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Mapping the global value and distribution of coral reef tourism

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ABSTRACT

Global coral reef related tourism is one of the most significant examples of nature-based tourism from a single ecosystem. Coral reefs attract foreign and domestic visitors and generate revenues, including foreign exchange earnings, in over 100 countries and territories. Understanding the full value of coral reefs to tourism, and the spatial distribution of these values, provides an important incentive for sustainable reef management. In the current work, global data from multiple sources, including social media and crowd-sourced datasets, were used to estimate and map two distinct components of reef value. The first component is local "reef-adjacent" value, an overarching term used to capture a range of indirect benefits from coral reefs, including provision of sandy beaches, sheltered water, food, and attractive views. The second component is "on-reef" value, directly associated with in-water activities such diving and snorkelling. Tourism values were estimated as a proportion of the total visits and spending by coastal tourists within 30 km of reefs (excluding urban areas). Reef-adjacent values were set as a fixed proportion of 10% of this expenditure. On-reef values were based on the relative abundance of dive-shops and underwater photos in different countries and territories. Maps of value assigned to specific coral reef locations show considerable spatial variability across distances of just a few kilometres. Some 30% of the world's reefs are of value in the tourism sector, with a total value estimated at nearly US$36 billion, or over 9% of all coastal tourism value in the world's coral reef countries.

1. Introduction

Coral reef related tourism is an important and still fast-growing industry, providing employment and income to over 100 jurisdictions world-wide, and often generating much-needed foreign earnings [1–6]. Coastal tourism in the vicinity of coral reefs is not always benign: negative impacts can include degradation and loss of marine life through activities such as diving and snorkelling [7–9], as well as indirect impacts arising from poorly planned coastal development, including dredging, building on intertidal spaces, and increases in pollution and solid waste [10–12]. Despite these risks, tourism may be a less significant threat than fishing, land-based run-off or coral bleaching [13], and may even help to reduce some threats, notably over-fishing, by offering financial or social incentives for sustainable management [14–17]. Many visitors to coral reefs already have heightened environmental awareness [18] and reef visitation can both help to fund [19] and to encourage [20] coral reef conservation.

Much of the focus on the value and impacts of coral reef tourism has focused on the direct use of coral reefs for in-water activities. The indirect value of coral reefs in driving coastal tourism remains less well quantified, but is also important. Studies have shown the considerable importance of clear water and beach characteristics such as fine sand in influencing tourist preferences [21–23]. There is also a sizeable literature on the multiple ecosystem functions provided by coral reefs which may support tourism benefits, including the generation of fine sand beaches [24], the maintenance and building of islands [25,26], protection from wave erosion and storm damage [27], and the production of seafood [28]. Coral reef imagery also plays an important

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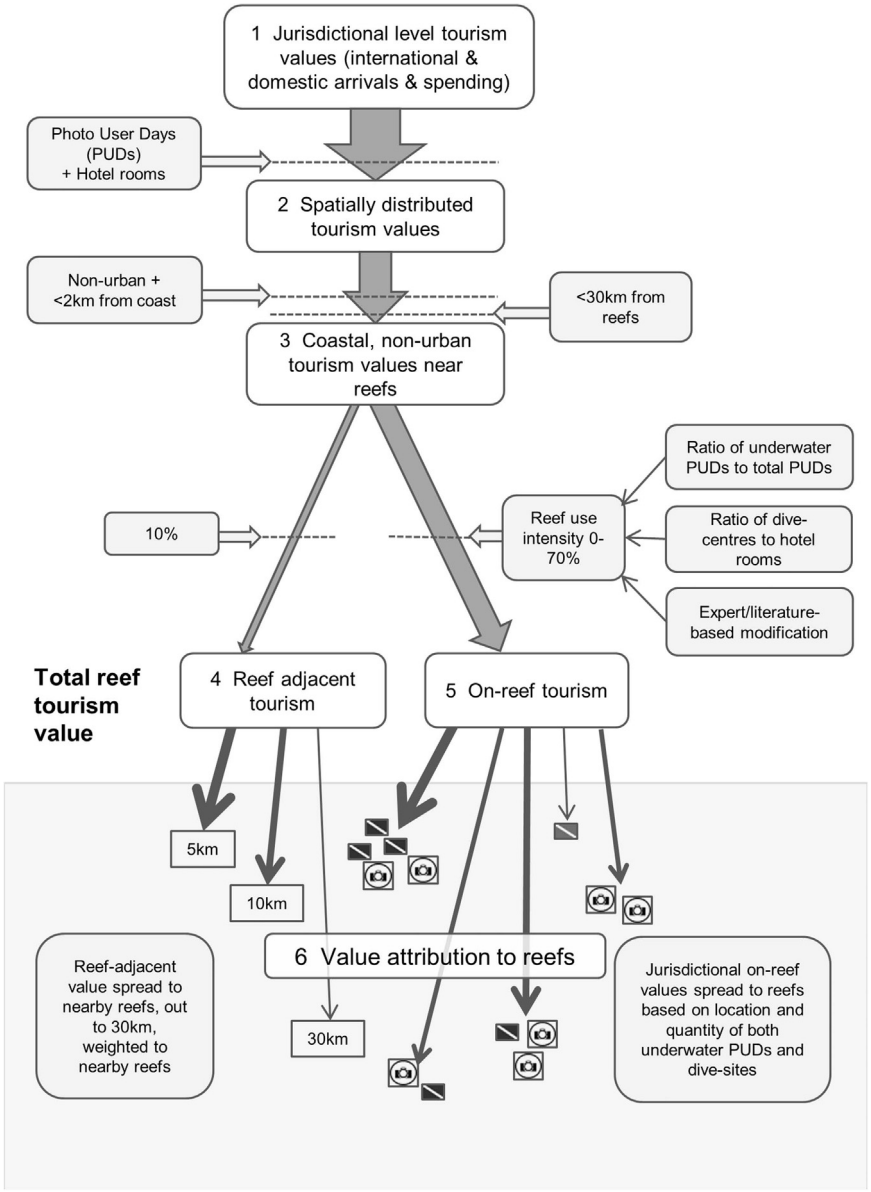

Fig. 1. A schematic representation of the methods employed to filter and spatially distribute components of national tourism statistics to coral reefs. Numbered stages are set out in detailed text description. Photo User Days (PUDs) give a measure of the intensity of photography in specified locations, they are more fully explained below.

role in marketing [29], while the perception of reef proximity, even for non-reef users, may be an important draw [23,30]. Finally, the health benefits associated with proximity to nature and to marine environments more generally are now increasingly realised [31,32], and are also likely to be played out in coral reef settings.

Given the broad array of economic and social benefits that coral reefs provide, there are growing attempts to build more sustainable approaches to reef-related tourism [33–37]. In large part, however, such efforts remain the target of individual operators, a few small island nations or some operators in the diving sector. The wider call for corporate social responsibility (CSR) has been slow to influence the tourism sector in general, with biodiversity conservation remaining low on the agenda even among those corporations who are engaging in CSR more broadly [38]. Against this background, a clear, quantified and reliable understanding of the value of coral reefs for tourism in specific settings could help, by raising awareness and highlighting opportunities for strengthening coral reef conservation, both in the public sphere and in the tourism sector.

Previous efforts to quantify the value and to describe the spatial distribution of reef-related tourism at large scales have been limited. Without mapping, de Groot et al. [39] generated a mean value for coral reef recreation of US$96,302 ha^{-1} yr^{-1}. This figure was derived from 29 studies, with a median value of US$1562 ha^{-1} yr^{-1}, but ranging from zero to almost US$1.5 million ha^{-1} yr^{-1}. The large mean value from this study was used in preference to the median value in a direct benefit transfer approach to all coral reefs, generating a global estimate of value of US$2.7 trillion per year, or 2.2% of all global ecosystem service values [derived from supplementary materials in 40], a figure that seems impossibly high given the spatially restricted nature of coral reef tourism. Elsewhere, Brander *et al.* [1] had already drawn attention to the challenges of such extrapolation: with data from 100 separate reef recreation studies, they conducted out-of-sample value transfer tests and estimated average transfer errors of 186%, a figure they deemed “unlikely to be acceptable in most policy-making scenarios” (pg 215).

Given the challenges of developing value transfer approaches, alongside the acknowledged benefits of developing an understanding not only of global values but of the spatial distribution of such value, this work presents a novel approach to accurately quantify global reef values and to distribute these values to specific reefs at local scales. The