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Short Communication

Crisis sentinel indicators: Averting a potential meltdown in the Coral Triangle

Reniel Cabral [a,b,c,*], Annabelle Cruz-Trinidad [a], Rollan Geronimo [a,d], Lydia Napitupulu [a,e], Paul Lokani [f], Delvene Boso [g], Christine Marie Casal [h], Nurulhuda Ahmad Fatan [i], Porfirio Aliño [a,b,*]

[a] Asian Development Bank Technical Assistance on Regional Cooperation in Knowledge Management, Policy, and Institutional Support to the Coral Triangle Initiative (ADB-KM)
[b] Marine Science Institute, University of the Philippines Diliman, Quezon City 1101, Philippines
[c] National Institute of Physics, University of the Philippines Diliman, Quezon City 1101, Philippines
[d] Conservation International Philippines, Teachers Village, Diliman, Quezon City 1101, Philippines
[e] University of Indonesia, Department of Economics, FEUI – Kampus UI Depok 16424, Indonesia
[f] ADB-KM Papua New Guinea
[g] WorldFish Center – Solomon Islands, Tongs Maromaro Bldg, PO Box 438, Honiara, Solomon Islands
[h] FishBase Information and Research Group, Inc. (FIN), Khush Hall, IRRI Campus, Los Baños, Laguna 4031 Philippines and the Worldfish Center – Philippines
[i] Worldfish Center, PO Box 500, GPO, 10670 Penang, Malaysia

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ABSTRACT

The Coral Triangle (CT) includes some or all of the land and seas of six countries: Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands, and Timor-Leste (CT6). It covers only 1.1% of the world's area, but is the global hotspot for marine biodiversity and a rich spawning area for tuna. One-third of the CT6 population and millions more from outside the region are dependent on these resources. However, a range of human pressures threaten the biological health and diversity in the CT, affecting the food security and livelihoods of these people. A set of Crisis Sentinel Indicators (CSI) has been proposed to discuss the current state of affairs of the Coral Triangle based on the three dimensions of sustainability: Ecological, Socioeconomic, and Governance indicators. Furthermore, a Pressure-State-Response (PSR) analysis was performed for each CT6 country, using the three dimensions of sustainability, to capture and discuss the local state of affairs.

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1. Introduction

The Coral Triangle, which includes the whole or part of the land and sea of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste, covers only about 1.1% of the surface of the earth. Yet, it is home to 100,000 km^2 of diverse coral reefs, which constitutes one-third of the world's coral reefs. It has the world's highest diversity of coral reef species (76% of the world's coral species) [1] and coral reef fish species (37% of the world's coral reef fish species) [2], and exceptionally rich in other associated habitats such as mangroves and seagrass beds. The biological resources of this exceptionally high reef-associated biodiversity area sustain the livelihoods of more than 120 million people and more outside the region. However, these resources have been plagued with high levels of local and regional anthropogenic stresses [3,4].

The Reefs at Risk report has predicted that 85% of the CT's coral reefs are at risk to degradation due to high level of anthropogenic stresses and climate-impacts [3]. Furthermore, 40% of the region's mangroves and seagrass beds that are equally important as coral reefs in providing ecosystem functions and services have been lost for the past four decades [5].

To ensure the income, livelihood and food security of the people living within the Coral Triangle, and the economies and future market supplies of the marine species, the leaders of six countries in the Coral Triangle (CT6) have agreed to work together to safeguard and conserve the ecological functions of the coastal and marine environment of the region. National and regional plans of action were drawn up as the basis for regional cooperation in the five goals of the CT initiatives on Coral Reefs, Fisheries, and Food Security (CTI-CFF), i.e., Goal 1: designation and effective management of priority seascapes; Goal 2: the application of ecosystems approach to management of fisheries and other marine resources; Goal 3: the establishment and effective

* Corresponding authors at: Marine Science Institute, University of the Philippines Diliman, Quezon City 1101, Philippines. Tel.: +632 433 1806.
E-mail addresses: reniel.cabral@gmail.com (R. Cabral), pmalino@upmsi.ph (P. Aliño).

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management of marine protected areas; Goal 4: achievement of climate change adaptation measures; and Goal 5: improvement in the status of threatened species.

Crisis Sentinel Indicators (CSI) constitute an integration of well-established indicators that represent three major categories of pressures experienced in the CT today: ecological, socio-economic, and governance pressures. With a myriad of activities occurring in the CTI and with donors and countries continuingly seeking for progress towards targets, it is necessary keep track of the state and progress of the CTI-CFF. To date, output indicators for the CTI-CFF exist, although collection of baseline information is still in progress. However, indicators for the higher-level outcomes of: (1) sustained coral reefs ecosystem and its services, (2) sustainable fisheries established, and (3) improved food security [6] are not yet established. In this light, a set of Crisis Sentinel Indicators (CSI) was developed, and a Pressure-State-Response (PSR) analysis [7] conducted for the CT6 based on socio-economic, ecological, and governance dimensions of sustainability.

2. Method

Two indicators were used for each dimension of sustainability of the CSI (Table 1). The World Governance Indicator (WGI) provided annually by the World Bank and the Human Development Index (HDI) provided annually by the UNDP represents our governance indicators. The WGI [8] is an aggregation of perceptions of governance from 31 different data sources provided by 25 different organizations according to the six indicators: control of corruption, rule of law, regulatory quality, governance effectiveness, political stability, and voice and accountability. Human development index was included as a governance indicator as it reflects the strength of the governance structure and governance strategy in improving human well-being. The poverty incidences by UNDP and the Global Hunger Index by IFPRI constitute the socioeconomic indicators. The countries' fisheries status and coral reef status based on the Reefs at Risk report models constitute our ecological indicators [3]. The Reefs at Risk report is a compilation of experts' assessments of coral reefs status and is currently the best available information at hand. All indicators are converted to 0, 1, and 2 scores with 0 being in good state and 2 in an alarming state. The categorization is based on the categorization of the development agencies whenever it is available and the authors' categorization otherwise. The composite score that represents a sustainability dimension is derived by adding the two components per dimension as discussed above. A composite score of 0 is interpreted as good state, 1–2 as moderate state, and 3–4 as alarming state. The result of the CSI is supplemented by a Pressure-State-Response analysis to anchor it with the local state of affairs.

3. Results and discussion

Based on the composite scores of the CSI, three typologies are apparent: (1) good governance and socioeconomic state with alarming ecological state (Malaysia); (2) alarming ecological and socioeconomic state with moderate governance state (Philippines and Indonesia); and (3) alarming governance and socioeconomic state with moderate ecological state (Timor-Leste, Papua New Guinea, and Solomon Islands) (Table 1 and Fig. 1).

Malaysia ranked good for both governance and socioeconomic indicators while Timor-Leste, Solomon Islands, and Papua New Guinea is in alarming governance and socioeconomic state. Research has shown that, amongst others, better governance is correlated with lower poverty and with improvement in living standards [8]. The governance rating of the CT6 countries correlates with their poverty condition. For example, Malaysia has the highest governance score and the lowest national poverty incidence (3.8%). On the other hand, Timor-Leste has the lowest governance score and the highest national poverty incidence (49.9%).

The Global Hunger Index (GHI) that combines three equally weighted indicators (undernourishment, child underweight, and child mortality) and a measure of countries' food security condition shows that Timor-Leste is in an alarming state. Malaysia, on the other hand, has a low GHI followed by the Solomon Islands and both have succeeded in improving their food security condition as their GHI state has been improving since 1990 (Table S5).

Smith et al. [14] has shown that countries with a high level of undernourishment combined with weak governance as per Kauffmann et al. [8] as proxy indicator often serve as the net exporters of high-valued seafood to well-nourished countries with strong governance and net importers of low valued species. This is the case for the CT6 countries particularly for the live reef fish food trade, tuna, beche-de-mer, and trochus amongst others. However, poor governance prevents countries to benefit from the surplus value derived from this trade to contribute to its food security state [15].

While the governance indicators may reflect events or issues occurring exclusively at the national level, it is recognized that no small-scale or common property resource system is immune from external influences dealing with external drivers of change such as markets and policies, and the problem of mismatched resources and institutional boundaries [16].

Indonesia, Malaysia, and Philippines have an alarming ecological state based on the ecological macro-indicators. These countries are the top countries worldwide with the highest reef area at risk ($>90\%$) based on the Reefs at Risk models mainly attributed to unsustainable and destructive fishing methods, unregulated coastal development, and inland and marine-based pollution [3].

Fig. 2 shows specific governance, ecological, and socioeconomic objectives for the Coral Triangle, which are drawn from the Regional and National Plan of Actions of the Coral Triangle Initiative. The governance objectives include strengthening the regional, national, and local governance systems, processes, and standards. Strengthening governance will facilitate the improvement of the ecological/biological systems that will eventually make social and economic impacts to the people directly dependent on the biological resources.

The Pressure-State-Response analysis of the region as a whole showed that inadequate coordination and integration of management across economic sectors and levels of government is the governance pressure experienced by the CT6 (Table 2). Undeniably, functional cooperation among the CT6 countries should be strengthened. In addition, there is a need for the CTI to accelerate the formalization of local working groups dealing with different aspects of sustainability in the CT with clear roles and mandates.

Ecological pressures include habitat degradation, overfishing, and climate change impacts (Table 2). Decline and overcapacity in the fisheries of the CT6 have been well-documented. Fish stocks in the Philippine's major fishing grounds have been drastically reduced to less than 10% of 1950s levels [17] with evidence of continuous decline and loss of targeted species [18]. The same is the case for Indonesia and Malaysia [19,20]. Of the three main tuna species that are harvested in the CT (i.e., skipjack tuna, yellowfin tuna, and bigeye tuna), bigeye tuna is overfished while yellowfin tuna is fully exploited in the western equatorial Pacific [21,22]. Recent stock assessment showed that there is a significant depletion of the juvenile yellowfin in the Western and Central Pacific Oceans (WCPO) due to fishing activities in the Philippines and

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