOAA (grants NA16FZ2958 and NA03OAR4170083) has succeeded in identifying essential nursery habitat for young of year groupers, including *Epinephelus fuscoguttatus, E. polyphekadion, E. fasciatus, Plectropomus areolatus, P. laevis,* and *P. leopardus* in Palau. Wild juvenile E. fuscoguttatus were found to survive and grow better in coral rubble and small patch reefs consisting of massive corals (Figure 1). We proposed to develop a pilot stock enhancement program in which juvenile brown-marbled grouper would be marked with injections of visible implant elastomer and released into known (mapped) nursery habitats. Where possible, cultured grouper were to be released into nursery habitats protected within one of Palau's Conservation Areas.



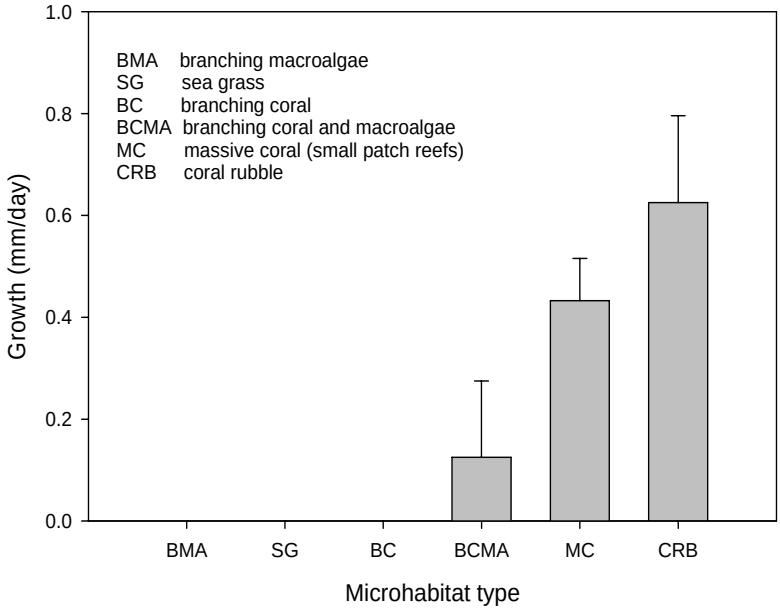


Figure 1. Survival (proportion of tagged juveniles remaining after 3 months) and growth of tagged wild brown-marbled grouper (*Epinephelus fuscoguttatus*) in Palau. Tupper, unpublished data.

Methods

During the project period, the BMR hatchery was able to produce *E. fuscoguttatus* fry, but not in the quantities expected. We were therefore only able to tag and release 400 juveniles (200 each in October 2006 and March 2007). This is far fewer than we had originally planned, but we were able to tag and release them at a larger size (mean ~ 30 mm total length), thus ensuring a low mortality from the tagging procedure (see Tupper 2007). When the BMR originally suggested tagging 20,000 individuals, these would have been pre-settlement size fish (around 12 mm) and mortality would likely have been very high. In October 2006, 200 fingerlings were marked by injection of visible elastomer implant (Northwest Technologies, Inc.) and equal numbers (50) of marked fingerlings were released into appropriate nursery habitat at 4 sites within Ngeseksau, between Babeldoab and Koror (see Figures 2a and 2b). This tag and release process was repeated in March of 2007.

Juvenile brown-marbled grouper recruit primarily into coral rubble along channel edges at a depth of 6-8 m and small patch reefs on channel bottoms and in lagoons, at depths of 10-15 m (Tupper, unpublished data). Two of the four release sites were in coral rubble habitat along the sides of the Ngeseksau channel and two consisted of small patch reefs at the channel bottom. Because the juveniles are highly cryptic at this point, and the water in this habitat is often turbid due to current flow, visual census techniques rarely detect the presence of these fish. The juveniles are best censused either by suction or by the use of an anesthetic such as Quinaldine or Eugenol (clove oil). Over the past few years, we have successfully used a 10% solution of Quinaldine sulfate in seawater to capture, mark, and recapture several hundred juvenile groupers and humphead wrasse in these same nursery areas (Tupper 2007). We have seen no adverse effects of Quinaldine on coral or other invertebrates, despite several hundred applications over the course of a year. We therefore used anesthetic to recapture marked individuals from nursery habitats at the Ngeseksau sites. Prior to this study, staff at Palau International Coral Reef Center were trained in the capture and tagging procedure using the lyretail grouper (*Variola louti*) as a test species (Figure 3). Lyretail grouper are highly abundant at Ngeseksau and elsewhere around Palau and are easily captured.

For a period of 2 weeks after each batch was released, each of the release sites was searched daily (whenever possible) for marked groupers by injecting a small dose of anesthetic into appropriate areas of rubble or small coral patches. Our original plan had been to conduct weekly censuses for a period of 3 months, but is was evident after only 2-3 days post-release that the hatchery-reared fish were not site-attached like wild juveniles, and they dispersed rapidly from the release site.

During each of the daily censuses, divers searched for marked individuals by swimming concentric circles of increasing radius (0 m, 1 m, 2 m, 5 m, 10 m, 20 m, 30 m, 50 m, and 100 m) around each release point (see Tupper 2007). Captured fish were recorded and immediately released with a minimum of handling, at the point of capture. Their exact distance from the original release point was determined using hand-held GPS.

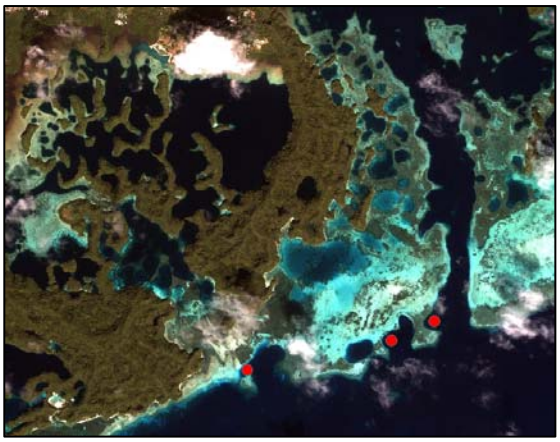


Figure 2a (above): aerial view of Ngeseksau. Red dots indicate release sites of tagged brown-marbled grouper. Figure 2b (below): map of Palau main islands showing location of Ngeseksau study site.

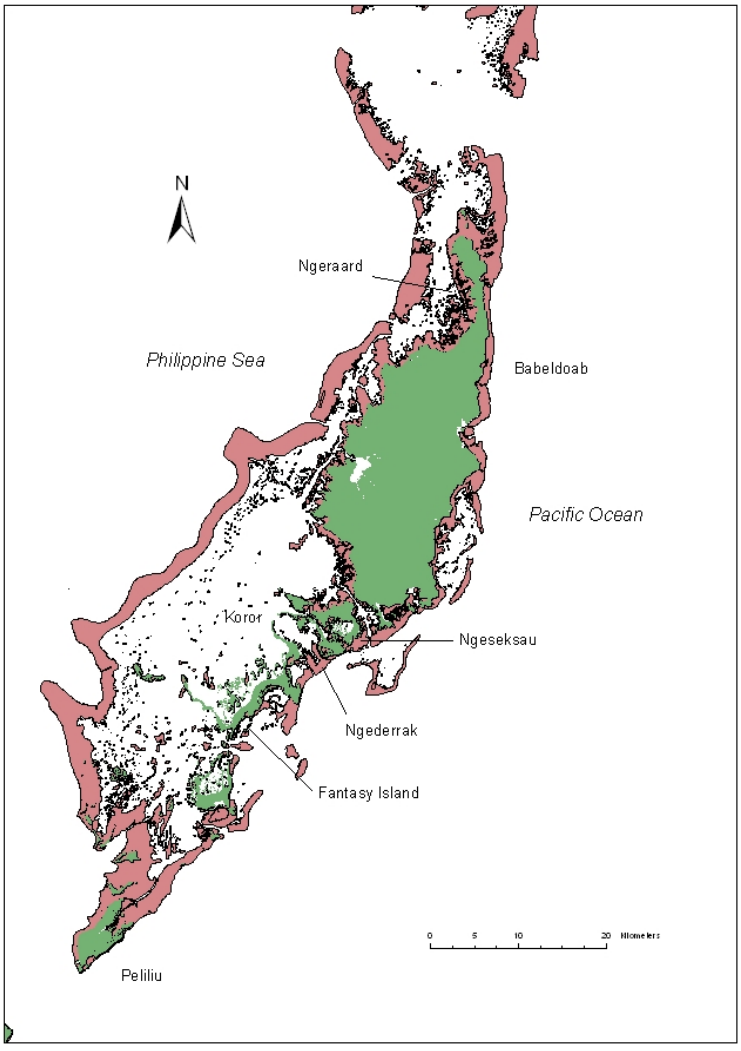


Figure 3. Training of local Palauan researcher in tagging methodology, using Lyretail grouper Variola louti as a test species.

Results

Only 18 of 400 tagged fish (11 in 2006 and 7 in 2007) were recaptured over the course of this study. In both years, all fish had disappeared from the release sites with 12 days of release. The mean distance of recapture was 4.3 ± 3.7 m from the original release site over 11 days in 2006 and 3.6 ± 4.1 m over 10 days in 2007. This interannual variation in distance moved was not statistically significant (Mann Whitney Rank Sum Test, $U = 248.5$, $p > 0.4$). The mean number of days that tagged fish remained within 100 m of the release site was 4.2 ± 3.0 days in 2006 and 4.6 ± 2.9 days in 2007. There was no significant interannual variation in the number of days that tagged fish remained near the release site (Mann Whitney Rank Sum Test, $U = 258.5$, $p > 0.5$).

Discussion

This project was not successful in that only a very small number of fish (400) were produced for the pilot stocking program, and even fewer (18) were recaptured, so little information is available on the feasibility of releasing groupers. In general, the technology and methodology used by the Bureau of Marine Resources should be sufficient to produce large numbers of juvenile grouper, as was the case in 2003 and early 2004. Unfortunately, water quality problems, staff turnover, and various other issues drastically reduced juvenile output during the course of this project. Problems also arose concerning the scheduling of boat use with PICRC once the project PI was no longer employed there. Arrangements with private boat operators and local divers were made to circumvent these problems. Ultimately, the data do suggest some interesting differences between wild-caught and hatchery-raised juvenile grouper in terms of site fidelity and movement patterns.

The most notable difference between the releases of hatchery-reared vs. wild-caught tagged juveniles was the lack of site fidelity shown by hatchery-reared fish. Tagged wild fish were still found at the release site up to 12 weeks after tagging, compared to 10-11 days for hatchery-reared fish. One possible explanation for this could be differences in seasonality of releases, but the October 2006 batch was released at the same time that similar size/age wild juveniles were recruiting to nursery habitats. Moreover, there was no difference between October and March releases in the length of time tagged fish spent at their respective release sites. One might assume that the need to stay close to shelter would be an inherent behavior in all juvenile fish. For example, the association of juvenile groupers, including *E. fuscoguttatus*, with shelter is well established and forms the basis of a widespread capture-based aquaculture industry in Southeast Asia (Mous et al. 2006). The only logical explanation I can offer for the behavioral differences between hatchery-reared and wild fish is that the hatchery fish were raised in large concrete tanks with little or no structure in which to take shelter. Juveniles in the hatchery tended to form large schools in the corners of the tank, and use safety in numbers rather than shelter. When releasing hatchery-reared fish at Ngeseksau, the fish did head for shelter, but only after several minutes of swimming together in a school. Based on many past observations of groupers in Palau, this is not a natural behavior. It was also observed that during this schooling period, several fish were lost to predation, primarily by the snapper *Lutjanus fulvus*.

From the results of this study, it is impossible to draw any solid conclusions about the usefulness of a stock enhancement program for groupers in Palau. Obviously the problems at the BMR hatchery need to be resolved before sufficient numbers of grouper juveniles can be produced. This will likely be the easiest problem to fix, as BMR has in the past produced large quantities of fry. A more pressing problem may be the apparent differences in behavior of released hatchery-reared fry. However, this behavior could possibly be changed by simply adding artificial (or natural) shelter to the grow-out tanks. This would require further experimentation to confirm.

Because the tagged fish all dispersed within 10-11 days, it is impossible to know what the survival and growth rates of hatchery-reared fish would be over the critical first 6 months, when groupers disperse from their nursery habitats to offshore or deeper lagoon reefs (Tupper 2007). In order to determine this, a much larger-scale, more expensive tagging experiment would be required, and the costs of such a study would probably be prohibitive, particularly given the risk of failure (i.e. too few recoveries for analysis).

Literature cited

Mous, P.J., Sadovy, Y, Halim, A., and Pet, J.S. (2006). Capture for culture: artificial shelters for grouper collection in SE Asia. *Fish & Fisheries*, 7:58-72.

Roberts, C. M., N. Quinn, J. W. Tucker, Jr., and P. N. Woodward. (1995). Introduction of hatchery-reared Nassau grouper to a coral reef environment. *N. Amer. J. Fish. Mgt.* 15:159-164.

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