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Analysis of marine ecosystem of Toamasina and foulpointe facing human activities and investment project (mining, port infrastructure and tourism)

Abstract

This study, realized in July 2014 in the eastern region of Madagascar, particularly in Toamasina allows analyzing the state of vitality of marine ecosystems facing human activities and investment projects. Few cases were studied, among other mining activities, tourism, port infrastructure. The eastern region was chosen as the site of study because it brings the typical cases of what is happening in the Big Island in terms of potential impacts of investment projects on coastal and marine ecosystems. Several indicators were assessed, such as: the percentage of coral coverage of the substrate and the existing of bio-indicator species, the concentrations of heavy metals in water, sediments and biota, and the availability of fishery resources. The results obtained during this intervention showed that there are two major types of ecological underwater formations in the vicinity of Toamasina. These are coral reef and non-coral formations. This last one is represented either by sandy-muddy bottoms, or by rocky outcrops. From this study, it has been also noticed that several factors are among others responsible for the gradual degradation of the marine and coastal ecosystem in this area. The reef flat tends to have more degradation comparing to the reef slope. So far, the analysis of the heavy metal component extracted and analyzed using sediment and biotas, showed that there is not yet a significant threat to the biodiversity, but rigorous monitoring should be put in place to be able to follow on time any potential changes.

Keywords: coral reef, mining project, heavy metals, coastal and marine infrastructures, Toamasina, Madagascar

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Introduction

In accordance with the legal and regulatory framework for the protection of the environment in force in Madagascar, any public or private investment project likely to affect the environment, must be subject either to an environmental impact assessment or an environmental commitment program according to technical, project scope and sensitivity of their establishment circles. Madagascar's marine ecosystem is both vast and rich in biodiversity. Currently, this heritage is threatened because of marine pollution, linked to tourism, port and mining activities. However, knowledge of the effects of these investment projects is very limited or even rudimentary. To remedy this problem, ecological monitoring was carried out. The overall objective is to diagnose the potential impacts of investment projects towards the marine and coastal ecosystem. To achieve this objective, the following specific objectives are given:-identify the structure of the ecosystem or the underwater typology, by means of a scuba diving, - evaluate the percentage of coral reef cover of the substrate, by means of " a sampling transect LIT", inventory of the main underwater fauna that form the reefs; as well as fish, to get an idea of the species richness and biomass; and assess the potential impacts of mining activities onto the marine ecosystem, by physico-chemical analysis of some biota; and wastewater coming straight from the outlet of the mining project itself.

Methodology

The sampling campaign was conducted in July 2014.Toamasina is a big city that lies to the Eastern of Madagascar. It has the first biggest port in the country, playing a key role in the Malagasy economy, by the various imported and exported products. During the assessment of the potential impact of mining activities into the environment, three specific areas were taken into consideration. It is the Baie of Tapakala (18°8'57.1" S49°24'8.4" E), where the pipeline of the mining company is located. This pipeline discharges wastewater into the sea after having been neutralized upstream. The second area is located at Iles aux Sables or Nosy Faho (18° 18' 00" S49° 25' 00" E) and the third site is located at Iles aux Prunes (18°2′55.45″S 49°27′36.15″E). For the port Infrastructure, the Bain des Dames (18°8'57.1" S 49°24'8.4" E) and the Great Reef were chosen. And finally, Foulpointe (17° 41' S49° 31' E) Barrier reef was chosen to assess the impact of Tourism activities towards the littoral ecosystem.

Data collection in the field requires at least the possession of scuba diving equipment and logistics associated with its use (the inflation compressor, the equivalent logistical base ...). The use of satellite positioning system (GPS) is recommended to facilitate the recognition of sampling site. According to the weather in Toamasina, the use of powerful boat is necessary. At least two certified divers dived the same time, while a bubble follower remains on the boat with the skipper. The boat will be equipped with radio communication, mobile phone on board, buoy and life jacket. Divers will be equipped according to the required safety standards for work in diving professionals such as the scope of the aqualung, the Aladin dive computer, fins, mask, snorkel, and combinations. The thickness of these combinations should be at least 5mm to fully adapt to the temperature of the water in Toamasina to prevent colds. A handmade foil was specially made in case of possible attack by sharks in view of rumors thereon in Toamasina.

The collection of data on the type, the health of reef environments, biodiversity is done by diving (scuba or snorkeling).These operations can be performed from the coast when the weather conditions or environment permit. This technic identifies the main dominant benthic organisms and fish composition, and then help to estimate their quantitative and qualitative representation. Simultaneously, sampling method for "benthos" is using LIT (Line Intercept Transect), developed by English et al.[1] Transect line is used to estimate the percentage of coverage of an object or group of objects in a specific location.[2] For this study, it is used to quantify the recovery rate of the substrate by sessile organisms, counting fish to assess of biomass, and also to evaluate the impacts of natural or anthropogenic disturbances into the marine environment.[3] The monitoring protocol recommends three transects minimum at each station: Three transects were conducted at the reef flat and three others at the slope. Data analysis were performed using CoReMo (Coral Reef Monitoring)software. This software was developed by the IOC (Indian Ocean Commission) regional taskforce, inspired from the "Survey Manual for Tropical Marine Resources"[1] published by the Australian Institute of Marine Science. The Mann Whitney test was used to analyze the difference that may exist between the percentage of coral cover in the reef flat and the outer slope of a given site. The identification of fish species was done using works from Lieske et al.[4] The fish biomass (weight per unit area) was determined using the diving area coverage, which is 250 m^2 (50m *5m). The "Cubic law", Weight (g) = 0.05 * $(length)^3$ was used to estimate fish weight.

The determination of heavy metals concentration in sediments and biota were made at the National Centre for Environmental Research (CNRE, Tsimbazaza, Madagascar).

Results and discussion

The site of the mining project's is characterized by a fine-grained sandy-mud bottom. The sedimentation is due to the proximity of the Ivondro river which discharges the contributions coming from erosion and deforestation of the watershed. In the marine environment, the metallic elements can beings absorbed onto sediment particles or precipitate on the bottom, or be ingested by organisms and accumulate in their tissues to reach concentrations that may be toxic.

For the water quality assessment in the vicinity of the outlet, samplings were made on five stations instead of a single station. It is interesting to work on several stations to have an average of the amount of heavy metals contained in the water. Heterogeneity of the values obtained could be interpreted by a variation of the direction of the surrounding currents. Compared to the "Iles aux prunes", used here as a control site, the results of this analysis show that there is still no extraordinary concentration of heavy metals discharged into the sea, from this project, at the Bay of Tapakala. Registered values are relatively similar in both the control site (0.264mg/l), and at other followed stations, among other the outlet (0.197 mg/l). Other metals are weakly detected. The analysis of the evolution of the concentration of heavy metals from 2008 until 2014 showed that Nickel ha the highest concentration retained in 2012, about 0.40 mg / l, and a fairly sharp drop in 2013, less than 0.01 mg / l. As for other metals, Pb, Mn, Zn, have a higher concentration retained in 2010. These concentrations varied from 0.2 mg / l to 0.002 mg/l. The concentration of Cr has little variation between 2010 and 2014. It was approximately 0.05 mg/l. The heavy metal concentrations had its lower rate in 2014, close to zero.

Apart from that, the analysis of sediment and biota (crabs, sardines), collected around the outlet, in the Bay of Tapakala provided more detailed rate on the heavy metal concentration at this station. From the resulting we obtained, zinc remains the most abundant chemical element encountered in these samples. Then come Manganese and Chromium, Lead, and finally Nickel. According to the Nairobi Convention in October 2009, Chrome has a harmful concentration of 160 mg/kg, 271 mg/kg for Zinc, 42,8mg/kg for nickel. The values obtained from this study showed that none of the thresholds is reached. The recorded values are significantly lower than those that can have lethal risks.

Iles aux Sables "Nosy Faho "reef

The analysis of the coral cover and fish richness in reef flat was not able to be carried out due to the difficult access to the area. Only the study at the outer slope was carried out. The average coral cover is around 43.52% against 39.78 % during follow-up of the year 2013. The percentage of coral vitality remains almost the same for two successive years. It would take several years of monitoring in order to observe the formation of new coral colonies. Abiotic Rate during this intervention is 38.23% while it was 32% in 2013. There was a slight increase in the percentage of this component. It's important to say that Nosy Faho is made by a rocky substratum. The outer slope is largely constituted by submassive or encrusting corals which bind strongly to the substrate, thus better resistant to hydrodynamic effects. The corals of the genus *Acropora*, which in most cases are branching corals do not have the full ability to grow in such hydro dynamics condition. It is important to notice that distribution of corals is very heterogeneous at this site. The west side facing the mainland has higher rate of degradation; whereas the north-east side, which is free from any human activity due to its positioning, has a higher coral cover rate. Compared to "Iles aux prunes", Nosy Faho has higher level of sensitivity due to a higher rate of coral vitality.

Iles aux Prunes

This site is characterized by a fringing reef surrounding the small island. The reef flat itself shows an abundance of coral debris. The deterioration observed is the result of a strong hydrodynamic activities observed at this site. Bad weather condition occurring frequently is also leading at a fragmentation of coral branches or tearing of several colonies. The resulting shows that coral colonies are formed by massive species like *Porites*, *Goniastrea*, *Diploastrea* and sub-massive like *Pocillopora verrucosa*, *Pavona clavus, Galaxea fascicularis*. The marine sponge colonies Alcyonarians and calcareous algae was also observed. The observed percentage of coral cover is 38.03% against 40.5% in 2012. For component "Abiotic" this rate is 39.15%, somewhat higher than the percentage of live coral. This result reflects the context 'in-situ' at "Ile aux Prunes", because the disintegration of coral debris helps to increase the percentage of sediment, including sand coral on the reef flat. The algae represent 2.78% of the coverage of the substrate while the component called "Other", which regroups marine sponges and soft corals amounted to 7.42%. The percentage rate of algal turf is 12.61%. This fact witnesses the result of coral bleaching, then as dead colonies favor the growth of algal turf. The sites affected by the expansion of the port are mainly reef "Bain des Dames" and the Great reef.

Reef of "Bain des Dames"

This site is dominated by *Millepora sp.* The reef flat has a fairly low coral cover, 17.54% against 81.72% for the Abiotic components.

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The dominance of Abiotic form indicates low vitality and intense destruction observed. Due to the fact that it is attached to the port; at low tide this site is offering an access pass to the fisherman and octopus collector. At high tide, this area could still serve as a refuge shelter for many species, due to the presence of a certain amount of coral colony (17.54%).

The great reef of Toamasina

This site is also an area of intense collection of fisheries products. The Mann Whitney test shows a significant difference (p-value=0.0038 < 0.05) between the percentage of coral cover on the reef flat and the reef slope. The outer slope has an average coral cover of 23,11%, against Abiotic form, which is 37,86 %. This indicates that the destruction observed is not only limited on the reef flat, but also reached the outer slope. The percentage of "Dead corals" is also high, which is 27,30%. This is probably due to the various pollutants released at the port, which is close to this station, and thereby contaminating it. These pollutants could reach the reef, killing some colonies and subsequently promoting the proliferation of algal turfs. This station is also heavily watered by household waste, dumped into the sea by Ivoloina River. These various terrigenous sediment supply and flock to the level of the reef, killing coral subsequently by asphyxiation. This sedimentation problem is not only affecting underwater life, but now causes great problem at the port.

When it comes to fish, carnivorous fish are rare. They are overexploited. Due to the lack of finding viable habitat for food, certain species such as Ludjanidae, Carangidae, Serranidae prefer to move somewhere else, more conducive to their survival. Another consequence of the discharge of organic waste into the sea is the abundance of echinoderms of the genius *Echinometra*, herbivorous fish and a few groups of grazing fish, represented by the family Acanthuridae. Commercial reef fish have an average biomass around 11.98 ± 0.78 tons / Km^2. Foulpointe reef flat is degraded because of all kinds of recreational activities and a poorly managed ecotourism. The coral cover was 44.08% in 1999, against 13.67% in 2014.

Conclusion and recommendations

This present study showed that the scarcity of sessile and motile organisms around the outlet's site would not necessarily be conditioned by discharges of the mining company. It was found that this area is watered by terrigenous elements from Ivondro's river, creating mud-dominated funds. Hence, only the most suitable species for this kind of environment can reside there. The analyzes of the data collected revealed that the destruction and siltation of the reef flat of" Bain des dames" are the consequences of the implementation of the port in this site, rejection of waste into the sea and also the crowding of household waste.

The east coast of Madagascar is currently experiencing a rush of unparalleled industrialization. However, most of these investment projects have interactions with the sea. Fouls places for evacuations of wastewater from household and industrial waste, it is the ocean that makes the cost of these actions. Currently, no significant change is observed in the marine ecosystem of Toamasina, in connection with the rejection from the outlet of the mining project. The analysis of the water quality, biota and sediment showed that there is still no heavy metal concentration outside the international standard, spilled into the sea by the project. Still a slight annual increase on the heavy metal concentration is noticed. Since the depletion of fisheries resources is felt on the east coast of Madagascar, the enactment of laws on the collection of these fishery products must be enforced and implemented.

The protection of our coastal and marine environment does not depend solely on government decision makers. It is the duty of each one of us to protect and rigorously defend this natural beauty that makes Madagascar a unique island in its kind.

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None.

Conflicts of interest

The author declares there are no conflicts of interest.

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