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Research Note

Evidence of a biomass hotspot for targeted fish species within Namena Marine Reserve, Fiji

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Abstract. Namena is Fiji's oldest and second largest no-take marine reserve, and has relatively high abundance and biomass of targeted fishes within its boundaries due to a high level of protection since its creation in 1997 (formalised in 2005). Following anecdotal reports of exceptionally high fish abundance at the Grand Central Station dive site within Namena, we conducted a 500-m meandering diver-operated video transect along the main reef formation, to obtain abundance, length and biomass estimates for fish species targeted by local fishers. Our census revealed extremely high diversity, abundance and biomass (11 436 kg ha^{-1}) of targeted fishes. While demersal reef fishes were present at higher densities than on typical fished reefs in the region, they were dwarfed by aggregations of reef-associated pelagics, namely the barracuda *Sphyraena forsteri* (5540 kg ha^{-1}) and the trevally *Caranx sexfasciatus* (4448 kg ha^{-1}). These estimates are comparable to those of historically unfished or 'pristine' locations, an unexpected finding given the historical fishing pressure within the reserve before its establishment and ongoing pressure in surrounding fished areas. This finding presents Grand Central Station as a useful reference site for ecologists and managers, and highlights the ability of protected coral reefs to support or attract very high densities of fish.

Additional keywords: abundance, coral reef fish, diver-operated video

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Introduction

The tropical western Pacific is a marine biodiversity hotspot, but the combined effects of artisanal and commercial fishing have led to severe declines in target fish species in recent decades (Campbell and Pardede 2006; Veitayaki *et al.* 2011). Fijians rely heavily on inshore artisanal fisheries for local livelihoods, but fish stocks have declined sharply with the growth of commercial fishing activity (DeMers and Kahui 2012). No-take marine reserves can be an effective and inexpensive tool for maintaining biodiversity where fishing regulations have insufficient scope or enforcement (e.g. Claudet *et al.* 2008; Lester *et al.* 2009), with high apex predator biomass reported following the establishment of marine reserves elsewhere in the Pacific region (Stevenson *et al.* 2007). In 2005, the local chiefs of Kubulau District, Vanua Levu Island, established a network of marine reserves with the aim of maintaining sustainable inshore fish stocks. This network consists of 17 reserves (mostly small and periodically harvested: Goetze *et al.* 2015), while the adjoining areas are managed through customary native fishing rights with ongoing offshore commercial fishing activity. The oldest and second largest reserve in Fiji, the Namena Marine Reserve, encompasses an area of 88 km^2 surrounding the island of Namenalala, and was informally established in 1997. While small, young reserves, both in Fiji and elsewhere, often show little evidence of recovery (Goetze *et al.* 2011; Edgar *et al.* 2014), Namena has been found to contain a greater abundance and biomass of target reef fish species than comparable fished areas (e.g. Goetze *et al.* 2011; Jupiter and Egli 2011). Reef sharks have also benefited from the reserve, most likely due to an increased prey availability (Goetze and Fullwood 2013). Here we report findings from an opportunistic rapid census of a popular dive site within the Namena Marine Reserve, conducted following anecdotal reports of exceptionally high local fish abundance.

Materials and methods

We conducted a diver-operated video survey at the Grand Central Station dive site (17°4′16.90″S, 179°6′31.75″E) within the Namena Marine Reserve, Fiji, in October 2012. We used the same calibrated stereo camera system described by Goetze *et al.* (2017), which permits the measurement of fish length using CAL and EVENTMEASURE software (http://www.seagis.com.au). The census consisted of a single 35-min meandering 5 × 500-m transect that followed the main reef structure at an average depth of 15 m, with fish recorded when they passed within 8 m of the cameras. Transect width was controlled by the automatic rejection of measurements made further than 2.5 m either side of the camera in EVENTMEASURE, while transect distance was measured by trailing a thin cotton thread from a 'cotton counter'. We only considered species that are targeted by local fishers (*sensu* Goetze *et al.* 2016), providing a conservative estimate of biomass. However, Fijians target a broad range of species, and excluded species were small, primarily belonging to the family Pomocentridae. As a result, they were unlikely to have contributed significantly to total biomass. Biomass for each species was estimated using standard weight equations taken from the literature (*sensu* Jupiter and Egli 2011). Individuals that could not be measured (e.g. partially obscured by reef or other fish) were assigned a length equal to the mean length of conspecifics at the site. Mean length estimates could not be obtained for four of 36 species (*Acanthurus leucocheilus*, *Melichthys niger*, *Cetoscarus bicolor* and *Scarus ghobban*). As a result, a total of 10 individuals from those species were excluded from biomass estimates.

Results

We observed a total of 2132 individuals (8528 fish ha^{-1}) from 12 families, 26 genera and 36 species, with a combined biomass of 2859 kg (11 436 kg ha^{-1}). Two pelagic species, the barracuda *Sphyraena forsteri* (6560 fish ha^{-1}, 5540 kg ha^{-1}) and trevally *Caranx sexfasciatus* (1160 fish ha^{-1}, 4448 kg ha^{-1}), were present in large schools over the reef (Fig. 1), comprising the greatest portion of biomass and abundance. Acanthurids, particularly the unicornfish *Naso brevirostris* (132 fish ha^{-1}, 128 kg ha^{-1}), were abundant in the midwater and demersal zones (288 fish ha^{-1}, 421 kg ha^{-1}), while the trigger (*Odonus niger*) (348 fish ha^{-1}, 43 kg ha^{-1}) was also prevalent in the midwater zone over the reef slope. Demersal predators (Carcharhinidae, Lethrinidae, Lutjanidae and Serranidae) comprised 116 fish ha^{-1} and 599 kg ha^{-1}.

Discussion

The high density of fish biomass (11 436 kg ha^{-1}) recorded at Grand Central Station in Namena Marine Reserve is comparable to the highest existing estimates of fish density in historically unfished or 'pristine' areas. At the Line Islands, an area of the Pacific known for its non-fished status and corresponding high densities of predatory fishes, Stevenson *et al.* (2007) reported a mean biomass of predatory fish of up to 5000 kg ha^{-1} at Palmyra Atoll, while Sandin *et al.* (2008) reported up to 8000 kg ha^{-1} at Jarvis Island. In the Indian Ocean, up to 8000 kg ha^{-1} was estimated at the Chagos Archipelago, another area without historical fishing pressure (Graham and McClanahan 2013).

Fig. 1. School of bigeye trevally (*Caranx ignobilis*) filmed with a diver-operated video system.

While we acknowledge that only a single site was recorded here and individual sites with similar biomass levels were likely recorded in the aforementioned studies, those studies described baseline biomass in historically unfished areas (McClanahan *et al.* 2011; MacNeil *et al.* 2015). Such high biomass at Namena was unexpected given the historical fishing pressure within the reserve before its establishment and ongoing fishing pressure surrounding the reserve (Jupiter and Egli 2011; Goetze *et al.* 2011), and likely reflects the large size, age and high enforcement associated with the reserve (Edgar *et al.* 2014). Prior to the present study, the highest biomass reported for a site within Namena was 2643 kg ha^{-1} (Jupiter and Egli 2011), although these results were obtained using different sampling techniques.

We provide evidence for a hotspot of targeted fish biomass primarily comprising large schools of *Sphyraena forsteri* and *Caranx sexfasciatus.* Residential behaviour of *Sphyraena barracuda* has been observed on the Atlantic Ocean (O'Toole *et al.* 2011), while restricted home ranges have been reported in *Caranx ignobilis*: tagged specimens tended to remain on a single atoll, making periodic movements of up to 29 km (Meyer *et al.* 2007). Both *S. forsteri* and *C. sexfasciatus* may exhibit similar site-fidelity to their respective congenerics. As our sampling was not replicated spatially or temporally, our results are unlikely to be representative of other areas in the reserve. In addition, it is now thought that these predatory fish aggregations

obtain a large proportion of their energy sources from pelagic zones rather than by local production (Trebilco *et al.* 2013). Regardless, aggregations of predatory fishes on a reef are likely indicative of ecosystem health, with large aggregations expected to become increasingly rare under fishing pressure (whether through direct or indirect effects). Anecdotal evidence indicates that the *Sphyraena forsteri* at Grand Central Station may be Namena residents. Given evidence for long-term patterns of population recovery in other marine reserves (e.g. McClanahan and Graham 2005; McClanahan *et al.* 2007; Russ and Alcala 2010), the local population may continue to grow in the future.

Demersal or midwater reef fishes are typically more susceptible to local population depletion than reef-associated pelagic species (e.g. Jennings *et al.* 1999), and, in Fiji, are more frequently targeted by fishers (pers. obs.). Although overshadowed by pelagic species in our census, the density of resident reef fishes (848 kg ha^{-1}) was nonetheless at the high end of estimates for coral reef sites worldwide and close to those of historically unfished sites (MacNeil *et al.* 2015).

These findings provide the first view of a potential hotspot of predatory fish within the Namena Marine Reserve, and present Grand Central Station as a useful reference site for ecologists and managers that highlights the capacity of protected coral reef systems to attract or support very high densities of targeted fish species.

Conflicts of interest

The authors declare no conflicts of interest.

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References

Campbell, S. J., and Pardede, S. T. (2006). Reef fish structure and cascading effects in response to artisanal fishing pressure. *Fisheries Research* **79**, 75–83. doi:10.1016/J.FISHRES.2005.12.015

Claudet, J., Osenberg, C. W., Benedetti-Cecchi, L., Domenici, P., García-Charton, J. A., Pérez-Ruzafa, Á., Badalamenti, F., Bayle-Sempere, J., Brito, A., Bulleri, F., Culioli, J. M., Dimech, M., Falcón, J. M., Guala, I., Milazzo, M., Sánchez-Meca, J., Somerfield, P. J., Stobart, B., Vandeperre, F., Valle, C., and Planes, S. (2008). Marine reserves: size and age do matter. *Ecology Letters* **11**, 481–489. doi:10.1111/J.1461-0248.2008.01166.X

DeMers, A., and Kahui, V. (2012). An overview of Fiji's fisheries development. *Marine Policy* **36**, 174–179. doi:10.1016/J.MARPOL.2011.05.001

Edgar, G. J., Stuart-Smith, R. D., Willis, T. J., Kininmonth, S., Baker, S. C., Banks, S., Barrett, N. S., Becerro, M. A., Bernard, A. T. F., Berkhout, J., Buxton, C. D., Campbell, S. J., Cooper, A. T., Davey, M., Edgar, S. C., Forsterra, G., Galvan, D. E., Irigoyen, A. J., Kushner, D. J., Moura, R., Parnell, P. E., Shears, N. T., Soler, G., Strain, E. M. A., and Thomson, R. J. (2014). Global conservation outcomes depend on marine protected areas with five key features. *Nature* **506**, 216–220. doi:10.1038/NATURE13022

Goetze, J. S., and Fullwood, L. A. F. (2013). Fiji's largest marine reserve benefits reef sharks. *Coral Reefs* **32**, 121–125. doi:10.1007/S00338-012-0970-4

Goetze, J. S., Langlois, T. J., Egli, D. P., and Harvey, E. S. (2011). Evidence of artisanal fishing impacts and depth refuge in assemblages of Fijian reef fish. *Coral Reefs* **30**, 507–517. doi:10.1007/S00338-011-0732-8

Goetze, J. S., Jupiter, S. D., Langlois, T. J., Wilson, S. K., Harvey, E. S., Bond, T., and Naisilisili, W. (2015). Diver operated video most accurately detects the impacts of fishing within periodically harvested closures. *Journal of Experimental Marine Biology and Ecology* **462**, 74–82. doi:10.1016/J.JEMBE.2014.10.004

Goetze, J. S., Langlois, T., Claudet, J., Januchowski-Hartley, F., and Jupiter, S. D. (2016). Periodically harvested closures require full protection of vulnerable species and longer closure periods. *Biological Conservation* **203**, 67–74. doi:10.1016/J.BIOCON.2016.08.038

Goetze, J. S., Januchowski-Hartley, F. A., Claudet, J., Langlois, T. J., Wilson, S. K., and Jupiter, S. D. (2017). Fish wariness is a more sensitive indicator to changes in fishing pressure than abundance, length or biomass. *Ecological Applications* **27**, 1178–1189. doi:10.1002/EAP.1511

Graham, N. A. J., and McClanahan, T. R. (2013). The last call for marine wilderness? *Bioscience* **63**, 397–402. doi:10.1525/BIO.2013.63.5.13

Jennings, S., Reynolds, J. D., and Polunin, N. V. C. (1999). Predicting the vulnerability of tropical reef fishes to exploitation with phylogenies and life histories. *Conservation Biology* **13**, 1466–1475. doi:10.1046/J.1523-1739.1999.98324.X

Jupiter, S. D., and Egli, D. P. (2011). Ecosystem-based management in Fiji: successes and challenges after five years of implementation. *Journal of Marine Biology* **2011**, 940765. doi:10.1155/2011/940765

Lester, S. E., Halpern, B. S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B. I., Gaines, S. D., Airam, S., and Warner, R. R. (2009). Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series* **384**, 33–46. doi:10.3354/MEPS08029

MacNeil, M. A., Graham, N. A., Cinner, J. E., Wilson, S. K., Williams, I. D., Maina, J., Newman, S., Friedlander, A. M., Jupiter, S., Nicholas, S., Polunin, N. V. C., and McClanahan, T. R. (2015). Recovery potential of the world's coral reef fishes. *Nature* **520**, 341–344. doi:10.1038/NATURE14358

McClanahan, T. R., and Graham, N. A. J. (2005). Recovery trajectories of coral reef fish assemblages within Kenyan marine protected areas. *Marine Ecology Progress Series* **294**, 241–248. doi:10.3354/MEPS294241

McClanahan, T. R., Graham, N. A. J., Calnan, J. M., and MacNeil, M. A. (2007). Toward pristine biomass: reef fish recovery in coral reef marine protected areas in Kenya. *Ecological Applications* **17**, 1055–1067. doi:10.1890/06-1450

McClanahan, T. R., Graham, N. A., MacNeil, M. A., Muthiga, N. A., Cinner, J. E., Bruggemann, J. H., and Wilson, S. K. (2011). Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries. *Proceedings of the National Academy of Sciences of the United States of America* **108**, 17230–17233. doi:10.1073/PNAS.1106861108

Meyer, C. G., Holland, K. N., and Papastamatiou, Y. P. (2007). Seasonal and diel movements of giant trevally *Caranx ignobilis* at remote Hawaiian atolls: implications for the design of marine protected areas. *Marine Ecology Progress Series* **333**, 13–25. doi:10.3354/MEPS333013

O'Toole, A. C., Danylchuk, A. J., Goldberg, T. L., Suski, C. D., Philipp, D. P., Brooks, E., and Cooke, S. J. (2011). Spatial ecology and residency patterns of adult great barracuda (*Sphyraena barracuda*) in coastal waters of the Bahamas. *Marine Biology* **158**, 2227–2237. doi:10.1007/S00227-011-1728-1

Russ, G. R., and Alcala, A. C. (2010). Decadal-scale rebuilding of predator biomass in Philippine marine reserves. *Oecologia* **163**, 1103–1106. doi:10.1007/S00442-010-1692-3

Sandin, S. A., Smith, J. E., DeMartini, E. E., Dinsdale, E. A., Donner, S. D., Friedlander, A. M., Konotchick, T., Malay, M., Maragos, J. E., Obura, D., Pantos, O., Paulay, G., Richie, M., Rohwer, F., Schroeder, R. E., Walsh, S., Jackson, J. B. C., Knowlton, N., and Sala, E. (2008). Baselines and degradation of coral reefs in the Northern Line Islands. *PLoS One* **3**, e1548. doi:10.1371/JOURNAL.PONE.0001548

Stevenson, C., Katz, L. S., Micheli, F., Block, B., Heiman, K. W., Perle, C., Weng, K., Dunbar, R., and Witting, J. (2007). High apex predator biomass on remote Pacific islands. *Coral Reefs* **26**, 47–51. doi:10.1007/S00338-006-0158-X

Trebilco, R., Baum, J. K., Salomon, A. K., and Dulvy, N. K. (2013). Ecosystem ecology: size-based constraints on the pyramids of life. *Trends in Ecology & Evolution* **28**, 423–431. doi:10.1016/J.TREE.2013.03.008

Veitayaki, J., Nakoro, A. D. R., Sigarua, T., and Bulai, N. (2011). On cultural factors and marine managed areas in Fiji. In 'Pacific Island Heritage: Archaeology, Identity and Community'. (Eds J. Liston, G. R. Clark, and D. Alexander.) Chapter 4, pp. 37–49. (ANU Press: Canberra.)