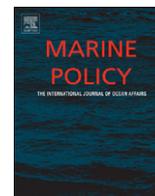




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A conceptual process-based reference model for collaboratively managing recreational scuba diving in Kenting National Park

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ABSTRACT

The purpose of this paper is to describe a management process to better control scuba diving on coral reefs. While the dive industry permits growth in local tourism revenues it can also create a degradation of the coral reefs if there are too many divers. Consequently appropriate management is essential. In this study, a case analysis of Kenting National Park was undertaken. The authors describe a process-based reference model and information system to better manage diving through collaboration by the different units, namely the divers, dive centers, the park office, the nuclear power plant bodies, the park police and the coastal guards. The management tool set of IDEFO (Integration Definition for Function Modeling 0) was applied to describe the overall diving service workflow. An object-oriented analysis approach was then applied to represent the design of the collaborative model. A prototype web-based platform was constructed to demonstrate the model for in situ information that potentially could monitor diving and improve communication channels between the actors.

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1. Introduction

Coral reefs constitute a highly diverse environment offering various habitats for countless marine organisms. For many coastal people in tropical regions, coral reefs not only are vital sources of food and income through their role in fisheries [1], but also provide protection for coastlines from storm damage by reducing wave action [2]. In addition, clear water and spectacular underwater scenery attract many tourists who swim over reefs to observe coral, invertebrates and colorful fishes [3–5]. Tourism based on coral reefs is rapidly growing in many tropical maritime nations. The commercial values of marine tourism activities contribute greatly to the economy [6,7]. However, non-stopping tourism development may harm environments [8–10]. Managing the tourism impact on coral reefs has become urgent and necessary [11,12].

Recreational scuba diving has become one of the most popular activities on coral reefs [13–15]. Diving lessons and certification, equipment rentals, dive tours, and diving accessories being easily available from coastal dive centers have made this activity more accessible. Visitors have more chances to remain in close contact with marine wildlife through scuba diving [16,17]. Some dive

sites are more renowned. They not only harbor a wide variety of coral-reef creatures but also particular species, for example hammerhead sharks at Layang Layang Island in Sabah, Malaysia [18], Nassau grouper in the Turks and Caicos Island, Bahamas [19], and cryptic species like pygmy seahorse and frogfish [20]. Tourist divers gain a great level of satisfaction through viewing and interacting with underwater wildlife [6,17,21].

Diving is now an essential part of international and domestic travel [13], and has become a fast growing component of the marine tourism industry. The benefits of recreational diving services are tremendous. For example, the estimated consumer surplus per visit to the Similan Islands from diving was US\$3,233 and the economic value was estimated to be up to US\$54.96 million per year [22]. Financial gains from the diving industry significantly contribute to regional economies [6,23].

A flourishing dive industry benefits to revenue growth. However, the increasing dive tourism has anthropogenic impacts on environments [10]. Popular dive sites are threatened because too many divers use the same area [14,24–30]. Too many divers not only decreases visitors' underwater wilderness enjoyments [31], but also harms coral reefs [14]. Divers may touch corals by hand, and kick, grab, and scrape corals with their fin blades, or scrape it with their console or tanks, and some photographers deliberately creep over reefs to take pictures [20,24,29]. Such contacts may remove the outer layer of the tissue of corals, or break the corals, and wounded coral tends to become infected by pathogens and has a higher risk of dying [32], subsequently, the assemblages

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of species associated with coral reefs change [33]. The influence of contact by an individual diver is minor, but the cumulative effect of contact from a large number of divers is significant [14,30].

The phenomenon of diving impact on coral reefs is a result of too many divers using the same dive site over the long-term. The causes of cumulative diver's contacts are more complicated than it seems. To systematically illustrate the possible causes leading to diving impacts on coral reefs, herein, the fishbone diagram method is used (Fig. 1). This method reveals the causes (fish bones in the diagram) of a certain event (fish head), and identifies possible causes leading to an effect, and for each cause there could be sub-cause emphasizing more detailed parts of a certain cause, all affecting the overall problem. It is helpful for visually displaying many potential causes, and is useful in a group setting and for situations in which little quantitative data is available for analysis. In this, some possible causes resulting in diving impact on coral reefs were sorted from research articles, and the others were derived from the authors' brainstorming sessions. Then the causes sharing the same or similar causes were put together and labeled as categories of the fishbone. There were four causes proposed—people, equipment, processes and regulations (Fig. 1). The "people cause" discussed diver's improper behaviors that hurt corals. It included the diver not being skillful enough, the diver touching corals and other creatures out of curiosity, the diver cannot perceive corals because they are not within eyesight, photographers creeping over corals for taking pictures of creatures, and strong current and turbid waters possibly causing divers to grab corals for holding their body or moving. The "equipment cause" pointed out the diver's basic scuba set or accessories, including the console, tanks, fins, rope, camera and torch may break, scrape, scrape or entangle corals. Such an effect becomes more significant when equipments are unbraced. Diving boat's anchoring also brings about serious damage because the anchor scratches the reefs and the anchor line sweep up the sessile creatures [34]. The "process cause" indicated there is absence of in situ management of the divers that are about to go on, and during, their activities. There is a lack of monitoring of the cumulative number of divers, let alone controlling the maximum number of divers on the featured dive site. In addition, diver's improper behaviors are not supervised during diving. The "regulation cause" means diving regulations, rules or guidelines are absent. The diving impact on reefs are cumulative and the

process is slow, therefore, the dive center, local officials and private organizations do not have sufficient knowledge to recognize the impact is occurring, let alone make dive regulations. Even if there is regulation, it will be useless unless there is sharing and mutual understandings among the regulation makers, or it is based on knowledge of marine biology and conservation. Dive regulations are not executed because dive operators do not cooperate, or the enforcement unit is inadequate.

Diving impacts lead to degradation of the coral reefs, associated with a deterioration in the quality of tourism. Tourist divers can perceive the degradation in the condition of the biological attributes affecting their enjoyment. Such perceived environmental quality may affect the buying decisions of potential tourists [35]. Finally, degraded reef environments lead to less dive tourism and economic loss [36]. Consequently, sustaining coral reefs for quality assurance at the destination becomes the core issue of dive tourism management [37,38].

To mitigate increasing reef damage caused by divers, some management and conservation efforts have been made for both ecological and economic sustainability of reefs [14,39,40]. For example, a destination's coral reefs have been zoned, according to the level of diversity and vulnerability. Some zones are suitable for skilled divers while others are completely out of bounds for general divers [14,41,42]. Tourist divers can be directed to particular dive sites according to diver's certification level, experience, and the result of a check dive by the dive center [43]. An environmental awareness briefing including knowledge of marine biology conservation given before the dive is helpful for managing diving activities. During the dive, the guides will attempt to prevent any improper behaviors, such as kicking and touching corals [24,44]. In addition, a user fee system is employed to collect funds for conservation and management. Several studies have attempted to quantify the values of coral reefs and particular creatures in terms of diver willingness to pay an access fee for conservation [7,15,40].

These management acts are indeed collective efforts contributed to by all indirect and direct participants [45]. For example, the marine biologist collects baseline data of corals and associated creatures for monitoring destinations, and provides knowledge of marine biodiversity to the government council, dive center, and the tourist diver. The government council and dive center work together to make dive regulations that all of local dive

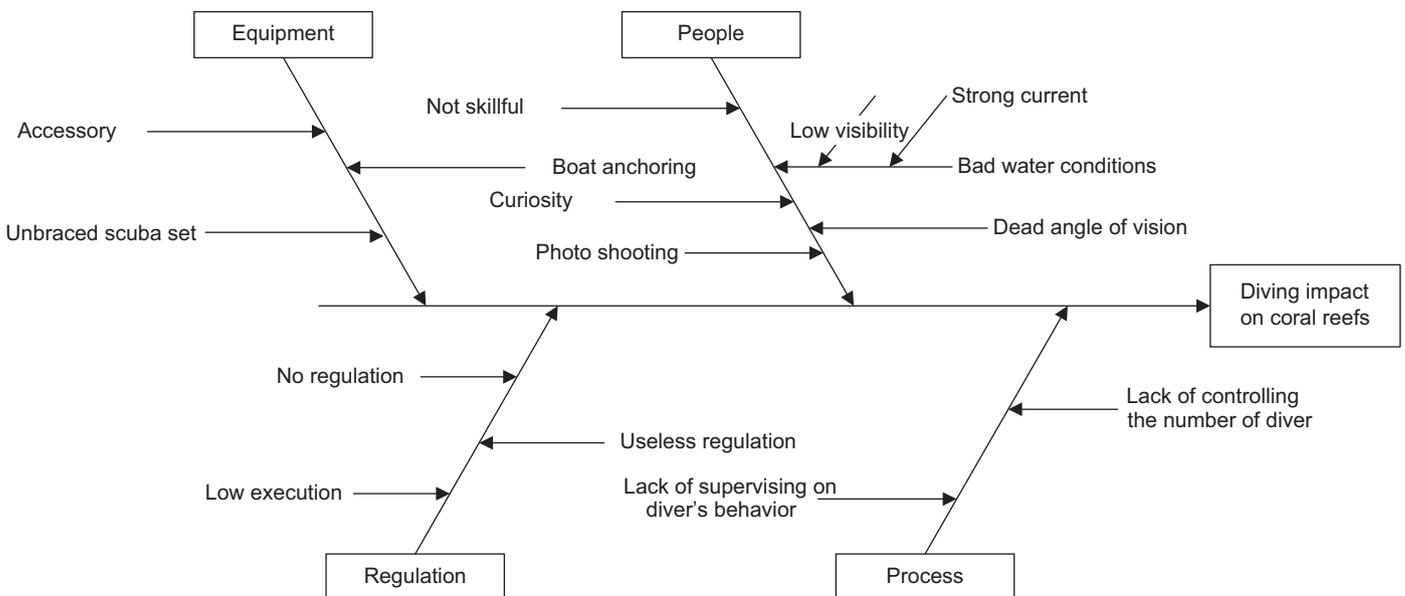


Fig. 1. The possible causes resulting in diving impact on corals reefs illustrated by a Fishbone diagram.

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