The Arnavon Islands Marine Conservation Area: Lessons in monitoring and management

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ABSTRACT

The Arnavon Islands Marine Conservation Area (AMCA) was declared in August 1995 as a refuge for marine invertebrates. Protection from harvesting was done with agreement from, and active participation by, local communities. Protection was also facilitated by appointment of a local management committee and conservation officers. Using a sampling design based on the assessment of environmental impacts, variation in abundance of species at the AMCA and at three fished "reference" areas was established before declaration, and monitored over the next four years. The monitoring program designed to test the effectiveness of the AMCA was based on assumptions related to the effectiveness of compliance within the AMCA, patterns of exploitation outside the AMCA, the period of time required for any recovery in stocks and the suitability of habitat within the AMCA to support any such recovery. Marine invertebrates responded in different ways to the harvesting closure. Some species showed no change after 3 years, but several others showed responses that were consistent with an effect due to the AMCA. One species, *Tridacna maxim*a, increased in abundance across the region which, without the data from reference areas, would be incorrectly interpreted as an effect due to the AMCA. The study provides valuable lessons for the management of marine reserves: It highlights the need for close collaboration with participating communities, for understanding changes in fishing practices and effort within the region and for the design of rigorous monitoring programs to test the effectiveness of marine reserves.

Keywords Marine Reserve, BACI, Trochus, Sea cucumbers, Holothuria, *Tridacna*, Solomon Islands

Introduction

Marine reserves or sanctuaries are increasingly being seen as a tool for managing exploited marine species. Successful management of such areas requires that local communities are closely involved in the process, that there is a high level of compliance with regulations (or at least, the extent of non-compliance is known) and that there is some indication of the success of the reserve in either maintaining or increasing the diversity, abundance or size of the species that the reserve is meant to protect. If scientists and managers can reliably demonstrate that marine reserves can be successful, it will be far easier to convince local communities to maintain reserves or declare them in other areas. This paper presents the lessons learned from the declaration and management of a marine reserve at the Arnavon Islands, in Solomon Islands, which was designed to restore the abundance of a variety of commercially exploited tropical invertebrates.

The Arnavon Islands Marine Conservation Area (AMCA) is located in the north-west of Solomon Islands and covers an area of approximately 80 km^2 (Fig. 1). The Arnavon Islands are uninhabited; they are an important nesting area for Hawksbill turtles and have traditionally been exploited for marine invertebrates by three local communities who access the islands by boat. Marine invertebrates, mainly trochus and sea cucumbers, are an important source of income for the local region because they can be collected with minimal equipment and they can be preserved without refrigeration (i.e. by drying or smoking) pending dispatch to Honiara on local trading vessels. Surveys of the sales of invertebrates indicated that the region around the Arnavon Islands was a significant national supplier of such products (Holland 1994). However, there were local concerns that invertebrates were being over-exploited and a rapid assessment of the Arnavon Islands concluded that the abundance and diversity were less than could be expected, given the variety and extent of habitats present (Ramohia and Tiroba 1993).

During the mid-1990's, The Nature Conservancy (TNC) helped negotiate a management plan for the Arnavon Islands, which involved declaration of the AMCA. The AMCA was officially declared for a 3-year period in August 1995, with provision to continue the reserve depending on the outcome of monitoring results for invertebrates. Apart from invertebrates, the closure also applied to taking fish commercially or by spear. Line fishing, whilst permitted, was believed to occur only at low levels in the AMCA. The AMCA is administered by a management committee of 6 members, 2 personnel each drawn from the 3 participating communities. The committee meets quarterly, with the meetings being facilitated by TNC. Day-to-day management of the AMCA is the responsibility of 6 Conservation Officers (COs), who, like the committee, provide equal representation for the 3 communities. The tasks of the COs are to maintain the field station, patrol the AMCA, provide information to visitors and assist with data collection.

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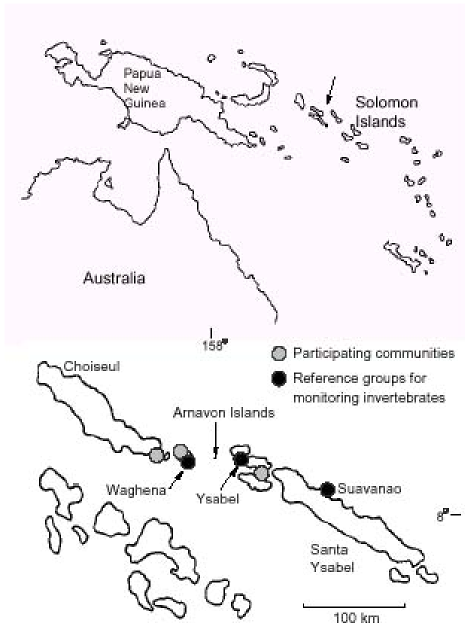

Fig. 1 Study area, showing location of the Arnavon Islands and reference areas, and the communities participating in the study.

Study rationale, assumptions and methodology

To provide information on the restoration of invertebrates for the Management Committee, abundances of invertebrates within the AMCA, and at 3 reference areas (i.e. places not subject to fishing closure), were estimated on 3 occasions prior to closure and on 3 occasions in 1998/9, 3 years after the closure. In addition, sampling was done at multiple spatial scales within each of the 4 areas, to enable evaluation of where major changes in abundance were occurring within the region (Fig. 2). This experimental design provides a relatively unambiguous test of the effectiveness of the AMCA (Lincoln Smith et al. 1997) and is based on models developed over the last twenty years to assess the impacts of human activities on aquatic ecosystems (Green 1979, Bernstein and Zaliniski 1983, Hurlbert 1984, Stewart-Oaten et al . 1986, Underwood 1993). An effect could be detected in several ways but, in simple terms, we would conclude that the AMCA was effective if the following conditions are met:

1. Differences in the number of exploitable invertebrates between the Arnavon Islands and reference areas are relatively small prior to the closure to fishing of the Arnavon Islands; and
2. Exploitable invertebrates at the Arnavon Islands become relatively more abundant than those surveyed at reference areas some time after the closure of fishing at the Arnavon Islands.

Note that under these conditions, even if exploitable stocks in the reference areas vary over time, or if there is a statistically significant difference in numbers between the Arnavon Islands and the reference areas prior to closure, it is the relative difference through time between the reference areas and the Arnavon Islands that is crucial to determining the success of the AMCA.

However, the success of this empirical test depends on four assumptions: 1) that the fishing closure at the Arnavon Islands is effective; 2) that fishing effort in the reference areas does not change during the study; 3) that the period of time between the before and after surveys is sufficient to allow for a significant recruitment to the exploitable stocks; and 4) that the small numbers of exploitable invertebrates reported from the Arnavon Islands (Ramohia and Tiroba 1993) are due to the effect of fishing rather than ecological processes (e.g. unsuitable habitat, poor natural settlement of larvae during the study period, etc).

The effectiveness of the closure depended on the acceptance of the AMCA by the local communities and/or the ability of the COs to discourage people from harvesting invertebrates within the AMCA. Given the presence of COs, and detailed negotiations with the communities and their commitment to the success of the AMCA, illicit fishing was not anticipated to be a problem. In relation to the second assumption, if fishing effort increased in the reference areas during the study with a subsequent decrease in the number of exploitable invertebrates, the analysis may lead us to conclude that the AMCA was effective when in fact it was not. This is because there would be relatively more invertebrates at the Arnavons compared to the reference groups after the closure than before. A further confounding factor is that effort may be distributed away from the Arnavon Islands into other parts of the region, including the reference areas.

Of potentially greater concern is the possibility that fishing effort in the reference areas decreased during the study, with a subsequent increase in the number of exploitable invertebrates, leading to the false conclusion that the AMCA at the Arnavons was not effective when in fact it may have been. This is because there would be relatively similar numbers of invertebrates at the Arnavons compared to the reference groups before and after closure. In such an event, an increase in abundance at the AMCA and reference groups through time would probably be interpreted as a natural phenomenon (e.g. large, widespread settlement events) rather than an effect due to reduced fishing at all sites. Given the relatively small human population of the region and the large amount of habitat from which invertebrates could be harvested, we predicted that the second assumption would be relatively secure for the period of the study.

The period of time allowed for recruitment of stocks is dependent upon the arrangements negotiated with the local communities who collect invertebrates at the Arnavon Islands.However, three years should be sufficient for a recovery of trochus (Nash 1993) and to observe significant growth in giant clams (Hart et al. 1998). Consequently the third assumption is reasonable, although little is known about the settlement and growth rates of sea cucumbers. The fourth assumption also seems reasonable on the basis that anecdotal information suggests that sea cucumbers and trochus were previously abundant at the Arnavon Islands and that Ramohia and Tiroba (1993) identified numerous locations at the Arnavon Islands considered to be suitable habitat for the invertebrates of interest. Moreover, according to Holland (1994), Ysabel Province is the third largest producer of sea cucumbers in the Solomon Islands, with most purchases coming from Kia, the closest major village to the AMCA.

As the exploitable invertebrates in the AMCA occur over a depth range of at least 0 - 30 m (Wright and Hill 1993), surveys were done in two distinct habitats: "shallow" and "deep" habitat. The shallow reef habitat ranged in depth from about 0.5 to 3.5 m and consisted mostly of flat terrace with live and dead coral. The deep habitat ranged in depth from about 15 m to 22 m and consisted of a relatively steep slope with sand and rubble substratum. Shallow reef was surveyed for trochus, giant clams, pearl oysters and sea cucumbers; the deep slope was surveyed only for sea cucumbers and pearl oysters. Pilot investigations were used to evaluate the appropriate size of transects (i.e. length and width) and the optimal number of replicates, based on statistical considerations (maximising the power of tests to detect spatial and temporal variation), logistics and safe scuba diving practices (Lincoln Smith 1994).

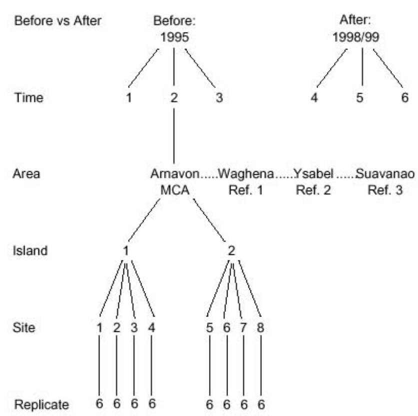

Fig. 2 Experimental design for testing the effectiveness of the AMCA. Note that replicate transects were sampled within both shallow and deep habitats, but the two habitats were analysed separately.

Surveys in the shallow habitat enumerated giant clams *(Tridacna* spp. and *Hippopus hippopus*), trochus *(Trochus niloticus*), pearl oysters and several sea cucumbers (e.g *Holothuria artra*, *Bohadschia graeffei*, *Chloronotus stichopus*, *Actinopyga mauritiana* and *A. miliaris*). At each site, one diver laid out a 50 m tape over the reef, then a second diver (the observer) swam along the tape holding a pvc "t-bar", which was a 2 m long pipe with a handle used to define the transect width of 2 m. The observer counted invertebrates within each transect (i.e. over an area or 100 m 2 per transect). Two teams of divers laid 3 transects each, giving a total of 6 replicates per site. Surveys in the deep habitat focused on sea cucumbers along coral, rubble and sand slopes. The deep habitat contains some of the most valuable species of sea cucumbers, including *Holothuria fuscogilva*, *H. fuscopunctata* and *Thelanota ananas*. At each site, two teams of divers each laid their transect line 3 times to count and measure sea cucumbers and pearl oysters, giving a total of 6 replicates per site. Each transect was 50 m long (defined by the tape measure) and 5 m wide (defined by a 5 m length of rope with a small float in the middle connecting the two divers).

Data were recorded on writing slates and transferred to log books at the end of each day. Data were analysed statistically using Asymmetrical Analysis of Variance, which provided a test of abundance at the AMCA against the abundance at all the reference areas simultaneously. In this way, we compared variability among reference areas to variability between the AMCA and the reference areas. The mechanics of the procedures are described in Underwood (1993) and detailed for the Arnavon Islands study in Lincoln Smith et al. (1997, 2000 and in review).

Results

Marine invertebrates responded in several different ways to the closure to harvesting at the AMCA. Some species showed no change in abundance that could be attributed to the AMCA (e.g. *Stichopus chloronotus*), but others showed responses that were consistent with an effect due to the AMCA. In general, 3 patterns emerged in the abundances of marine invertebrates.

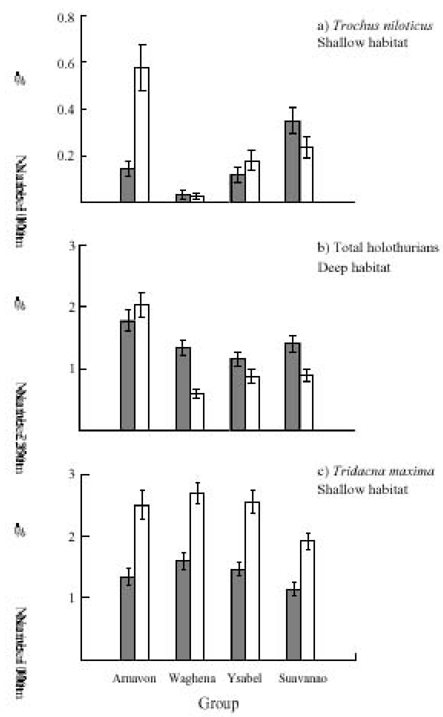

Fig. 3 Mean abundance (and SE) of selected invertebrates at the Arnavon Islands and reference areas before (shaded bars) and after (open bars) declaration of the AMCA. Means combine all sites and times within periods at each area.

First, numbers increased at the Arnavon Islands from before to after declaration of the AMCA and remained similar at the reference locations. This is exemplified by the abundance of *Trochus niloticus* within the shallow habitat (Fig. 3a). At the AMCA, numbers increased more than threefold (i.e. from about 17 to 60 individuals per hectare) in the 3 years following declaration.

It is noteworthy that, while there was a statistically significant increase in *Trochus* at the scale of the AMCA,there was also significant variation among sites within the study groups (Fig. 4). At the AMCA, increases were measured at all sites, but relatively large and statistically significant increases in mean abundance were measured at Sites 1 and 6, while much smaller increases that were not significant occurred at Sites 3 and 4. Thus, changes in abundance following declaration of the AMCA were far from uniform throughout the marine reserve.

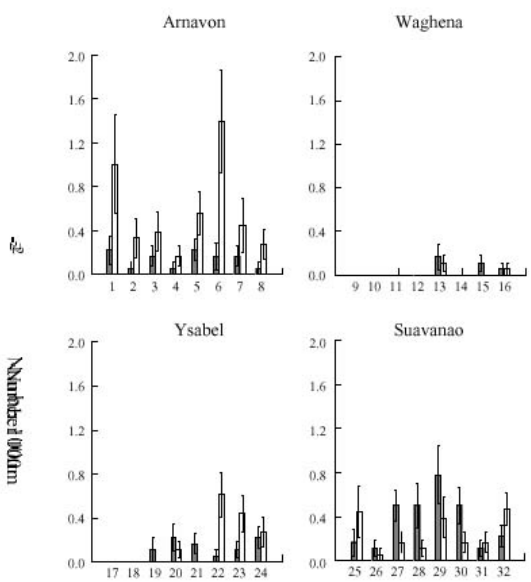

Fig. 4 Mean abundance (and SE) of *Trochus niloticus* at the scale of sites before (shaded bars) and after (open bars) declaration of the AMCA. Means combine all times within periods at each site.

The second pattern, exemplified by the total number of sea cucumbers in the deep habitat, showed no significant increase in abundance within the AMCA, but significant decline through time within the reference areas (Fig. 3b). This might be due to continued exploitation of invertebrate resources outside the AMCA. Thus, the marine reserve could have arrested within a small area a continuing trend of overexploitation within the region.

The third pattern identified a trend for increasing abundance throughout the region, both within and outside the AMCA. This was shown for abundance of the giant clam, *Tridacna maxima* (Fig. 3c). Without the information from the reference areas, data from the AMCA would suggest that the marine reserve had facilitated an increase in the abundance of this species.The findings for the reference areas, however, indicate that broad changes have occurred in the abundance of this species over the region.

Discussion

The variable patterns observed in the abundance of marine invertebrates at the AMCA indicated that, whilst the closure was effective for some species, it was either not effective or showed ambiguous results for others. The outcome of the study suggested 5 general lessons that might help in the design and management of marine reserves, the first 4 of which relate directly to the study assumptions described above

Lesson 1: The importance of ensuring the effectiveness of the fishing closure within the AMCA.

Quite clearly, unless we can ensure that management rules governing harvesting within the AMCA are enforced, we cannot assess whether the marine reserve is working. If harvesting continues and we assume that rules are being complied with, we would probably conclude that the reserve is ineffective due to natural factors rather than social ones. This is exemplified by the small scale variability in abundance observed for trochus within the AMCA, which could indicate variable quality of habitat or poaching on some reefs.

The use of COs drawn from local communities appeared generally to be effective, but some incidents of poaching of trochus was reported. Fortunately, it appears that most of the poachers were intercepted and it is known that local communities also helped to deter poachers. To assess the effectiveness of the AMCA, it is important to ensure minimal poaching or, at the very least, to have some measure of how significant poaching is. This requires the strong support of the local communities.

Thus, the lesson here is that compliance is essential for both the management of marine reserves and the interpretation of monitoring results. There is little point in declaring a reserve if resources are not made available to ensure compliance or at least understand the extent of non-compliance.

Lesson 2: Determining if fishing effort in the reference areas changed during the study

An implicit assumption sometimes made in the management of marine reserves is that fishing effort will not change outside the reserve. The second pattern identified in this study suggested that there may have been an increase in the take of sea cucumbers outside the AMCA. This might be due to continued over-fishing at the same level of effort, with continued fishing-down of stocks. Alternatively, it may be due to a re-distribution of effort from the AMCA across the region following declaration of the reserve. Given the very large area of the study (spanning > 100 km), and the fact that there is a very large amount of suitable habitat available outside the AMCA, we do not consider that the closure of the Arnavon Islands would have affected abundance of harvested sea cucumbers outside AMCA, but we have no hard data to support this. In some situations, where a large proportion of the available habitat may be within a marine reserve, there is a strong possibility that significant effort would be distributed from inside to outside the reserve following exclusion of harvesting.

An important lesson from this is that researchers should try to evaluate how fishing might change outside a reserve either as a result, or independently of, the reserve.

Lesson 3: Evaluating if the period of time between the Before and After surveys was sufficient

The monitoring program revealed a range of responses by different species, including some species that showed no detectable change over the period of the study. Furthermore, the recovery of other species, whilst statistically significant, was small in terms of populations densities we might expect from studies elsewhere. For example, the average density of trochus within the AMCA after 3 years was about 60 ha^{-1}, with maximal densities at one site of up to about 140 ha^{-1}. Nash et al (1995) reported mean densities of 222 – 2,016 trochus ha^{-1}, with maximal densities of 2,775 ha^{-1}, while Tsutsui and Sigrah (1994) reported maximal densities of 1,290 trochus ha^{-1}. Preston (1993) described densities of several sea cucumbers on reefs in the Pacific that were much greater than recorded in the AMCA 3 years after declaration. The period of the study was determined largely by timing set by the Management Committee, but it was also assumed that three years would be a suitable period to show recovery.

There are two lessons that should be considered in the design and management of marine reserves. First, the recovery period is likely to be species dependent and may take many years, even decades. In the case of the Arnavon Islands, the encouraging monitoring results have been used to argue successfully for a continuation of the AMCA. Second, marine reserves may not be effective for some species and different forms of management (e.g. complete closures, re-stocking, size/bag limits) are probably necessary in such cases.

Lesson 4: Determining the extent to which restoration was affected by natural ecological processes

The large variation in abundance of trochus among sites within the AMCA may reflect large natural variability (and some effects of poaching – see above) such as differences in the quality of habitat, variable larval settlement, etc. We suspect, however, that many reserves are dedicated on the assumption that the habitats would, in the absence of fishing pressure, support large populations of harvestable biota.

Interestingly, this assumption is generally not an issue when using the similar experimental designs in environmental impact assessment. Where a human disturbance is administered to an area, the issue is how the biota change from a "natural" baseline (for a pulse or press disturbance – Bender et al. 1984) and then possibly how they recover (for a pulse disturbance). In the case of a marine reserve, the human disturbance (i.e. fishing) is removed or reduced and we rarely, if ever, have information on the baseline before fishing began in that area.

An important lesson here is that study designs to test the effectiveness of marine reserves should incorporate sampling at multiple spatial scales and allocate as many sites as possible within the marine reserve and reference areas to provide a measure of natural variability.

Lesson 5: Use of the study design incorporating multiple reference areas, times and spatial scales.

The study design used provides a more robust test of the success or failure of a marine reserve than simply relying on anecdotal evidence or sub-optimal sampling designs (see also Lincoln Smith et al. in review, which focuses in detail on how environmental impact designs can be used for studies of marine reserves). Importantly, it helps to avoid the incorrect interpretation of trends within the reserve. The example here is the abundance of *Tridacna maxima*, which showed an increase within the region beyond the AMCA. We attributed this increase to a probable broadscale settlement event during the study period, although it could have been due to growth and therefore greater visibility of a pre-existing cohort. The study design can also be readily adapted for future sampling with increasing statistical power. For instance, the AMCA study could be expanded by sampling the same sites in another 3 years to enable a comparison of longer term changes against the baseline (before declaration) and against the shorter term changes after the first 3 years. The lesson here is that a rigorous study design will enhance the assessment of marine reserves and it can be built upon to test changes as the reserve matures or to test the effectiveness of future management strategies.

Conclusions

The findings of this study identify the need for close collaboration between all stakeholders, especially communities most likely to be affected by the implementation of a marine reserve. The findings also demonstrate the utility of adopting a rigorous approach to monitoring, including the use of reference areas and allocation of sufficient time to establish a baseline of information before the reserve is declared. This type of approach requires considerable resources. Furthermore, our results suggest that this must also be supported by maintaining the commitment of local communities and collection of information on social factors, particularly the extent of compliance within the reserve and patterns of exploitation outside the reserve. At a time when marine reserves are being seen as one significant way of preserving and/or restoring stocks and biodiversity, careful planning and implementation of management and monitoring programs will help to ensure that effort is not wasted on sub-optimal reserves or management practices, and that more convincing arguments are made for maintaining effective reserves and sound management practices.

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