THE NATURE CONSERVANCY'S MAPPING OCEAN WEALTH PROJECT:

MODELLING AND MAPPING FISHING PRESSURE AND THE CURRENT AND POTENTIAL STANDING STOCK OF CORAL-REEF FISHES IN FIVE JURISDICTIONS OF MICRONESIA

Final technical report prepared by:

Alastair R. Harborne
University of Queensland

Marine Spatial Ecology Lab, School of Biological Sciences
Goddard Building, University of Queensland, St Lucia Campus
Brisbane, QLD 4072, Australia

Tel: +61 (0)7 336 51671 | Fax: +61 (0)7 336 51655
email: a.harborne@uq.edu.au

January, 2016

Acknowledgements

The Phase 1 project to map fishing pressure and standing stock in Micronesia was a collaborative effort between:

- Alastair Harborne (University of Queensland)
- Alison Green (The Nature Conservancy)
- Nate Peterson (The Nature Conservancy)
- Philine zu Ermgassen (The Nature Conservancy)
- Eddie Game (The Nature Conservancy)
- Trina Leberer (The Nature Conservancy)
- Peter Mumby (University of Queensland)
- Hugh Possingham (University of Queensland)
- Mark Spalding (The Nature Conservancy)
- Elizabeth Terk (The Nature Conservancy)
- Steven Victor (The Nature Conservancy)

We are very grateful to those people who have kindly donated data for the project, particularly Katrina Adams (Kosrae Village Resort), Serge Andréfouët (Institut de Recherche pour le Développement), Jorg Anson (Conservation Society of Pohnpei), Maria Beger (UQ), Eva Buthung (Yap Community Action Program), Rodney Camacho (University of Guam Marine Laboratory), Karl Fellenius (College of the Marshall Islands), Yimnang Golbuu (Palau International Coral Reef Center), Marine Gouezo (Palau International Coral Reef Center), Curtis Graham (Chuuk Marine Resources Department), Don Hess (College of the Marshall Islands), Peter Houk (University of Guam Marine Laboratory), Steven Johnson (Commonwealth of the Northern Mariana Islands Bureau of Environmental and Coastal Quality), Eugene Joseph (Conservation Society of Pohnpei), Emma Kabua (Marshall Islands Marine Resources Authority), Marston Luckymis (Kosrae Conservation and Safety Organization), Selino Maxin (Conservation Society of Pohnpei), Matthew McLean (University of Guam Marine Laboratory), Osamu Nedlic (Kosrae Conservation and Safety Organization), Brett Taylor (NOAA Fisheries), Eric Treml (University of Melbourne), Laurent Vigliola (Institut de Recherche pour le Développement), Ivor Williams (NOAA CRED), Anthony Yalon (Yap Community Action Program), and Benedict Yamamura (Marshall Islands Marine Resources Authority).

This work is supported by grants from the Lyda Hill Foundation and Carnival Foundation for The Nature Conservancy's Mapping Ocean Wealth project.

Cover photographs:

Left: *Plectropomus leopardus* (leopard coral trout) is an important fishery species from many reefs in Micronesia. © Mark Priest.

Right: Surveying the catch of the day in Micronesia. © TNC.

Summary

Marine ecosystem goods and services, such as protein provision, are being affected by a range of anthropogenic stressors, and maintaining their integrity represents an important goal of conservation and management. Consequently, there is a need for a greater effort to incorporate ecosystem services into policy making at a range of scales. In response to this need, The Nature Conservancy (TNC) has established the Mapping Ocean Wealth Project to quantitatively describe what global oceans provide today, and facilitate better decision making.

Within a larger project framework, TNC contracted the University of Queensland (Australia) to undertake Phase 1 of the effort to map coral reef fisheries. The key aims of this work were to model and map fishing pressure, model and map the current value of coral reef fisheries (current fish standing stock), and assess the potential benefit of conservation and management measures, such as the potential standing stock on a reef if fishing was managed through the establishment of no-take reserves or other fisheries management tools. The research at UQ also aimed to identify options for using the resulting maps and models for marine spatial planning, and to assist with the preparation of practical tools summarizing the findings of the research and its potential applications. Phase 1 modelled and mapped these variables (fishing pressure, current and potential standing stock) across five jurisdictions of Micronesia (the Republic of Palau, the Federated States of Micronesia, the Territory of Guam, the Commonwealth of the Northern Marianas, and the Republic of the Marshall Islands). Micronesia represented a tractable spatial scale to explore the mapping and modelling approaches, and the project results will complement on-going conservation and management initiatives in the region. Furthermore, fisheries are of significant economic importance in the region. The final products were delivered in January 2016, with the aim of extending to a global scale in a funding-dependent Phase 2 later in the year. This report outlines the methods used to achieve the mapping and modelling aims of Phase 1, shows the results of the statistical models, and includes the resulting maps.

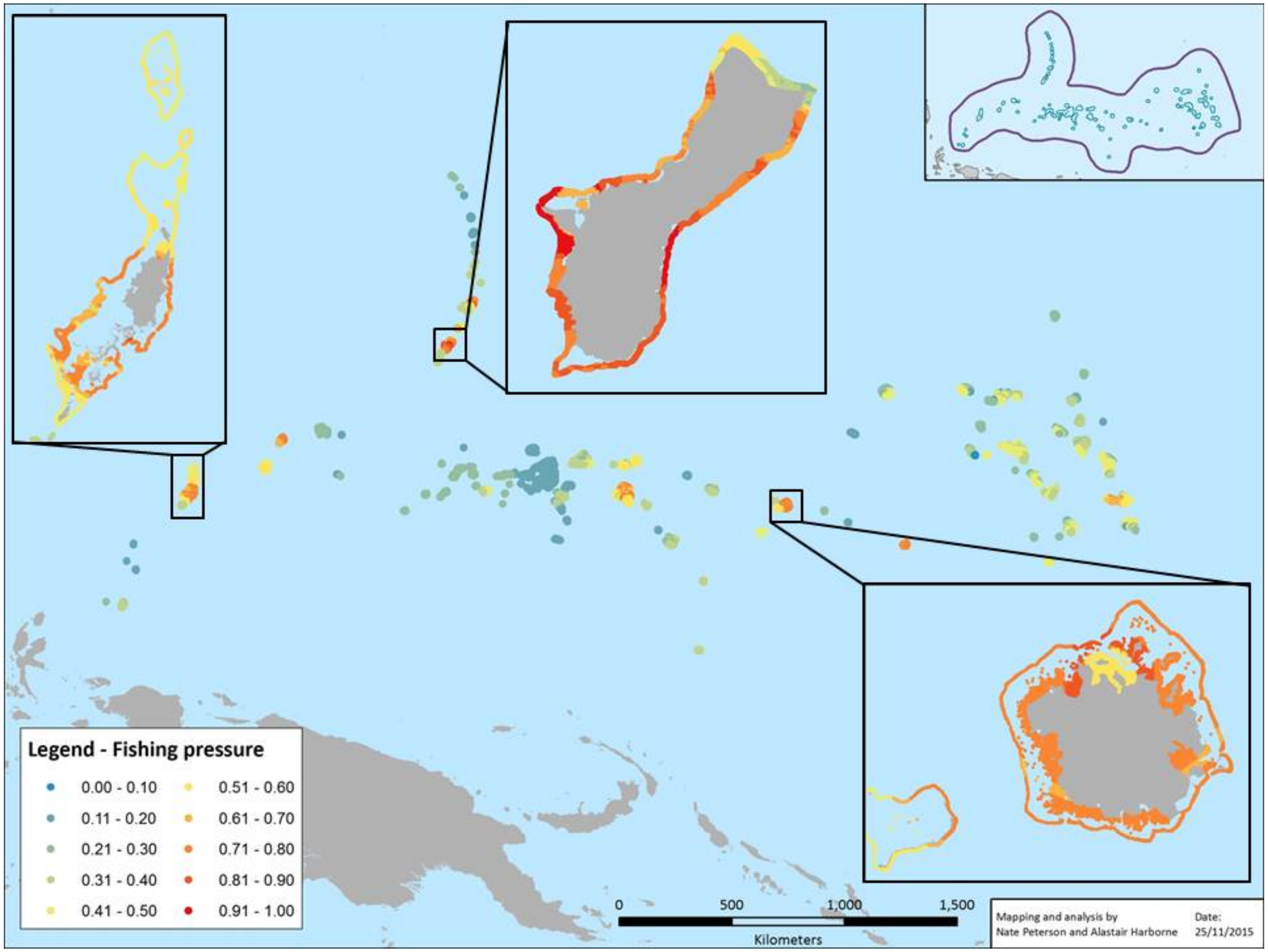
Through the generous provision of fish survey data from a range of sources, the Phase 1 project had access to >1,100 fish surveys from all five jurisdictions. Data from locations where surveys were conducted by more than one data source suggests that the data are comparable, and can be pooled to obtain robust, region-wide models. The first step was to statistically model fishing pressure, which used fishery-independent data on parrotfish mean size from the fish surveys. This approach builds on a growing literature suggesting that the size of larger parrotfishes represents an excellent indicator of fishing pressure. Data on parrotfish sizes across all jurisdictions were modelled in relation to 22 potential predictor variables, including human population size, distance to markets, and oceanic temperature and productivity. When controlling for biophysical gradients, the model demonstrated that fishing was best predicted by distance to the nearest port and human population pressure within 200 km. This model was then used to extrapolate relative fishing pressure (specifically the total cumulative impact of fishing on the fish assemblage, which may be decoupled from current fishing effort) to all sites across the region, and generate a continuous map (Map 1). However, the values of fishing pressure (and standing stock) were generally restricted to forereef slopes, reflecting that the fish survey data were collected in this particular habitat type. This map represents the first continuous assessment of fishing pressure across the region.

Estimates of fishing pressure were then used as a key data layer, along with 16 other potential environmental variables, to model current standing stock at an independent set of sites where additional survey fish data were available. The metric of standing stock was the total biomass of 19 key fisheries species from a range of taxa and trophic groups that were surveyed in all data sources and are found across the region, and are a good proxy of standing stock of all species. The model demonstrated that standing stock increased with increasing oceanic productivity, upstream larval supply, depth, and coral cover, and decreased with increasing sea surface temperature and fishing

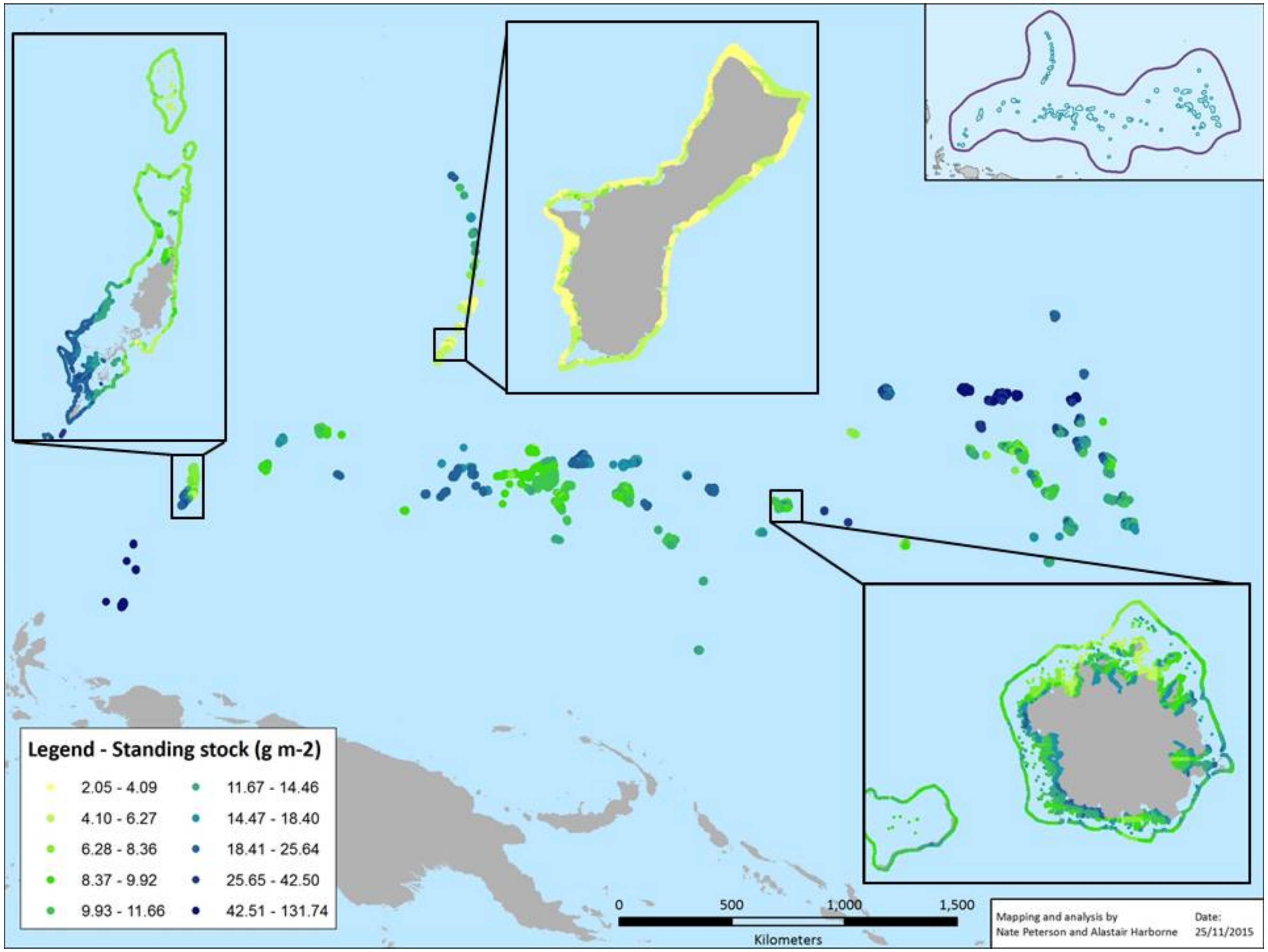
pressure. As for fishing pressure, this model was then used to extrapolate estimates of current standing stock across the region to generate a previously unavailable map of fish biomass (Map 2). Finally, the model of current standing stock was adjusted to represent a potential management scenario (fishing pressure reduced to zero to simulate the establishment of a no-take reserve or other fisheries management tool) to allow the production of a map estimating patterns of potential standing stock across the region (Map 3). Using the maps of predicted current and potential standing stock also allowed the project to generate a map of the expected percentage gain in biomass following the cessation of fishing (Map 4). These data suggest that the current standing stock of these 19 species alone might increase by a regional total of ~12,200 metric tonnes following the cessation of fishing. In addition to models and maps of the total biomass of all 19 species, maps of current standing stock and potential gain following the cessation of fishing were also produced for the species separated by trophic group: herbivores, invertivores, and piscivores. All maps were produced at a resolution of 100 x 100 m cells (1 hectare).

Summaries of the map products from the project provide a snapshot of the status of fishing and fisheries in Micronesia. These summary figures clearly show the impact of human populations on fish stocks, with generally lower biomasses on reefs close to relatively heavily populated islands, and more intact fish assemblages on more remote reefs. The summaries also demonstrate the variation within the region with, for example, the reefs around Guam clearly more heavily impacted than the reefs of the Marshall Islands. The data were also summarised following calculation of the ratio of current to potential standing stock. This metric has been proposed as providing important insights into the status of fisheries, and potentially benthic dynamics. Although the majority of reefs in Micronesia appear to be relatively functionally intact (current biomass >50% of potential biomass), the exact thresholds where loss of fishes alters ecosystem processes are not well defined in the region. We also used published relationships between the ratio of current to potential biomass and the time to recover to a fully functioning fish assemblage (current biomass >90% of potential biomass). Many of the reefs in the region would take decades (maximum time ~50 years) to reach this state, which highlights the importance of establishing no-take reserves or other fisheries management tools as soon as possible.

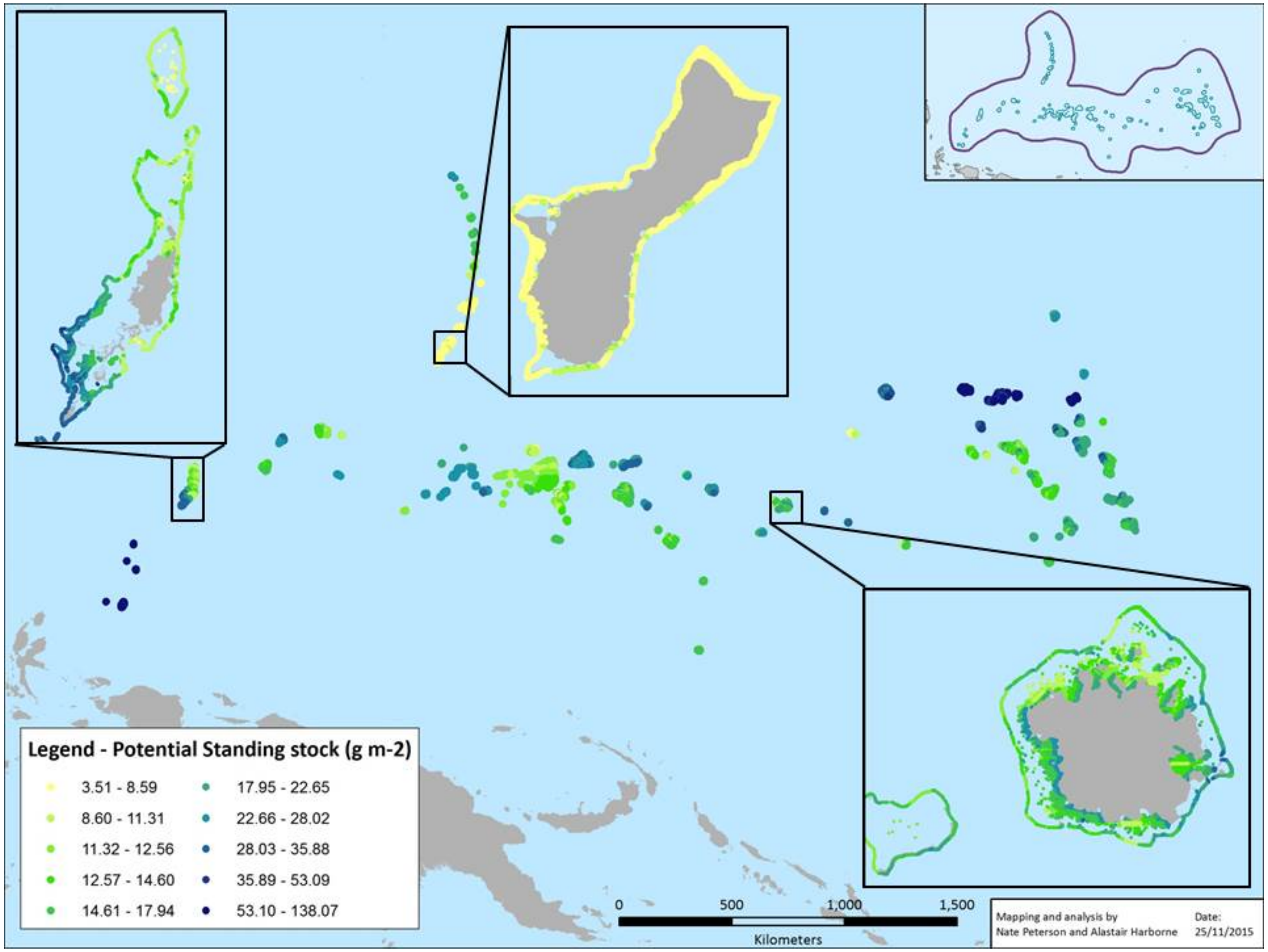
Along with mapping aspects of ocean wealth (e.g. harvestable protein), it is anticipated that the products of the Phase 1 project will be useful for on-going marine spatial planning in Micronesia. For example, the Micronesia Challenge aims to conserve 30% of the region's marine resources by 2020, and we anticipate that the maps of fishing pressure and standing stock can be used as previously unavailable data layers within analyses to plan protected area networks. These opportunities, and other possible uses of the project products, were discussed at two workshops during Phase 1 and are outlined in detail in a separate report.



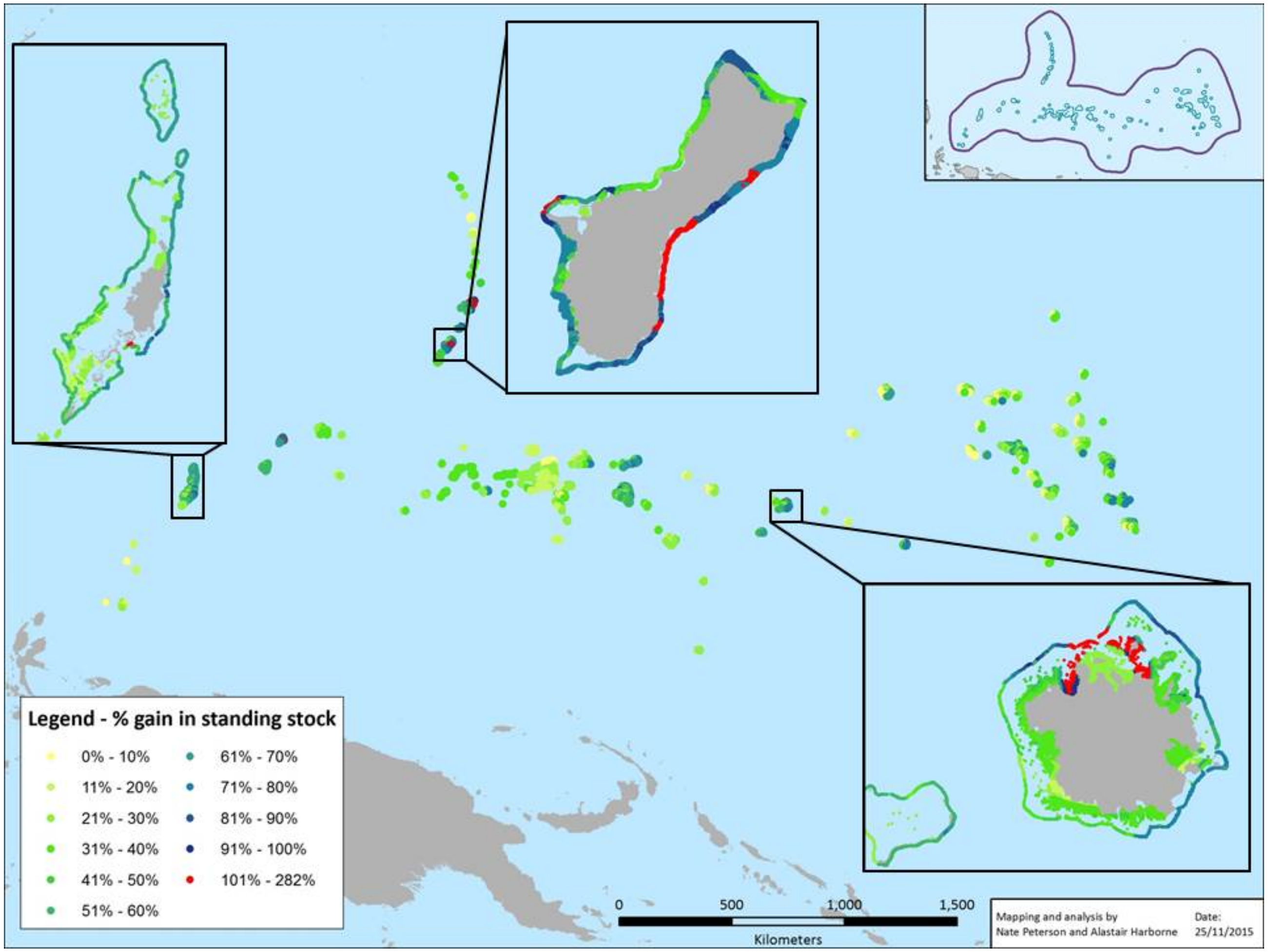
Map 1. Regional map of predicted relative fishing pressure, including larger-scale insets of fishing pressure around Palau, Guam, and Pohnpei. Map shows predicted values for both well-parameterised and possibly well-parameterised habitat types (see Table 4 for explanation).



Map 2. Regional map of predicted current standing stock of 19 key fish species, including larger-scale insets of the biomass around Palau, Guam, and Pohnpei. Map shows predicted values for both well-parameterised and possibly well-parameterised habitat types (see Table 4 for explanation).



Map 3. Regional map of predicted potential standing stock of 19 key fish species if there was zero fishing, including larger-scale insets of the biomass around Palau, Guam, and Pohnpei. Map shows predicted values for both well-parameterised and possibly well-parameterised habitat types (see Table 4 for explanation).



Map 4. Regional map of predicted potential percentage gain of standing stock of 19 key fish species if there was zero fishing, including larger-scale insets of the gain around Palau, Guam, and Pohnpei. Map shows predicted values for both well-parameterised and possibly well-parameterised habitat types (see Table 4 for explanation).