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Contrasting effects of marine protected areas on the abundance of two exploited reef fishes at the sub-tropical Houtman Abrolhos Islands, Western Australia

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SUMMARY

A unique assemblage of tropical and temperate marine organisms characterizes the Houtman Abrolhos Islands, four clusters of islands and reefs off the coast of mid-Western Australia. Four reef observation areas or marine protected areas (MPAs) were established in 1994 to examine their value in protecting vulnerable reef fish species, including the sub-tropical wrasse, *Choerodon rubescens*, and the coral trout, *Plectropomus leopardus*. In 1993 and 1994 (prior to protection), population densities and body sizes were monitored at two island groups (Easter and Wallabi). At each location, the MPAs and the equivalent 'control' areas to remain open to fishing were monitored by underwater visual censuses. These closed and open areas were subsequently monitored four more times between 1995 and 2002 to assess long-term trends in abundance and population structure. Populations of the wrasse, *C. rubescens*, did not appear to respond to protection, exhibiting irregular fluctuations in both closed and open areas throughout the study. In contrast, although there were no significant increases for *P. leopardus* for the first three years of closure, after eight years of protection there were significantly larger numbers of *P. leopardus* in the closed areas. There was a three-fold increase at the Easter Group and a seven-fold increase at the Wallabi Group, relative to open fishing areas, attributed primarily to reduced fishing mortality. Significant closed areas (17% of the *P. leopardus* habitat) provided substantial stock-wide impacts. The data also indicate that the MPAs can be effective where some forms of fishing (such as lobster fishing) are permitted which are compatible with the objectives of the MPA. While MPAs are clearly an effective tool for increasing the local abundance of some reef fishes, the spatial and temporal scales required for their success may vary among species.

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INTRODUCTION

Coral reefs support important fisheries throughout the tropical and sub-tropical oceans of the world and, in recent decades, many reefs in south-east Asia and the Caribbean have suffered serious habitat damage and overfishing of large reef fishes such as grouper (Serranidae), humphead wrasse (Labridae), snapper (Lutjanidae) and parrotfish (Scaridae) (Morris *et al.* 2000; Sadovy 2001; Sadovy & Vincent 2002).

The Houtman Abrolhos Islands and their surrounding coral and limestone reef systems off Western Australia are highly productive, possibly because their high-latitude location enables a combination of abundant temperate macroalgae with the habitat structure of coral reefs (Hatcher 1985). The whole reef system has been declared a Fish Habitat Protection Area by the Department of Fisheries, Western Australia (DoFWA). The system supports a significant part of the fishery for western rock lobster (*Panulirus cygnus*), which is a model of good fisheries management. The sandy areas between and inshore of the reef systems are also productive with a fishery for saucer scallops (*Amusium ballotti*) managed by ensuring that a sufficient part of the annual spawning occurs prior to the opening of the fishing season. A conservative catch quota protects pelagic fish in the vicinity (Penn 2002).

There is also a fishery (commercial and recreational) on the demersal reef fish that is not currently subject to management, except for minimum legal sizes and recreational bag limits. While there is no evidence in the catch-per-unit-effort time-series that these fish are overexploited, their potential vulnerability to overfishing has been recognized and measures to limit fishing effort are to be implemented within a few years.

Within the Fish Habitat Protection Area, four 'reef observation areas' (i.e. marine protected areas [MPAs]) have also been declared, where no fishing other than rock lobster potting is permitted (Anon. 1998). Collectively, the MPAs constitute approximately 5% of the total area of the state territorial waters of the Abrolhos Islands and 17% of the shallow water lagoonal reef habitat (Fig. 1). Protection from

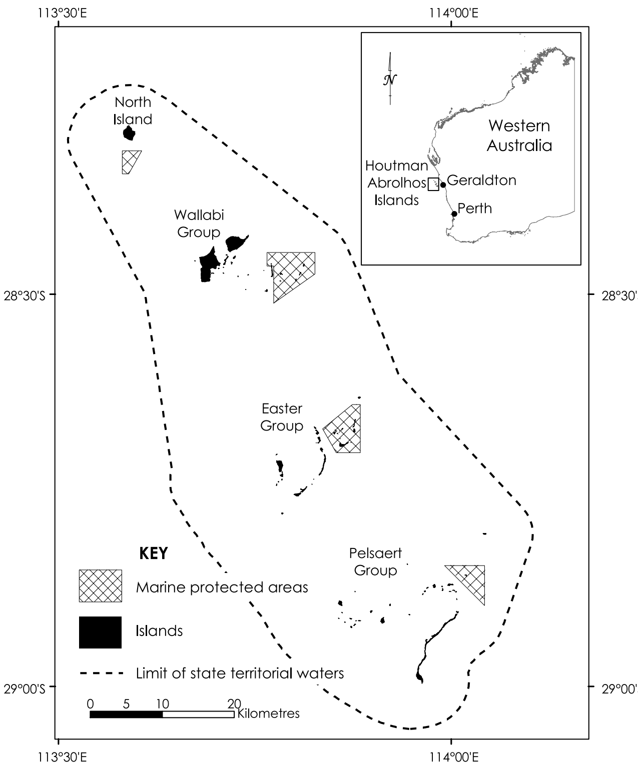

Figure 1 Location of the Houtman Abrolhos Islands, Western Australia, showing marine protected areas (MPAs) and the limit of the state territorial waters.

fishing would build up the numbers and size of resident fish. Non-extractive users of the fish resources (divers and eco-tourism operators) would thus appreciate the coral reef environment with all its small fish, and increased numbers of large spectacular fish, such as the coral trout (*Plectropomus leopardus*) and baldchin groper (*Choerodon rubescens*). These fishes were thought, but not proven, to have small home ranges.

Over the last 15–20 years, there have been a large number of studies reporting increases in abundance and mean size of fish species in closed areas compared with adjacent areas open to fishing (see reviews by Roberts & Polunin 1991; Russ 1991, 2002; Jones *et al.* 1993; Halpern & Warner 2002). However, benefits of MPAs to fisheries' yields and total breeding stocks (open and closed areas combined) have rarely been demonstrated (but see Russ & Alcala 1996).

On Australia's Great Barrier Reef, several MPAs have been created within the reef-based fisheries. This region has shown increases in the abundance and size of coral trout (*Plectropomus* spp.) in areas closed to commercial and recreational fishing (Beinssen 1989; Russ *et al.* 1995).

We aimed to assess the effect of MPAs at the Abrolhos Islands on the abundance and size distribution of *C. rubescens* and *P. leopardus* over the eight years following MPA establishment. Our hypothesis was that, over time, the MPAs would exhibit an increased abundance and mean size of *C. rubescens* and *P. leopardus* in comparison to similar areas that remained open to hook-and-line fishing. Following recommended procedures (Roberts & Polunin 1991; Dugan & Davis 1993; Jones *et al.* 1993), we set out to quantify the effects of MPAs by monitoring multiple closed and open areas in two of the island groups (Wallabi and Easter), before and on four occasions during the eight years following protection.

METHODS

Study sites

The Houtman Abrolhos Islands and associated reefs are located at the edge of the continental shelf between 28°15′S and 29°S, approximately 60 km offshore from the mid-west coast of Western Australia (Fig. 1). Windward areas are characterized by large areas of macroalgal-covered limestone reef and sand, common to temperate Western Australian waters, and these are typically dominated by temperate reef fishes (Hatcher 1985). Greater development of coral reefs occurs in sheltered back-reef areas, and most tropical reef species are associated with these habitats. The Wallabi and Easter Groups of the Abrolhos Islands (Fig. 1) were chosen for this study because of their accessibility and the availability of departmental research stations and vessels. The size of the Easter Group MPA is 6.5 square nautical miles and the Wallabi Group MPA is 8.0 square nautical miles.

Transect method

The technique of underwater visual census (UVC) developed by Ayling and Ayling (1987), and modified by Brown *et al.* (1992) for estimating the stock abundance of reef fish along Queensland's Great Barrier Reef, was used for this work. This method involved two scuba divers swimming along a 50 m transect line. One diver laid out the transect tape and the other diver simultaneously counted numbers and estimated the size categories of *C. rubescens* and *P. leopardus*, at a pre-determined distance of 5 m on one side of the transect line. We attempted to minimize variation and bias by using the same divers for all the surveys, using the same methodology for each survey and locating the same transects throughout the study.

C. rubescens has a maximum size of 70 cm and a minimum legal catch length of 40 cm, however, most of the fish taken recreationally and commercially are in the 40–55 cm range. *P. leopardus* has a maximum size of 75 cm and a minimum legal length of 45 cm and most of the fish taken are in the 45–55 cm range. Observers classified *C. rubescens* into three size categories: small (<40 cm), medium (40 cm–55 cm) and large (>55 cm). *P. leopardus* was also divided into three size categories: small (<45 cm), medium (45 cm–55 cm) and large (>55 cm). Surveys were not conducted when the underwater visibility was five metres or less.

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Sampling design

To quantify the effects of environmental impacts and management strategies, Green (1993) advocated more than one control (= open area) and one treatment (= protected area), as well as pre-impact and post-impact measurement of differences among treatment and control sites. Thus two sites within each MPA, and two adjacent control sites outside each MPA (and thus open to fishing) were surveyed at each island group. Each site was approximately one hectare in area and contained two dominant habitat types (back-reef and leeward slope). Back-reef habitats consisted of isolated patch reefs of coral (largely *Porites* and faviid spp.) surrounded by sand and rubble. Leeward reef-slopes consisted of fringing coral reefs, sometimes monospecific areas of branching or plating *Acropora* or *Montipora* spp. Plating forms dominate shallow areas, but are replaced by branching corals and algal species (particularly *Sargassum* spp.) in deeper water. Windward reef-slopes were not used for the fish abundance surveys in this study, as these areas are often exposed to large open ocean swells. Both fish species occur on the shallow reefs and in depths to 40 m, however, the depth of the base of many reef-slope and back-reef habitats within the Abrolhos lagoons is in the 8–20 m range. All UVC surveys were undertaken in depths of 12 m or less, to reduce the risk to divers being exposed to multiple daily dives.

The number of transects within each of the two habitat types at each site was five in the Easter Group and four in the Wallabi Group. The difference in transect numbers between the island groups was a cost-benefit decision based on logistic constraints. Strip transects (50 m × 5 m) were initially randomly placed in reef-slope and back-reef habitats. The same transects were located on subsequent surveys using global positioning system (GPS) technology and maps of topographic features of the reef. Thus, for each island group, there were two treatments (MPA versus control) × two sites × two habitats × five (or four) transects.

A baseline population abundance survey for *C. rubescens* and *P. leopardus* comprising ten transects per site, randomly selected within two 1-ha areas of the MPA and two adjacent control sites of similar size and reef morphology, was conducted in the Easter Group during summer, in November/December 1993. In the Wallabi Group, the baseline survey comprising eight transects per site was conducted during autumn, in May 1994, prior to legislation establishing the reserves on the 20 May 1994. Using the same sampling design and the same baseline survey sites, the surveys were repeated twice after protection: Easter Group in 1995 and 1996, and the Wallabi Group in 1996 and 1997. After reviewing the experimental design and associated data analyses in 1999, we determined that four, 100 m × 5 m transects in back-reef and reef-slope habitats in one MPA site and two adjacent control sites, would provide a significant reduction in the variance. We assumed that these changes in design would not significantly affect the mean abundance measures by altering the survey coverage relative to the local populations being sampled. Based on this assumption, the modified experimental design was introduced for the 2000 and 2002 surveys. The raw data (fish counts) derived from the expanded transects were still expressed as mean densities of fish per 250 m^2 to standardize the abundance measures for the two methods. The new sampling design, consisting of twenty-four 100 m × 5 m transects per survey for both island groups, was initially undertaken during May 2000. Thus, in total, 168 transects were undertaken in the Easter Group and 136 (8 were not sampled in 1996 due to poor underwater visibility) in the Wallabi Group, with the two sampling protocols providing a total of five surveys for each island group, spanning eight years and six months.

Statistical analyses

The response variables were counts of the three size classes and all size classes combined for both species. These were log $(x + 1)$ transformed to remove zeros and heavily-tailed distributions. The main effects to be tested were closed areas (levels: yes or no), year (levels: 1993–2002) and habitat (levels: reef-slope and back-reef). These data were analysed using repeated measures analyses (Maceina *et al*. 1994). Split-plot analyses (referred to as the univariate approach) were used when the data satisfied the circularity property, in addition to the usual conditions for ANOVA (i.e. the variance for the difference of measures at different times is constant). All main effects and interactions were tested with the within subject residual mean square and the between subject residual mean square. A quantile-quantile normal plot against predicted values was used to test whether the residuals were normally distributed. Cook's distance (Cook 1977) was used to check for outliers and none were detected. An ANOVA was used to test for any direct effect of the transects with the response variables (Maceina *et al*. 1994), and assumed that there were no higher order interactions among the effect of the transects and the other factors.

RESULTS

Effects of protected areas on the abundance of *Choerodon rubescens*

The MPA in the Wallabi Group showed no consistent effects ($p > 0.05$) on the abundance of *C. rubescens* after eight years of closure, for any of the individual size classes examined (Table 1). However, for all size classes combined, the repeated measures ANOVA detected a significant interaction ($p < 0.05$) between treatment (closed versus open) and year (Table 1). Fish density over time showed a similar pattern between open and closed areas for the first three surveys. Although there were greater numbers of *C. rubescens* in the MPA than the open area in the 2000 survey, the final survey in 2002 showed very similar relative abundances between open and closed areas to those in the initial survey in 1994 (Fig. 2). There was no significant three-way interaction

Table 1 Results of the repeated measures ANOVA for log $(x + 1)$ transformed data for *Choerodon rubescens* fish counts in the Wallabi and Easter Groups of the Abrolhos Islands. * = $0.05 > p > 0.01$. All main effects and main effects interactions were fixed effects and tested against the within-subject error.

Island group	*Species size*	*Value*	*Main effect and interactions*								
			Closed	*Year*	*Habitat*	*Closed × year*	*Closed × habitat*	*Year × habitat*	*Closed × year × habitat*	*Residual within transect*	*Residual between transect*
Wallabi	Small	*p*	0.84	0.126	0.347	0.125	0.172	0.969	0.934	–	–
		Mean squares	0.024	1.09	0.528	1.095	1.119	0.079	0.122	0.589	0.626
		df	1	4	1	4	1	4	4	85	20
	Medium	*p*	0.584	0.574	0.91	0.162	0.262	0.360	0.468	–	–
		Mean squares	0.106	0.257	0.005	0.592	0.450	0.389	0.317	0.352	0.360
		df	1	4	1	4	1	4	4	85	20
	Large	*p*	0.062	0.135	0.084	0.278	0.337	0.377	0.076	–	–
		Mean squares	0.472	0.239	0.405	0.171	0.123	0.141	0.290	0.132	0.159
		df	1	4	1	4	1	4	4	85	20
	All sizes	*p*	0.304	0.294	0.685	*	0.096	0.927	0.603	–	–
		Mean squares	0.685	0.804	0.106	1.726	1.813	0.140	0.439	0.640	0.685
		df	1	4	1	4	1	4	4	85	20
Easter	Small	*p*	*	0.091	0.671	0.132	0.831	0.233	0.822	–	–
		Mean squares	2.501	0.82	0.072	0.720	0.018	0.563	0.152	0.398	0.425
		df	1	4	1	4	1	4	4	109	29
	Medium	*p*	0.991	0.056	0.548	0.134	0.689	0.799	0.394	–	–
		Mean squares	0.00	1.047	0.158	0.790	0.071	0.181	0.453	0.439	0.575
		df	1	4	1	4	1	4	4	109	29
	Large	*p*	0.46	0.125	0.086	*	0.444	0.454	0.086	–	–
		Mean squares	0.142	0.477	0.776	0.813	0.153	0.238	0.542	0.258	0.401
		df	1	4	1	4	1	4	4	109	29
	All sizes	*p*	0.056	*	0.626	*	0.800	0.608	0.329	–	–
		Mean squares	1.904	1.433	0.122	1.403	0.033	0.345	0.593	0.508	0.776
		df	1	4	1	4	1	4	4	109	29

($p > 0.05$) among treatment (closed versus open), habitat and time that may have indicated a habitat-specific effect of closure (Table 1).

The interaction of treatment (closed versus open) with year was significant ($p < 0.05$) at the Easter Group for large *C. rubescens* and all size classes combined, because of a high count on the second survey in the MPA compared with the controls, and similar densities in open and closed areas for the other four surveys (Fig. 3, Table 1).

Effects of protected areas on the abundance of *Plectropomus leopardus*

In contrast to *C. rubescens*, there were highly significant effects of area closures over time on the abundance of *P. leopardus* ($p < 0.001$) in both groups (Table 2, Figs 4 and 5). This result was because of the significant increases in abundance of this species in the latter two surveys towards the end of eight years of closure. When all size classes were combined, there was a seven-fold increase for the Wallabi Group and a three-fold increase in the estimated abundance of *P. leopardus* in the Easter Group relative to the control sites at the end of the time series. However, in the Easter Group MPA, all size classes of *P. leopardus* decreased in abundance by approximately 50% between 2000 and 2002 (Fig. 5). This decreasing trend was not evident in the Wallabi Group over the same period of time, where the abundance of fish in all size classes remained high after 2000 (Fig. 4).

There were highly significant interactions in the Easter Group ($p < 0.001$) between closure and year for medium, large and combined size classes of *P. leopardus* and a significant interaction ($p < 0.01$) for small fish (Table 2). In comparison, the level of significance between closure and year for the Wallabi Group was ($p < 0.05$) for medium and combined size classes and ($p < 0.01$) for small and large fish (Table 2). These were clearly the result of large increases in the abundance of *P. leopardus* in the MPAs only.

The final densities of combined medium and large (i.e. non-cryptic and mature) *P. leopardus* in the closed areas were approximately 15 and 10 times greater than the final densities in the open fishing areas for the Wallabi and Easter Groups, respectively (Figs 4 and 5).

Effects of habitat and transects

The repeated measures ANOVA revealed no main effect or interaction involving habitat for *C. rubescens* at either the Wallabi or Easter Groups. In contrast, significant effects for *P. leopardus* in the Wallabi Group were detected between closure and habitat in the small ($p < 0.05$) and combined

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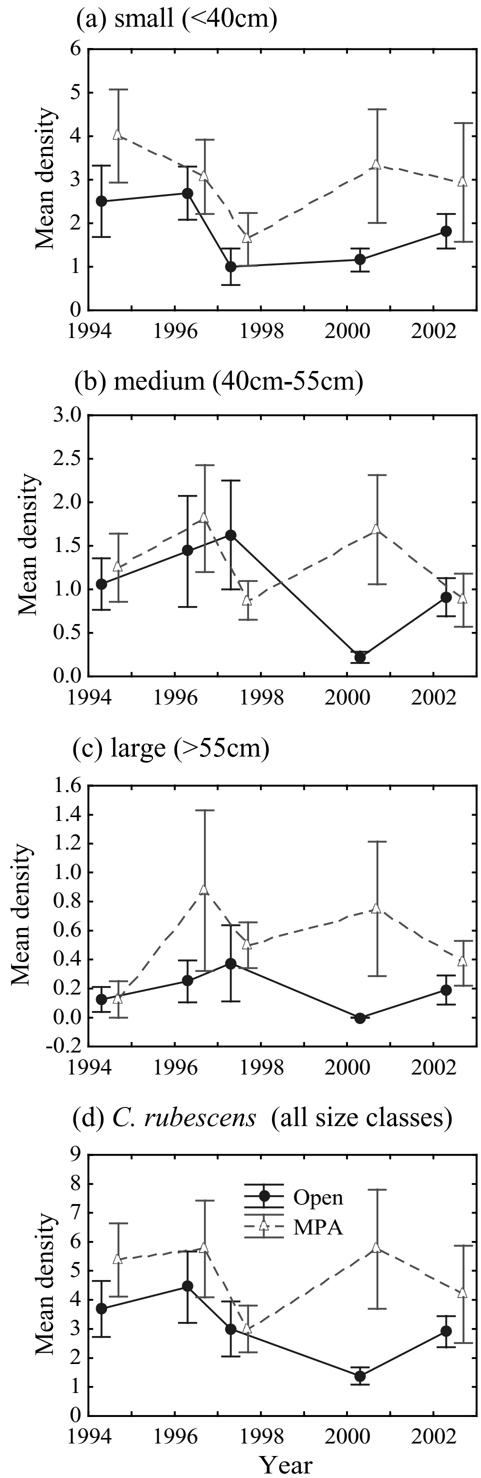

Figure 2 Mean density (number of fish per 250 m^2 transect ± SE) for (*a*) small, (*b*) medium, (*c*) large and (*d*) all size classes combined of *Choerodon rubescens* in back-reef and reef-slope habitats in closed and open areas of the Wallabi Group. Baseline surveys were undertaken before fishing stopped in May 1994.

($p < 0.01$) size classes. Moreover, highly significant effects ($p < 0.001$) were recorded between year and habitat in the small and combined size classes in the Easter Group (Tables 1 and 2).

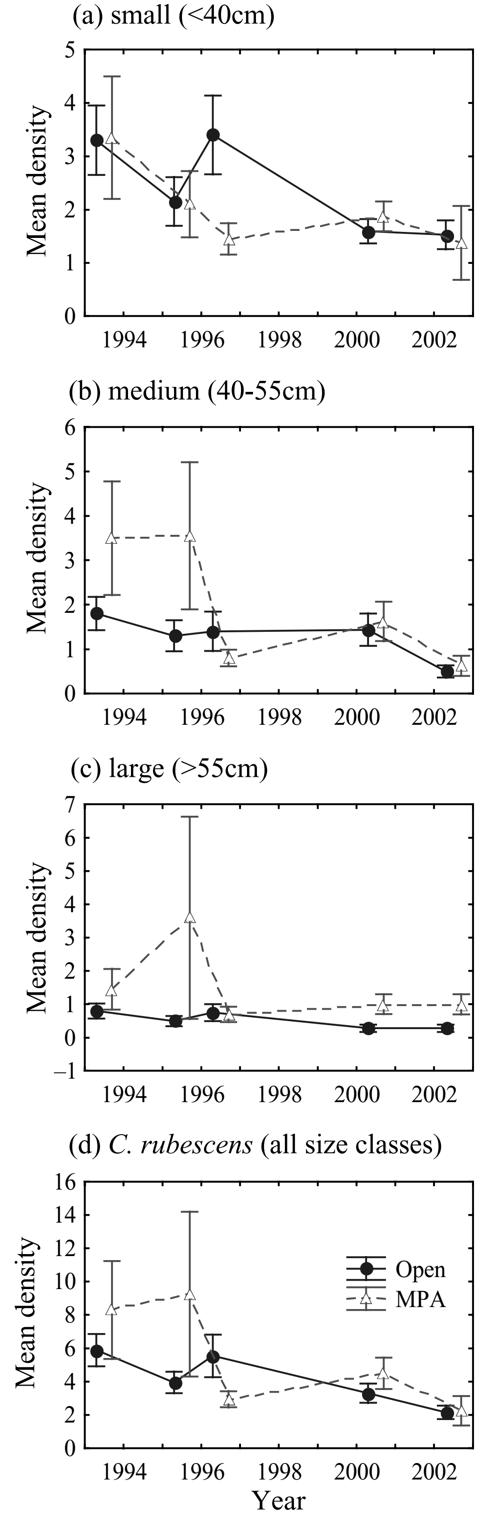

Figure 3 Mean density (number of fish per 250 m^2 transect ± SE) for (*a*) small, (*b*) medium, (*c*) large and (*d*) all size classes combined of *Choerodon rubescens* in back-reef and reef-slope habitats in closed and open areas of the Easter Group. Baseline surveys were undertaken in 1993. Fishing stopped in May 1994.

We used ANOVA to test for any direct effect of the transects with the response variables used in this paper, and determined that there was no significant effect ($0.15 < p < 0.65$).

Table 2 Results of the repeated measures ANOVA of log $(x + 1)$ transformed data for *Plectropomus leopardus* fish counts in the Wallabi and Easter Groups of the Abrolhos Islands. * = $0.05 > p > 0.01$; ** = $0.01 > p > 0.001$; *** = $p < 0.001$. All main effects and main effects interactions were fixed effects and tested against the within subject error.

Island group	*Species size*	*Value*	*Main effect and interactions*								
			Closed	*Year*	*Habitat*	*Closed × year*	*Closed × habitat*	*Year × habitat*	*Closed × year × habitat*	*Residual within transect*	*Residual between transect*
Wallabi	Small	*p*	***	***	0.184	**	*	0.402	0.112	–	–
		Mean squares	6.782	3.688	0.641	1.332	2.355	0.364	0.691	0.357	0.362
		df	1	4	1	4	1	4	4	85	20
	Medium	*p*	*	**	0.917	*	0.445	0.215	0.419	–	–
		Mean squares	1.717	1.174	0.004	1.097	0.187	0.469	0.313	0.317	0.356
		df	1	4	1	4	1	4	4	85	20
	Large	*p*	**	**	0.548	**	0.517	0.653	0.085	–	–
		Mean squares	1.141	0.586	0.058	0.677	0.068	0.098	0.339	0.16	0.211
		df	1	4	1	4	1	4	4	85	20
	All sizes	*p*	***	***	0.302	*	**	0.870	0.22	–	–
		Mean squares	9.283	4.591	0.565	1.704	3.976	0.162	0.768	0.523	0.561
		df	1	4	1	4	1	4	4	85	20
Easter	Small	*p*	*	***	0.180	**	0.066	***	0.474	–	–
		Mean squares	1.309	2.273	0.352	0.785	0.671	1.980	0.172	0.194	0.169
		df	1	4	1	4	1	4	4	109	29
	Medium	*p*	**	***	0.423	***	0.501	0.205	0.195	–	–
		Mean squares	1.085	1.402	0.074	0.693	0.521	0.172	0.176	0.114	0.135
		df	1	4	1	4	1	4	4	109	29
	Large	*p*	***	***	0.325	***	0.622	0.276	0.466	–	–
		Mean squares	0.620	0.485	0.038	0.579	0.010	0.051	0.035	0.039	0.022
		df	1	4	1	4	1	4	4	109	29
	All sizes	*p*	**	***	0.110	***	0.094	***	0.461	–	–
		Mean squares	2.510	3.568	0.703	2.140	0.771	2.141	0.246	0.270	0.230
		df	1	4	1	4	1	4	4	109	29

DISCUSSION

Using a before-after-control-impact experimental design, we monitored MPAs and areas open to fishing before and after the MPAs were established at the Houtman Abrolhos Islands. The eight-year study found contrasting effects of the reserves on the abundance and population structure of two large fish. We found protection had no effect on the abundance of the wrasse, *Choerodon rubescens*. In contrast, our survey recorded large increases in abundance of all size classes of the serranid, *Plectropomus leopardus*, six years after the creation of the MPAs at the Wallabi and Easter Groups.

Although we altered the survey design in 2000, changing the length of the transects from 50 m to 100 m and deleting one closed site, densities remained standardized as the number of fish per 250 m^2 for 2000 and 2002 survey data. Using longer transects was not expected to affect the mean fish counts, but was expected to reduce the variance, thus strengthening the statistical comparisons. Moreover, as there was no effect of the transects with the variables of closure, habitat and year, the possibility of a higher order interaction between the transects and the main effects variables is minimal. We therefore consider that the changes in fish counts for *P. leopardus* after 2000 reflect real changes in abundance. Noting that the density of mature *P. leopardus* in the MPAs after eight years of closure was approximately ten times that in the open fishing areas, and that the closed areas represent about 17% of the habitat of mature *P. leopardus*, the overall effect of the closure was an approximately 2.5-fold increase in density of mature fish over the whole Abrolhos system. That is, for this species, with its low mobility and with most of the Western Australian fished population occurring in the Abrolhos reef system, the closed areas are considered to have had a significant positive effect on population size, as well as the local benefit for divers of being able to see abundant large reef fish.

It is likely that the more widely distributed *C. rubescens* is a more mobile fish than *P. leopardus* (K. Nardi, personal observation 1993), which may reduce the effects of local protection on this species. Bohnsack (2000) suggested that small marine reserves are likely to be less effective for more mobile species. The two species may also differ, in terms of fishing intensity and the proportion of the stock accessible to fishers (M. Moran, personal observation 1997). For example, *P. leopardus* is common in Western Australian waters only at the Abrolhos Islands and it is heavily targeted on these shallow reefs where both commercial and recreational fishers focus considerable fishing effort close to the islands (Anon. 1998). The fish do not appear to have a refuge in depth. Although *C. rubescens* is also heavily targeted in shallow areas, it may be buffered from the effects of exploitation by having

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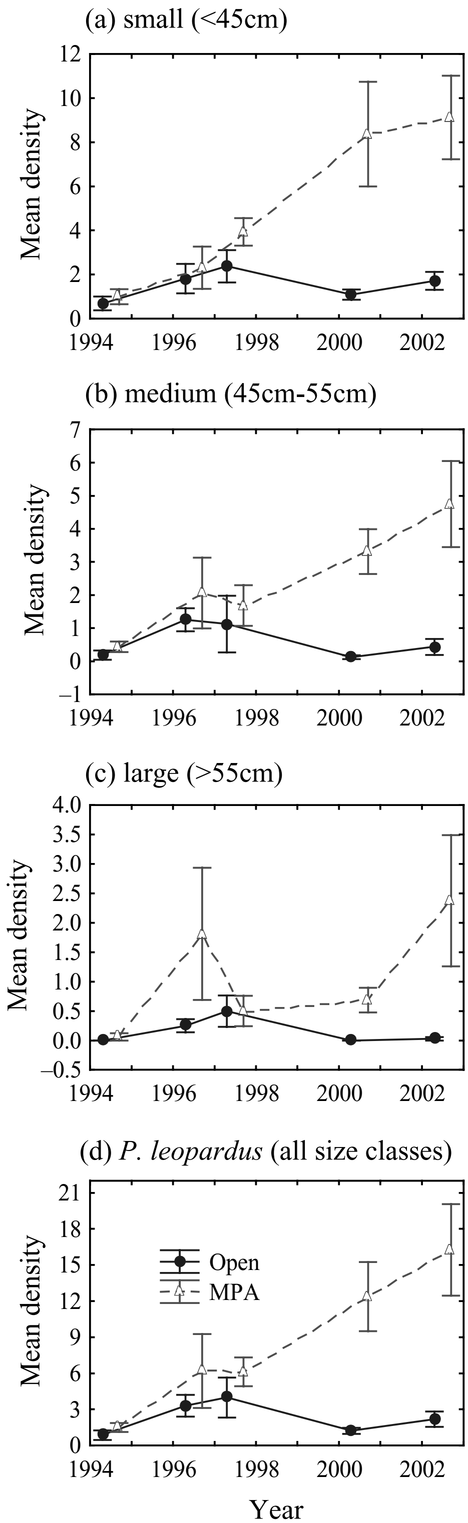

Figure 4 Mean density (number of fish per 250 m^2 transect $\pm$ SE) for (*a*) small, (*b*) medium, (*c*) large and (*d*) all size classes combined of *Plectropomus leopardus* in back-reef and reef-slope habitats in closed and open areas of the Wallabi Group. Baseline surveys were undertaken before fishing stopped in May 1994.

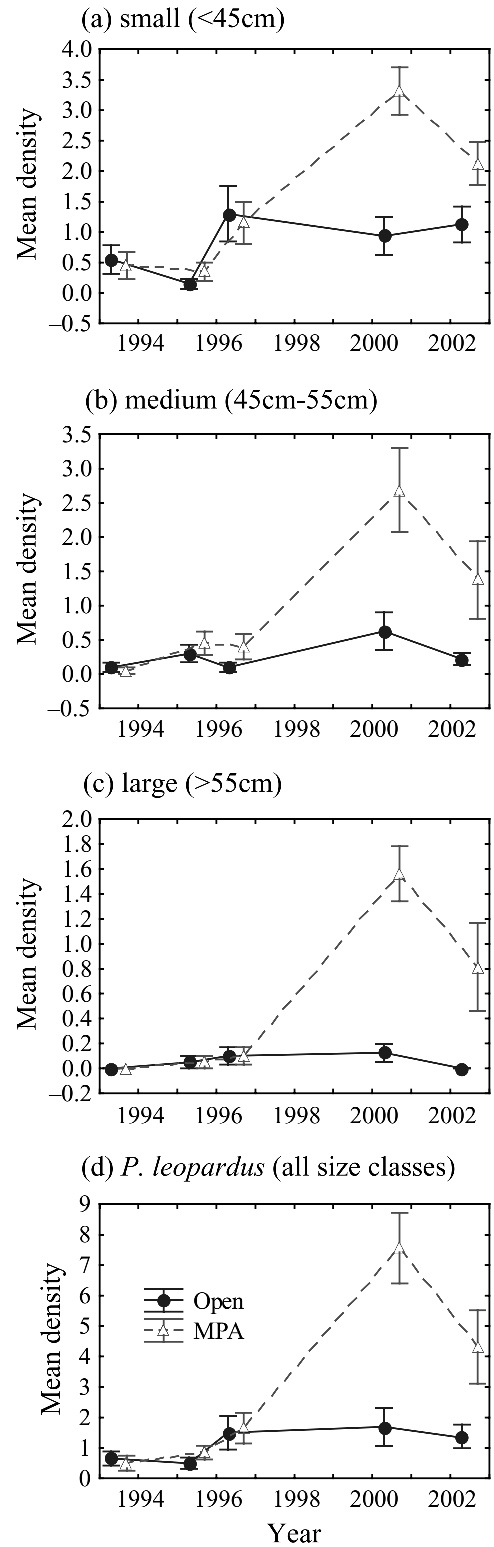

Figure 5 Mean density (number of fish per 250 m^2 transect $\pm$ SE) for (*a*) small, (*b*) medium, (*c*) large and (*d*) all size classes combined of *Plectropomus leopardus* in back-reef and reef-slope habitats in closed and open areas of the Easter Group. Baseline surveys were undertaken in 1993. Fishing stopped in May 1994.

unfished deeper-water populations. The size of the MPAs at the Abrolhos Islands (less than eight square nautical miles) may be too small to allow local increases in any but the least mobile of fish species.

The magnitude of the increase in numbers of *P. leopardus* observed in our study has not previously been recorded in closed areas affecting this species. Russ *et al*. (1995), for example, found no significant differences in the mean size and age structure for *P. leopardus* on reefs that had been closed for six years in the central Great Barrier Reef. Similarly, Wantiez *et al*. (1997) did not detect a change in the average size of *P. leopardus* on New Caledonian reefs after five years of fishing prohibition. It is not clear why this species should respond to protection in some areas but not others, or why such a significant time lag in response should occur, though the frequency of strong recruitment events may be implicated. One possible explanation is that the large area of the Great Barrier Reef may make it more difficult to ensure compliance with closed area regulation. The degree to which MPAs work can be largely determined by the efficacy of protection (Roberts 2000). In our study, the substantial almost 50% decrease in the abundance in all size classes of *P. leopardus* in the Easter Group MPA between 2000 and 2002 may also reflect illegal fishing. Since the completion of the study, several fishers have been apprehended fishing inside the boundaries of the MPA.

In this study, our overall hypothesis was that recruitment would occur equally to both open and closed areas, then differential fishing mortality would result in increased numbers of first small, then medium and, finally, large fish accumulating in the closed areas relative to the open 'control' areas. This expected pattern is relatively consistent with our data for *P. leopardus* in the Wallabi Group. That is, the density of small fish showed an increase in the 1997 survey and the density of medium fish showed an increase in 2000. The density of large fish then increased in 2002. The numbers in each size group were also consistent with the hypothesis. In the Easter Group, there was some increase in small fish seen in 1996 in both open and closed areas, but a substantial increase in all size groups in the following 2000 survey does not fit with the hypothesis being tested. Whether the observed trend in abundance over time at the Wallabi Group is compatible with the time for fish to grow from the end of the cryptic phase to over 55 cm is unknown, but studies of growth of *P. leopardus* in this region are about to commence to allow this aspect of the study to be validated in future.

Habitat had little effect on the abundance of *P. leopardus* at the Wallabi Group. However, there was a significant interaction between closure and habitat for all size classes and small fish. *P. leopardus* were consistently more abundant on the reef-slope compared with back-reef habitats, but only on open reefs. Since this did not change over time, it may indicate that some other aspect of habitat may be more important than just reef-slope versus back-reef. Similarly, numbers of fish on back-reef habitats were considerably higher on closed reefs, compared with open reefs. This pattern was consistent throughout the study, suggesting that it is an effect of location rather than a habitat shift in response to protection from fishing. Habitat effects on the abundance were not significant for any size classes of *P. leopardus* in the Easter Group, however, there was a highly significant interaction between year and habitat for small fish and all size classes combined for which we have no explanation.

Despite some problems with the design of the study (for example, transect length being shorter in the early surveys) and results (habitat interactions that were difficult to explain), our study has shown that an outcome of the closures has been a significant increase in the abundance of *P. leopardus* over time with no detectable effect on *C. rubescens*. The mechanism for these increases is likely to be a combination of processes, including a significantly reduced fishing mortality of both juvenile and adult *P. leopardus*. Whilst significant increases in mean density were limited to one of the two species studied, we recommend that MPAs at the Houtman Abrolhos Islands should be maintained and that monitoring of fish densities be continued. It is considered unusual to find a short-term (<5 years) benefit of MPAs in a long-lived reef fish species (see Edgar & Barrett 1997; Russ 2002) and continued monitoring would be useful to determine at what level of abundance these populations reach a plateau reflecting a reef's carrying capacity.

Our study supports the use of closed areas or MPAs for local conservation of some reef fishes, however, it does caution against assuming that small-scale MPAs will be sufficiently effective at protecting all species. The findings also demonstrate that such closures can be effective where some forms of fishing (i.e. lobster potting) are permitted which are compatible with the objectives of the MPA. The study also cautions against assuming effects of MPAs will be rapid (see Halpern & Warner 2002). In our study, increases in coral trout were initially slow and densities were still increasing after eight years at one location. Similar long recovery times have been observed for other large reef fishes (Russ & Alcala 1996; Russ 2002).

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