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Scaling tropical island conservation planning to the regional level can lead to unbalanced ecological representation and poor social equity among islands

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ABSTRACT

The effectiveness of Marine Protected Areas (MPA) to manage natural resources has been undermined in small insular lagoons due to massive mortalities triggered by climatic events that have hit some lagoons but not others. To minimize the future risk of ineffective management efforts, it has previously been argued that management should focus on a multi-island conservation target (regional scale), rather than on individual lagoons (local scale). However, it is unclear how a MPA network designed to meet objectives at a regional scale would impact on the management of resources at the local scale. In particular, it is necessary to understand if a regional plan might incidentally maintain conservation objectives at the local scale, without disproportionately affecting, or relying on particular islands. This study used the population of the giant clam (*Tridacna maxima*) in a fishery context to explore the distributions of conservation features and socio-economic costs for regional networks (computed within a set of islands), compared to individual islands. Designing a MPA network at regional scale led to unbalanced representation of conservation features among atolls and incidentally missed the targeted level of protection for conservation features at local scale. Moreover, the regional network generated inequitable costs for fishermen between islands, which is likely to lead to poor perceived equity. This study suggests that perceived equity and the representation of local conservation objectives will be major factors to consider, if the French Polynesian authorities follow the path of implementing MPAs in each atoll for a regional-scale resource management plan.

1. Introduction

In the context of global climate change, the ability of coral reef fisheries in small tropical islands to survive is uncertain [1]. In many tropical marine environments, fishing has increased substantially, often contributing to the depletion of stocks. Moreover, the ability of insular socio-ecosystems to adapt to climate-driven changes is considered low, due to limited diversity, small population sizes, isolation, and greater exposure to natural disturbances [2–5]. For these highly vulnerable fisheries, the development of management strategies that integrate the long-term risk particularly those induced by climate variability is a priority.

To avoid frustration and ineffective marine management efforts in the face of climate change, it has been argued that marine environment managers could consider spreading conservation objectives across a set of islands rather than focusing only on those exploiting their natural giant clam resources commercially [6]. Indeed, a multi-island network of MPAs could help limit the risk of overall management failure due to climate-induced stress, as opposed to focusing conservation efforts on one or two sites. The term “network” implies that each site included in the multi-island MPA would draw conservation benefits from a scale larger than itself, and thus in this paper “network” refers to this synergic aspect of MPAs [7], without necessarily implying connectivity between islands. However, the implications for each individual island of adopting a regional planning strategy remain poorly addressed. In particular, it remains unclear if the cost of conservation induced by a regional network of MPA can be sufficiently even between islands to ensure compliance by local populations [8–10]. Compliance can be driven by numerous factors [11], one of them being fairness [12], or equity in outcomes [13]. To assess outcome equity, it is necessary to understand if a regional plan incidentally maintains conservation objectives at local scale, without disproportionally affecting, or relying on

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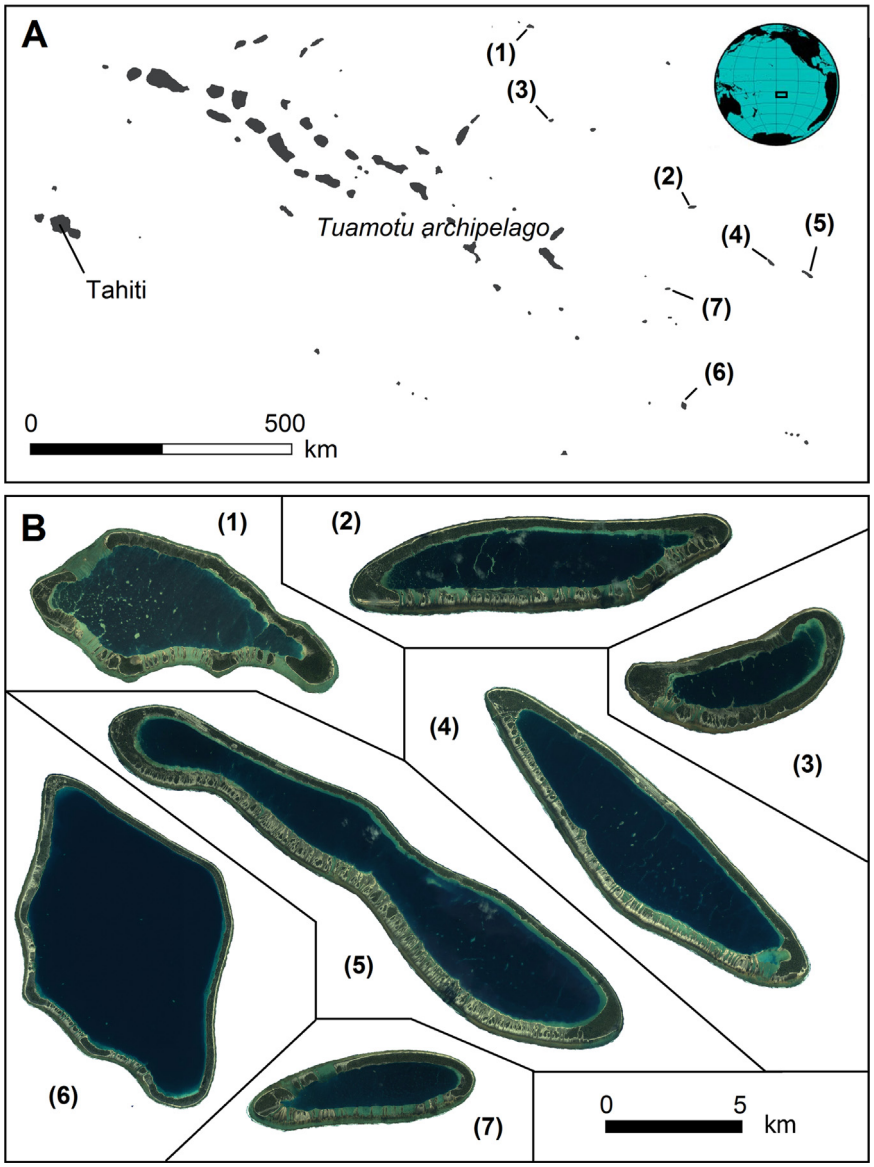

Fig. 1. A: Location of the seven atolls considered in this study in Tuamotu Archipelago, French Polynesia. B: Satellite view of each atoll. (1) Napuka; (2) Tatakoto; (3) Fangatau; (4) Pukarua; (5) Reao; (6) Tureia; (7) Vahitahi.

particular islands. This paper thus uses the concept of outcome equity in conservation and refers to an equitable distribution of costs (i.e. amount of resources not available to people), benefits (i.e. amount of resources protected) or risks (i.e. unprotected resources) between individuals or groups of people affected by the conservation action, although equity may also refer to broader considerations than conservation costs, benefits and risks [10,14,15].

Examples of managed small fisheries facing overfishing and climate change are found in the Tuamotu archipelago in French Polynesia [6,16,17]. The Tuamotu benefits from various legal schemes for the protection of its natural reef and lagoon assets in several atolls [18]. For instance, the six atolls of the Fakarava UNESCO Man and Biosphere Reserve have individual zoning plans with restricted fishing areas and among them, Taiaro atoll is a 'no-access' area. Several atolls have several no-fishing areas called *Zones de Pêche Réglementées* (ZPRs, or Regulated Fishing Zones). In Reao and Tatakoto atolls, these ZPRs are specific for the protection of the *Tridacna maxima* giant clam. These ZPRs are not seen as a unique form of protection as they complement the minimum size of catches (12 cm) which applies to the entire French Polynesia. Indeed, giant clam is an important resource in French Polynesia and worldwide. Worldwide, over the last three decades, the commercial exploitation of all giant clams (family Cardiidae; subfamily Tridacninae) [19] has led to the collapse of many populations, especially in the Pacific Ocean [19,20]. However, in the Eastern Tuamotu archipelago atolls, the small giant clam (*Tridacna maxima*) remains in densities several orders of magnitude higher than those observed for other giant clam species elsewhere [20–23]. In two atolls, Reao and Tatakoto, natural conditions were also suitable for the post-larval capture and culture (PCC) of *T. maxima*, an aquaculture technique that collects larvae on artificial structures [24,25]. In early 2016, with these two atolls, French Polynesia represented roughly 25% of the global trade in live giant clams sold for the aquarium trade.

Mindful of the sustainability of this new economic venture, the local fisheries service (DRMM, standing for *Direction des Ressources Marines et Minières*) has established small ZPRs for *Tridacna maxima* in 2004 in Tatakoto, and in 2016 in Reao. In theory, when certain conditions are met, MPAs can be efficient tools for natural resource management, by increasing recruitment, density, biomass, and organism size inside 'no-take' marine reserves [26] and in their surrounding areas [27,28]. However, MPAs can also pose significant socio-economic and cultural