Recovery of Coral Populations at Helen-Reef Atoll after a Major Bleaching Event

Yimnang Golbuu[1], Jay Andrew[1], Geory Mereb[1], Robert van Woesik[2]

[1]Palau International Coral Reef Center
[2]Florida Institute of Technology

PICRC Technical Report 13-03
July 2013

ABSTRACT

Marine protected areas are widely used as a tool to manage important marine resources throughout the world. While protected areas are common in Palau, none have been studied to assess whether they influence the recovery of corals and associated fishes after a thermal stress event. This study examined the recovery on Helen Reef after the 1998 thermal stress event that resulted in widespread coral bleaching and mortality. Ten sites were examined on Helen Reef, both outer- and back-reef sites, to assess changes in coral cover and fish densities between 2000 and 2007. Over the seven year period, coral cover on the outer reefs increased by 28% and 22% at 3 and 10 m, respectively. In contrast, recovery on the back reef was approximately 3—4% between 2000 and 2007, which did not differ across depths. The average density of fish did not change through time, and was 89 fishes 250 m^{-2} in 2007. These densities are the highest fish densities that have been measured in any of Palau's and Micronesia's marine protected areas. The recovery rates of corals and the fish populations at Helen Reefs suggest that the reef is healthy and resilient to thermal stress events.

INTRODUCTION

Marine Protected Areas (MPAs) are widely used around the world as a management tool to conserve precious marine resources. There are now 32 marine protected areas in Palau, and over 100 in Micronesia. Yet few protected areas have been studied to determine how effective they are in achieving their management objectives (Nestor et al. 2013; Koshiba et al. 2013). Over 95% of MPAs have management objectives that aim to increase fishes and other food resources over specific time periods (Final Report, the 2nd Meeting of the Micronesian Challenge Measures Working Group). Few studies, however, have measured the efficacy of protected areas and determined whether closures have met the strategic targets. Although protected areas are common in Palau, none have been studied to assess the recovery of corals and associated fishes from a major thermal stress event that resulted in coral bleaching. In this study, we used Helen Reef as a case study to assess how quickly a marine protected area recovers from a thermal stress event that caused widespread coral mortality.

Helen Reef (Fig. 1), located at the southern-most border of Palau, is among the world's most diverse atolls (Maragos et al, 1992). Historically, Helen Reef was known for its abundance of marine resources, including giant clams, trochus, fishes, and turtles.

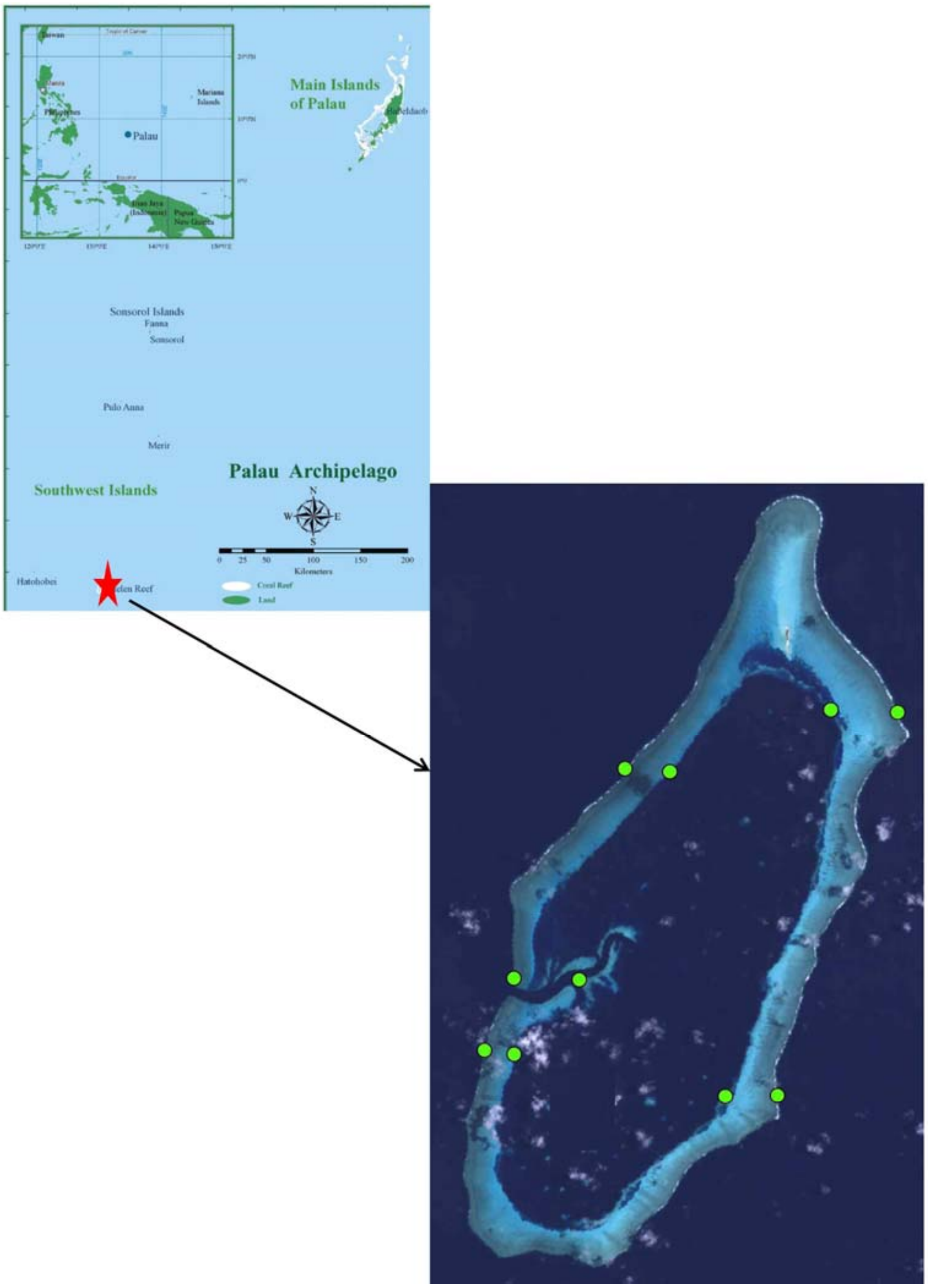

Figure 1. Location map of Helen Reef and close-up view showing survey sites marked by green circles.

Utilization and collecting of marine resources by both the people of Palau and by poachers outside of Palau have led to the putative decline of reef resources at Helen Reef (Helen Reef Marine Resources, 2000).

The apparent decline in these marine resources prompted the people of Hatohobei State to establish a Helen Reef Management Office (HRMO) to initiate strategies that would ensure that the resources of Helen Reef are sustained in perpetuity. The HRMO started its work in 2000 and by 2010 they had finalized a management plan for Helen Reef. The management plan initially called for total closure of Helen Atoll, but through several iterations, the plan was modified to include both open and closed areas. In preparation for the management plan, a team of researchers set out to assess the status of the resources at Helen Reef in 2000. Another scientific expedition was deployed to Helen Atoll in 2007; the researchers surveyed corals and fishes at the same study sites as in 2000.

The objectives of this study were to answer the following research questions:

1). Did the corals and fish populations at Helen Reef recover from the 1998 bleaching event?

2). Were there any differences in the recovery of coral cover between outer and inner reefs?

3). Were there any differences in the recovery rates of coral cover and fish densities between 3 and 10 m?

METHODS

Study Sites

Helen Reef is an atoll located at 3^0N and 131^0E in the western Pacific Ocean (Figure 1). The atoll is about 24 km long and 10 km wide, covering a total area of 162 km^2. Helen Reef was initially surveyed in 2000, two years after a major bleaching event and resurveyed again in 2007. Five sites were surveyed on the outer reefs and five sites were surveyed in the lagoon, hereinafter called the back reef (Fig. 1). The sites were used as the primary sampling units.

Coral surveys

At each site, both at 3 m and 10 m, divers placed five 50 m transects along the depth contours and recorded the reef substrate using an underwater digital video camera (SONY, DCR-PC120, NTSC, with a 0.6 X wide lens in a Sea & Sea VX-PC Underwater Video housing 120) that was held by an observer diving 60-70 cm above the plastic transect line. The video camera recorded ~50 x 50 cm wide segments of reef along each 50 m transect. It took approximately five minutes to complete the recording of each transect.

The videos were played in the laboratory and stopped every 6.5 -7.0 seconds to obtain images of the benthos. Each image was used to estimate percentage coral coverage. A total of 40 frames were extracted and analyzed for each 50 m belt transect. To estimate the percentage coverage of the main biological features of the reef from the images, five random crosses were placed on a computer screen and the features (i.e., coral, algae, rubble, and carbonate) under each cross were identified and recorded. Corals were identified to the lowest taxonomic unit, most frequently to genus.

Fish surveys

In 2000, reef fishes were surveyed using the visual-census technique along the five replicate 50 m transects that were deployed at 10 m. Each belt transect was 3 m wide in 2000 and 5 m in 2007; the data were subsequently normalized to compare the same unit area (150 m^{-2}). The number and size of each fish that are targeted by fishers, not labrids and chaetodons, were recorded along each belt transect.

Data Analysis

The data were transformed to remove the dependency problem involved in resampling the same sites over time. A 3-way ANOVA was used to test whether there were significant differences between coral cover over time, across depths, and between habitats. For fishes, we used a two-way ANOVA and tested fish density and fish biomass between years and habitats since we only measured fishes at one depth.

RESULTS

Corals

Coral cover increased by 28% between 2000 and 2007 at 3 m on the outer reefs (Fig. 2), whereas at 10 m the increase in coral cover was 22% (Fig. 3). The increase in coral cover on the outer reefs was highly significant over time (three-way ANOVA, $p<0.001$). In contrast, change in coral cover between 2000 and 2007 was minimal on the back reefs compared with the outer reefs (Figs 4 and 5), and those changes were not significantly different across depths (three-way ANOVA, $p=0.184$).

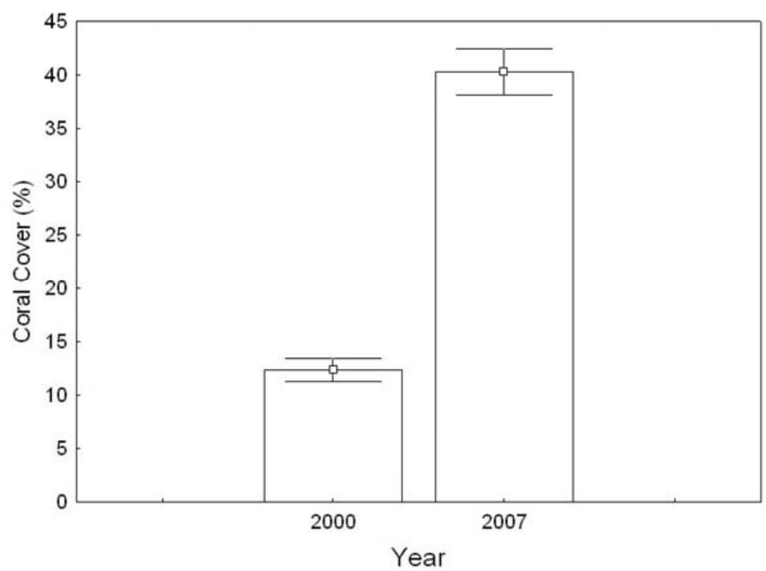

Figure 2. Coral cover at 3 m on the outer reef of Helen in 2000 and 2007; the bars show the means and the whiskers show the standard errors of the means.

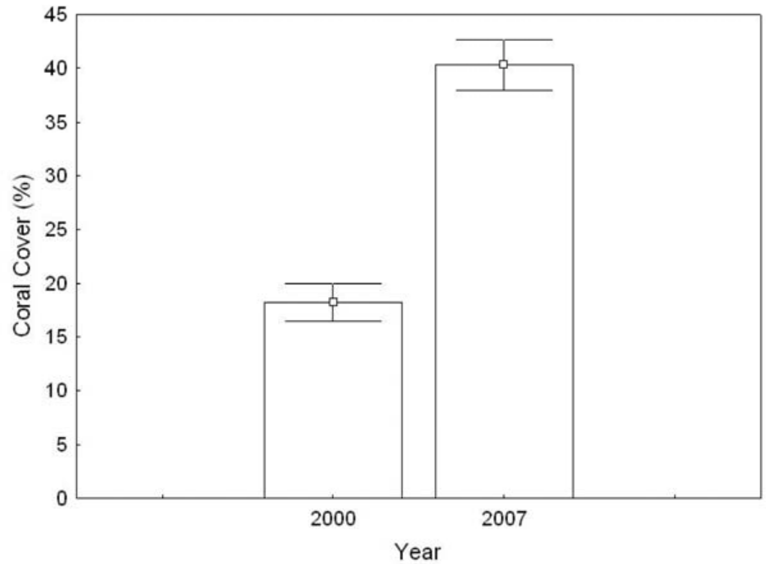

Figure 3. Coral cover at 10 m on the outer reefs of Helen; the bars show the means and the whiskers show the standard errors of the means.

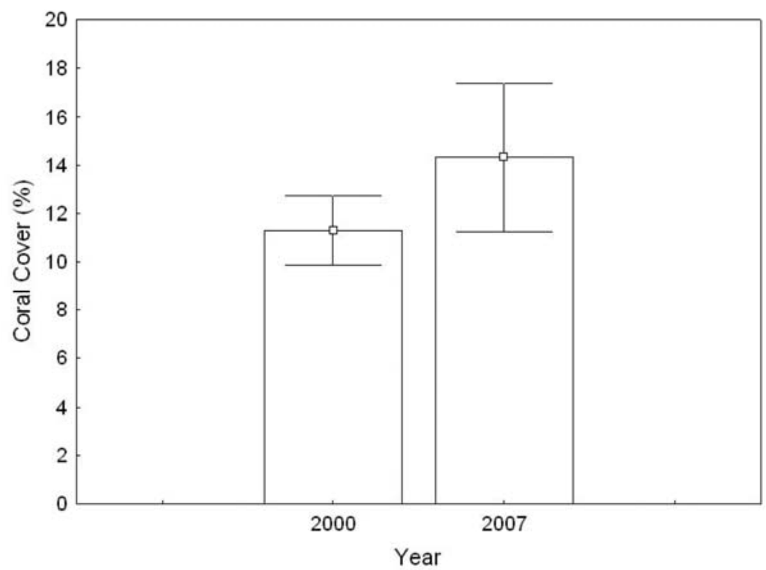

Figure 4. Coral cover at 3 m on the back reefs of Helen in 2000 and 2007; the bars show the means and the whiskers show the standard errors of the means.

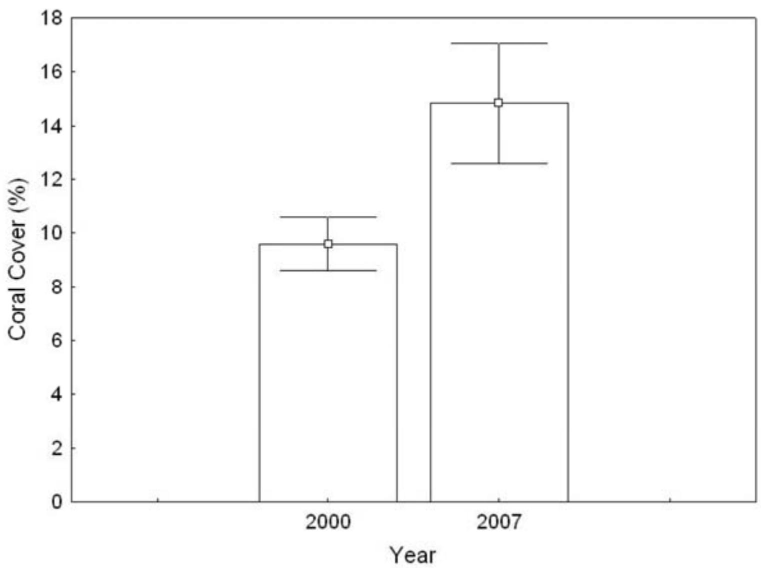

Figure 5. Coral cover at 10 m on the back reefs of Helen in 2000 and 2007; the bars show the means and the whiskers show the standard errors of the means.

Fishes

Fish densities on the outer reef of Helen Reef were similar in 2000 and 2007 (Fig. 6). Fish biomass on the outer reefs increased by 102 g m^{-2} from 2000 to 2007, but that increase was not statistically significant (two-way ANOVA, $p>0.05$; Fig. 7). Fish densities on the back reefs remained the same between 2000 and 2007 (two-way ANOVA, $p>0.05$; Fig. 8). The fish biomass on the back reefs decreased by 60 g m^{-2} from 2000 to 2007, but that decrease was not statistically significant (two-way ANOVA, $p>0.05$; Fig. 9).

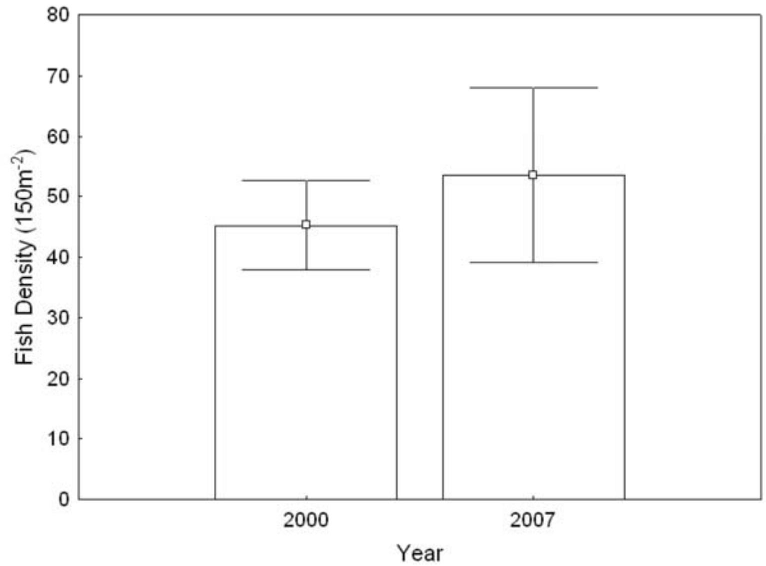

Figure 6. Fish densities at 10 m on the outer reefs of Helen in 2000 and 2007; the bars show the means and the whiskers show the standard errors of the means.

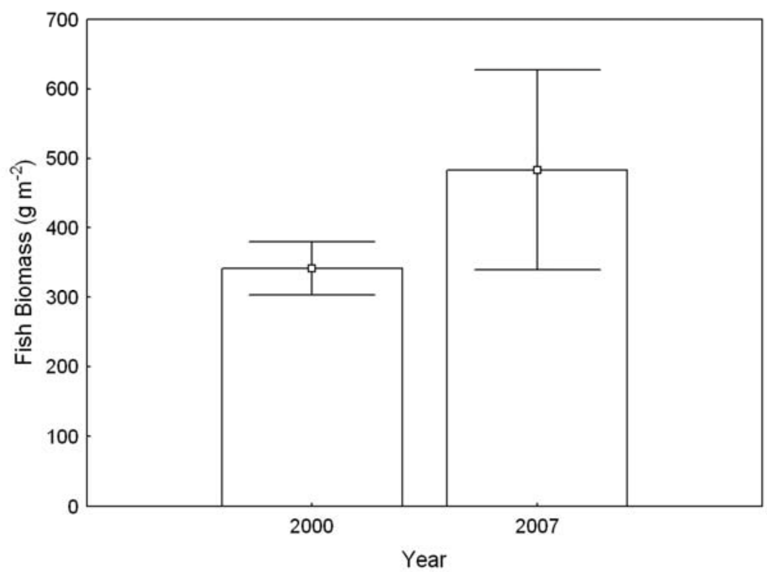

Figure 7. Fish biomass at 10 m on the outer reefs of Helen in 2000 and 2007; the bars show the means and the whiskers show the standard errors of the means.

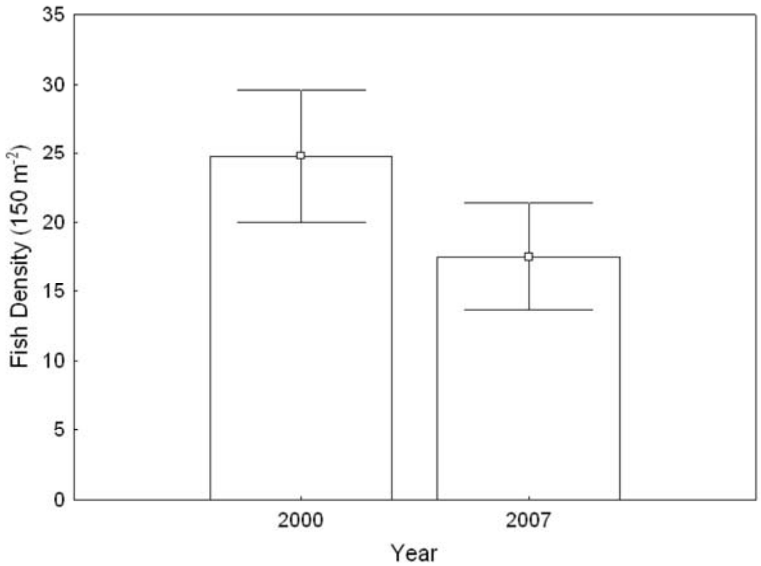

Figure 8. Fish densities at 10 m on the back reefs of Helen in 2000 and 2007; the bars show the means and the whiskers show the standard errors of the means.

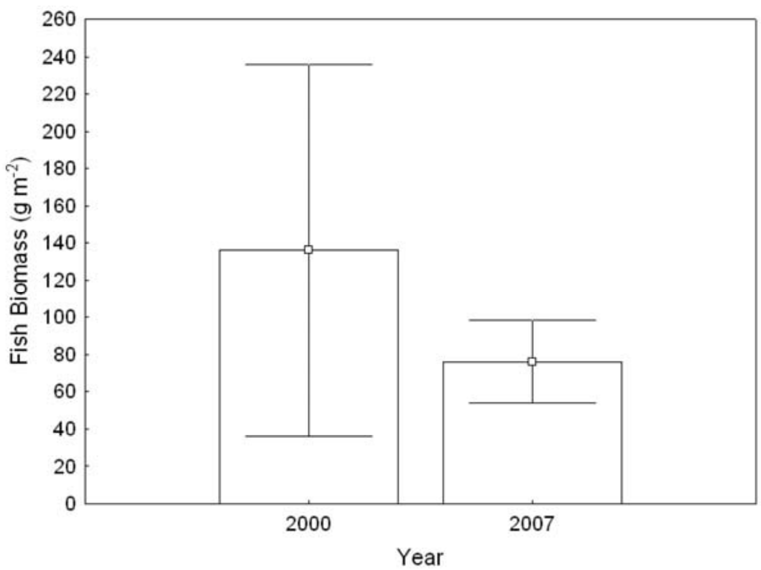

Figure 9. Fish biomass at 10 m on the back reefs of Helen in 2000 and 2007; the bars show the means and the whiskers show the standard errors of the means.

DISCUSSION

Between 2000 and 2007, coral cover increased at both 3 and 10 m on the exposed, outer reefs of Helen Reef. Recovery was considerably faster on the outer reefs than on the back reefs, and was faster at 3 m than at 10 m on the outer reefs. The rapid recovery of coral cover on Helen Reef was similar to what has been recorded on the main islands of Palau, some 600 km to the north (Golbuu et al. 2007). The main difference between localities was that recovery after the 1998 bleaching event at 10 m on the exposed reefs of Palau was more rapid that the recovery at 3 m. Helen Reef, however, showed slightly faster recovery at 3 m than at 10 m (Figures 2 and 3), although statistically, the differences were not significant between depths. Since recovery is in part dependent on the regrowth of remnant populations (Golbuu et al 2007), the main islands of Palau appeared to support more remnants at 10 m than at 3 m, and therefore recovery was higher at 10 m. Helen reef, on the hand, had similar cover at both 3 and 10 m in 2000, with few remnants, and recovery was almost entirely dependent on recruitment.

The density of fishes on the outer reefs of Helen Reef was 89 fish 250 m^{-2} 2007. These densities are the highest ever recorded in Palau's and Micronesia's Marine Protected Areas. Surprisingly, fish densities and biomass did not change between 2000 and 2007. This is interesting because we would expect fish populations to increase with the increasing coral cover; that, however, was not the case. One possible reason for the lack of change in fish densities and biomass is that the edible fish populations at Helen Reef were not affected by the thermal stress event, and stayed at maximum densities. Coral-obligate fishes, such as pomacentrids and chaetodons most likely declined with declines in coral cover after the 1998-thermal stress event. The average, edible fish density on the back reefs was estimated at 37 fishes per 250 m^{-2}, and on the outer reefs, the average fish density was estimated at 89 fishes 250 m^{-2}. These densities are extremely high, and may be close to the maximum capacity of a tropical coral-reef system.

In comparison with other localities for example, at Teluleu MPA, in Palau, fish densities have been estimated at on average 30 fishes 250 m^{-2} (Nestor et al. 2013), whereas at Ngemai MPA, the average fish density was about 18 fishes 250 m^{-2}, at Ebiil MPA the average fish density was 26 fishes 250 m^{-2}, Ileyakl Beluu

MPA had on average 19 fishes 250m^{-2}, and Ngeruangel MPA had on average 13 fishes 250 m^{-2} (PICRC, unpublished data). Our surveys of MPAs in Pohnpei (Koshiba et al. 2012), Chuuk (Andrew et al. 2011) and the Marshall Islands (Andrew et al. 2012) found that fish densities in MPAs ranged from 9-40 fishes 250 m^{-2}. Only Nimpal Channel Marine Conservation Area in Yap had comparatively similar fish densities of 70 fishes 250 m^{-2} on the outer reefs (Olsudong et al. 2012). These estimates approach the fish densities that were estimated for Helen Reef. Longer-term studies might provide more information to help us understand the maximum capacity of fish biomass on these tropical reefs, and if these densities change over time in any given MPA, and whether external disturbances including thermal stress events affect the MPAs differently.

While the coral surveys in 2000 and 2007 used the same protocol, the fish surveys in 2007 were slightly different, even though the data was subsequently normalized to the same area unit for analyses. It may be best however to resurvey the sites again, using exactly the same methods. We strongly recommend that the same sites around Helen be monitored again, using the same methods, for both corals and fishes. In conclusion, Helen Reefs showed spectacular recover from the 1998 bleaching events. Therefore, we can consider Helen Reef to be a resilient reef because of its capacity to rapidly recover coral cover in less than 10 years from such a massive thermal stress event that occurred in 1998.

ACKNOWLEGEMENTS

This study was supported by the Palau International Coral Reef Center, The David and Lucile Packard Foundation, Hatohobei Organization for People and Environment (HOPE), Helen Reef Resource Management Board and Hatohobei State Government. Special thanks to Allison Green for providing the 2000 fish data. Cover photograph provided by Hanna Muegge.

REFERENCES

Andrew J, Bukurrow A, Deresio C, Golbuu Y, Graham C, Idechong JW, Isechal AL, Nakaya S, Oldiais NW, Olsudong D. 2011. Biological Surveys of Three MPAs and their Reference Sites in Chuuk Lagoon, Chuuk State, Federated States of Micronesia. Palau International Coral Reef Center. PICRC Technical Report 12-04.

Andrew J, Bukurrow A, Muller H, Golbuu Y, Idechong JW, Isechal AL, Nakaya S, Olsudong D. 2012. Biological Surveys of Three MPAs and their Reference Sites in Majuro Atoll, Republic of the Marshall Islands. Palau International Coral Reef Center. PICRC Technical Report 12-03.

Golbuu Y, Victor S, Penland L, Idip D.Jr., Emaurois C, Okaji K, Yukihira H, Iwase A, van Woesik R. 2007. Palau's coral reef show differential habitat recovery following the 1998-bleaching event. Coral Reefs 26: 319-322

Koshiba S, Andrew J, Bukurrow A, Golbuu Y, Idechong JW, Isechal AL, Joseph E, Maxim S, Ladore K, Nakaya S, Oldiais NW, Olsudong D. 2011. Biological Surveys of Three MPAs and their Reference Sites in Pohnpei State, Federated States of Micronesia. Palau International Coral Reef Center. PICRC Technical Report 12-05.

Koshiba S, Idechong JW, Isechal AL, Nakaya S, Merep A, Mereb G, Oldiais NW, Olsudong D, Nestor V. 2013. Biological Surveys of Ngemai MPA, Ngiwal State 2011-2012. PICRC Technical Report 13-02.

Moving Toward Measuring Our Effectiveness: The 2nd Meeting of the MC Measures Working Group and PICRC-JICA Coral Reef Monitoring Project Meeting 15-19 February, 2010. Palasia Hotel, Koror Republic of Palau.

Nestor V, Isechal AL, Koshiba S, Idechong J, Merep A, Mereb G, Olsudong D. 2013. Marine protected area effectiveness report: Teluleu Conservation Area. Palau International Coral Reef Center. PICRC Technical Report 13-01.

Olsudong D, Gaag M, Golbuu Y, Gorong T, Idechong JW, Isechal AL, Merep A, Nakaya S, Oldiais NW. 2012. Biological Surveys of Nimpal Channel MCA and its Reference Site in Yap State, Federated States of Micronesia. Palau International Coral Reef Center. PICRC Technical Report 12-06.