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An economic and ecological consideration of commercial coral transplantation to restore the marine ecosystem in Okinawa, Japan

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ABSTRACT

The deterioration of coral reefs in Japan is a serious environmental problem. Conventional conservation policies for terrestrial ecosystems are sometimes difficult to apply to coral reef protection because of the large number of stakeholders involved. In what seems to be an interesting attempt to solve this problem, tourist divers in Okinawa, Japan have begun to transplant coral fragments onto deteriorated coral reefs, by participating in a tour provided by diving shops. However, the problem here is that when the transplanted fragments have been taken out from the natural coral colonies, it tends to cause a host of potential problems such as decreasing fecundity of donor colonies, negative effects on the surrounding environment of the exploited corals and low species diversity of transplanted fragments. In this paper, we examine the merits of commercial coral transplantation in marine ecosystem conservation, and to suggest some reforms that could help to mitigate the problems encountered when using sexually propagated coral transplants. Finally, we discuss how the commercial transplantation in Okinawa could be applied to the conservation of other marine ecosystem.

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1. Introduction

Undoubtedly, the benefits from ecosystem services provided by coral reefs to humans are remarkably high. Despite this, nonetheless, over the past decades, coral reefs throughout the world have degraded at an alarming rate (Cesar et al., 2003; Costanza et al., 1997). Recent assessment based on annually pooled survey data suggests that the estimated annual loss of coral cover was about 1% over the last 20 years and 2% (or 3168 km^2 per year) between 1997 and 2003 (Bruno and Selig, 2007). Wilkinson (2008) reported that 19% of the historically extant coral reefs have already been lost, and an additional 15% will soon be lost. Some evidence indicates that this ecosystem may not be able to recover naturally from anthropogenic stress (Rinkevich, 2005).

In Japan, the deterioration of coral reefs has been a serious environmental problem. For instance, the reefs surrounding Okinawa in southern Japan were devastated by a bleaching event. Such incident has dramatically reduced the abundance of many susceptible coral species in the region. An analysis of region-scale coral cover and species abundance at 17–20 sites on the turbid reefs of Okinawa Island (total of 79 species, 30 genera, and 13 families) from 1995 to 2009 indicates that coral cover surrounding the sites concerned has decreased drastically from 24.4% to 7.5% (1.1% per year) due to bleaching events occurred in 1998 and 2001 (Hongo and Yamano, 2013). Here, it may be remarked that conventional conservation policies for terrestrial ecosystems have not been able to contribute meaningfully in protecting the coral reef from degradation because of a large number of stakeholders involved. These include fishermen, diving shop owners, animal husbandry who shed excess waste to the rivers, and farmers who dispose pesticides and fertilizers into the sea, and land developers who indulged in land reclamation in coastal areas. In addressing these environmental degradation issues, the stakeholders especially the fishermen and divers should refrain from causing damage to the coral reefs when carrying out their social or economic activities. By the same token, the farmers and land developers are required to adopt more sustainable forms of agricultural or land development practices. In view of varied causal factors, which required different remedial measures, it would be difficult if not impossible to have a one-size-fits all solution in addressing each environmentally unfriendly activity, such as setting a tax on carbon emission in the context of climate change.

In an attempt to proliferate corals and to restore the reefs, the transplantation of coral heads or artificially produced coral

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transplants (abbreviated as APTs) is now conducted in Okinawa. Such technique of APT is like cutting propagation of trees by using asexual reproduction, and in several countries this technique has also been used to rescue the endangered corals from various disturbances (Rinkevich, 2014) such as ship groundings, harbor construction and shore embankments. The transplantation project was launched between 2012 and 2016 by using 90,000 APTs in 3 ha of coral farm in Onna- and Yomitan villages. According to Okinawa prefecture, the budget for project in its first three years of implementation is roughly 625 million JPY (6.25 million USD). However, despite the increasing number of restoration activities, the discipline of coral transplantation remains in its formative stage.

Clark and Edwards (1995) indicated that considerable uncertainty about the effectiveness and efficiency of coral transplantation still exists. For example, the mortality of transplanted fragments is highly site- and species-specific (Edwards and Clark, 1999). For instance, the survival rates at two different locations using tabular coral *Acropora hyacinthus* were 24% in the first year (Japan Marine Science and Technology Center, 1991), 44% in the 17th month (Plucer-Rosario and Randall, 1987), and 49% in the second year (Clark, 1997). Another study shows that the mortality rate can also be season-specific. For example, the mortality rate of a 5–10 cm sized *Acropora* fragment, which has the similar size of the commercially transplanted fragment in Okinawa, varied between 0% and 80% for 2 years depending on when the transplantation is conducted. In particular, APTs are prone to typhoon destruction (Okubo et al., 2007). Hence, relying on generalizations to guide transplantation is dangerous (Edwards and Clark, 1999).

However, the transplantation has a role to accelerate the recovery of damaged reef and the reason for it appears to be the human impatience with the speed of natural recovery processes (Edwards, 2010). While the transplantation is never a cheap method, the transplantation in Okinawa is commercially implementing restoration, in which tourist divers as well as the firms conducting Corporate Social Responsibility (CSR) shoulder the cost of transplantation. This paper aims to discuss some merits and problems arising from the transplantation in Okinawa, and to derive some lessons that may be applicable to the conservation of coastal ecosystems in other areas of the world.

In addition, the paper gives some suggestions that could help to mitigate the ecological problems of commercial coral transplantation as noted above. We argue that in reforming transplantation efforts, it is important to include more sexually propagated coral transplants (abbreviated as SPTs) in a "basket" of corals, which comprised of a controlled and predetermined mixture of APTs and SPTs. We argue further that naturally occurring fragments from typhoons could be used for transplantation purpose.

2. Transplantation and its practice in Okinawa, Japan

In Okinawa, coral transplantation has a distinctive feature in that it is conducted under ecotourism, with the name of "Restore the degrading coral reefs", though it will be realistically impossible to cover all the degraded reefs by only APTs. Under this ecotourism-based transplantation process, a diving tour is developed in which tourist divers provide services to transplant APTs under the sea on a voluntary base, i.e., they are not paid for the transplantation work. Representative sites of the commercial transplantation are near the harbors of Chatan Town and Onna village located in the main island of Okinawa.

The fee of the diving tour provided by the operators includes the fee of the APTs, i.e., the cost of the APTs is passed to the divers. A popular tour consists of two dives in a half-day's tour, one for transplanting and the other for leisure. The cost is 15,750 yen (some 150 US dollars) including insurance and the cost of boat and tank. Although providing labor services for free can be seen in many cases for people to contribute to restoring the environment on a voluntary basis, the Okinawa case is that the contributors also pay for the cost of APTs and yet derive utility from the cost incurred in term of personal enjoyment. Fragments can be taken from natural colonies after being permitted by Okinawa prefecture and the collected fragment must be reared at least for six months when the size of fragment grows to be APTs in 6–8 cm.

There are at least two Japanese shops, which produce and sell or transplant APTs. Sales of APTs continue to increase through various means of advertising. In addition to this, the shops also receive requests from companies to transplant APTs as a part of the CSR activities. This trend reflects that the scope of CSR activities of Japanese firms is now extending from the reduction of greenhouse gas emissions to biodiversity conservation. The shops undertake the coral transplantation process for the firms at a price of 3500 yen (35 USD) per APT. The firms concerned can advertise the transplantation as one of their CSR activities. According to an interview conducted with a producer, which started the commercial transplantation in 2005, it has transplanted more than 60,000 pieces of fragments for a number of firms in 9 years since its operation started. However, since the producer did not go further to monitor the progress of the transplanted corals after the transplantation process, we lack of the necessary data to assess whether commercial transplantation has truly contributed to restoring coral reefs in Okinawa, which is one of the major problems of the commercial transplantation as we explain later.

3. Merits in the commercial transplantation in Okinawa

Coral reefs give rise to not only huge economic benefit but also ecological advantage to the local economy. In Okinawa, for example, tourism contributed roughly 660 billion JPY (6.6 billion USD) to its economy in 2009, including the ripple effect, according to Okinawa prefecture. No data on the exact economic contribution of coral reef-based tourism in Okinawa exists, but according to the Japanese Ministry of the Environment, the average ratio of coral reef based tourists in Okinawa between 2003 and 2007 was as high as 43.4%. Thus, the loss of these potential tourists is economically damaging.[1] Apart from Okinawa, there are more detailed studies of the benefit derived from coral reefs of Great Barrier Reef in Australia, such as Kragt et al. (2009), Polak and Shashar (2013) and Great Barrier Reef Foundation (2009). In particular, Kragt et al. show that, a hypothetical decrease of coral and fish diversity in the Cairns management area of the Great Barrier Reef Marine Park would reduce the number of divers and snorkelers by 80%. Translating this into monetary term, it came to roughly 103 million AUD per year. At the same time, the Oxford Economics (2009) has also demonstrated that the

[1] The Ministry of the Environment of Japan (MOEJ) also showed that the travel and recreation cost incurred by the tourists in Okinawa is roughly 232 billion JPY (2.32 billion USD) annually. Indeed, MOEJ has revealed that the economic value of coral reef-recreation and tourism amounts to about 240 billion JPY (2.4 billion USD) annually. However, based on the information (in Japanese) as published in the website of MOEJ (see http://www.env.go.jp/nature/biodic/coralreefs/project/development.html), it may be remarked that the technique employed in ascertaining the value of the coral-reef recreational and tourism appears to be a non-standard one. For instance, although it is stated that the travel cost method (TCM) is used for estimating the value for tourism and recreation, there is a misunderstanding about TCM that the expenditure incurred by the tourists for traveling and the recreational activities is equivalent to the value. Thus the estimated value is far from reflecting a consumer surplus, which normally used to show the value of ecosystem in the context of tourism, and which TCM aims to derive.

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