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The importance of mangrove restoration: a case study of *Ceriops tagal* and *Rhizophora mucronata* in Ambodivahibe Marine Protected Area, Diana, Madagascar

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Introduction

Madagascar represents 2% of the global distribution of mangroves covering about 2800 km^2 (Giri *et al*. 2008). The mangroves of Madagascar are in a steep decline due to timber extraction, charcoal production, and land-use conversion to agriculture. Between 2000 to 2018, the mangroves forest coverage decreased by 13%, equivalent to 57,900Ha (Shapiro *et al*. 2019).

Ceriops tagal and *Rhizophora mucronata* are two species of mangroves found on the coasts and riverbanks in East Africa and the Indo-pacific region (Rastegar and Gozari, 2017). Both species belong to the family Rhizophoraceae (Saptiani *et al*. 2018).

The study site was in the northeast of Madagascar in Ambodivahibe marine protected area, about 30 km from the city of Diego-Suarez. This site is found at the rural Communes of Ramena and Mahavanona, District of Antsiranana II, in the Diana Region. It covers an area of 39,794 Ha. A mangrove restoration project was carried out in Ambodivahibe from 2016 – 2019.

We inquired into the effectivity of this restoration project, and the factors critical to the survival of the mangroves. The restoration took place in Matsatsoloko (2016), Ampasindava (2018), Ambanioaroe 1 (2018) et Ambanioaroe 2 (2019). These sites were chosen randomly. *Ceriops tagal* and *Rhizophora mucronata* were the two species planted in the four sites (Figure 1). We attempted to restore 2Ha per site.

Figure 1 ***Ceriops tagal*, JEANOT Jacob, 2020**

Figure 2 ***Rhizophora mucronata*, JEANOT Jacob, 2020**

In 2020, we investigated the survival rate of two species of mangroves: *Ceriops taga l*and *Rhizophora mucronata* in Ambodivahibe*,* northeast of Madagascar by using the Duvigneau transect method. This method was pioneered by botanists working in Comoros (Anllaouddine et al. 2022). It involved stretching a straight line parallel to the channel (perpendicular to the sea) on which squares were arranged alternately on the transect line. Lines were laid on muddy and sandy-muddy substrates.

Within a transect line of 60 meters length, a plot of 5mx5m was set up and separated every 5 meters. The distance between plots was 5 meters. In each transect, there were 6 plots. During this study, we prepared two transects per site and in total, we had eight transects.

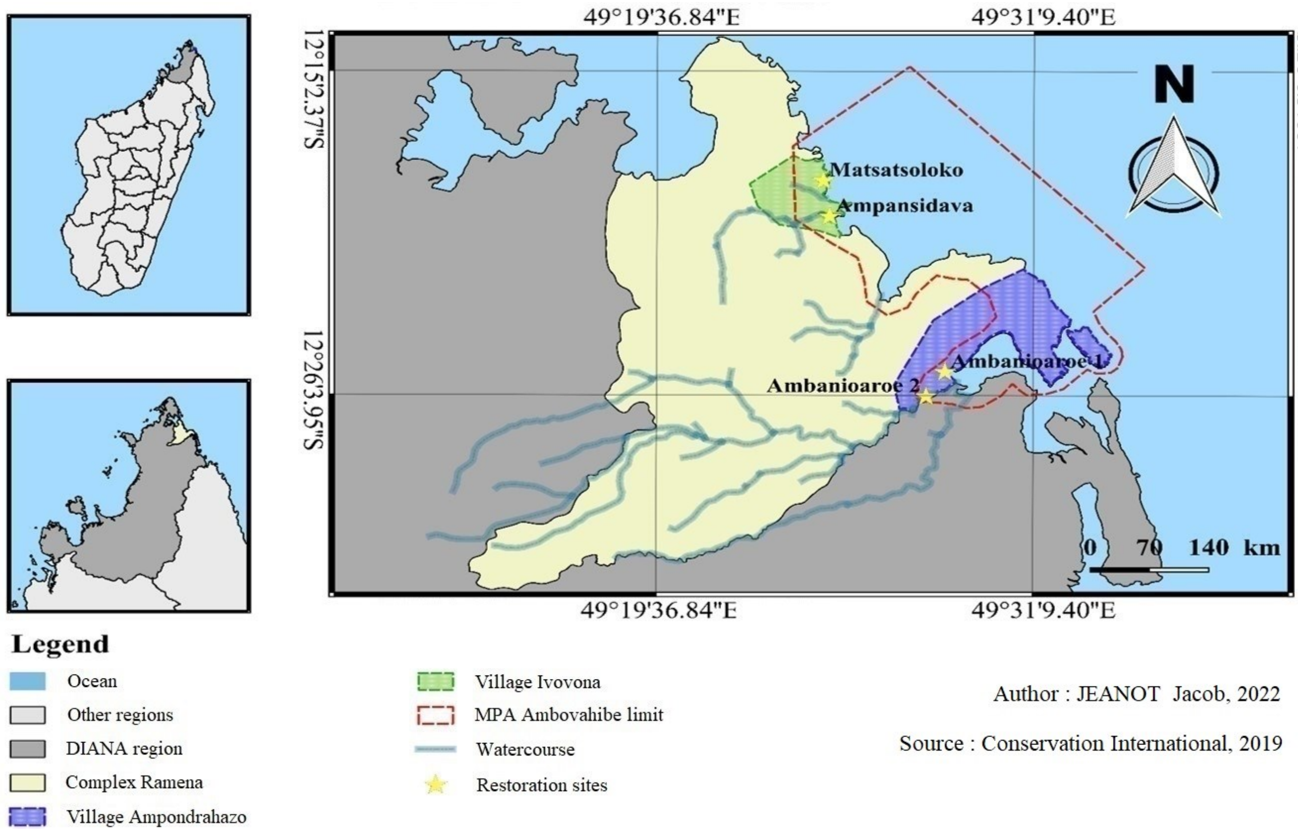

Figure 1.**Map of the study site and regional location**

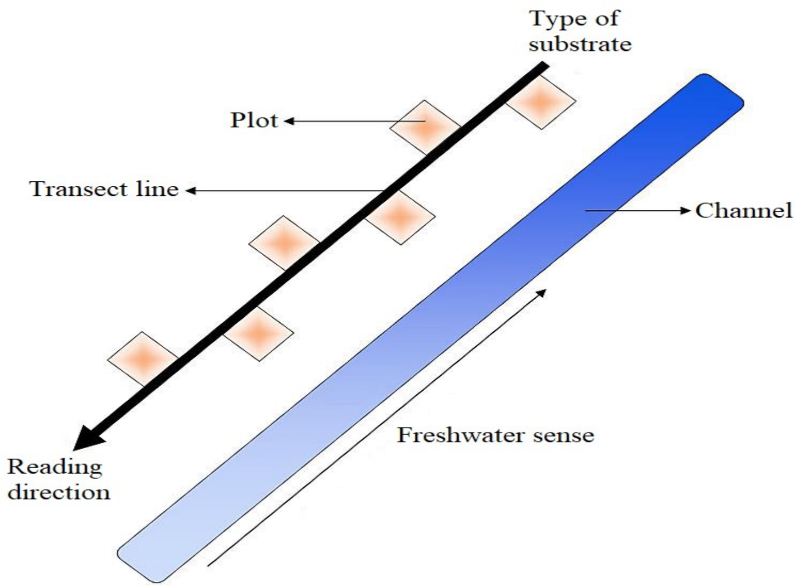

Figure 2. **Duvigneau transect design**

Site name	*Habitat/substrate characteristics*	*Presence of permanent water*	*Distance from agricultures activities*	*Distance from the nearest village*
Matsatsoloko	Muddy + sandy-muddy	-	500m	3km
Ampasindava	Muddy + sandy-muddy	-	250m	0.5km
Ambaniaroe 1	Muddy + sandy-muddy	+	100m	2km
Ambaniaroe 2	Muddy + sandy-muddy	-	50m	3km

+: presence permanent of water; **-**: seasonal water

Table 1**. Site description**

Findings

We planted the two species evenly at the four sites. Our findings show *Ceriops tagal* survived only in three sites (Figure 3.) and none of them survived in Matsatsoloko. *Rhizophora mucronata* grow up only in 2 sites (Matsatsoloako and Ampasindava). No propagules survived in Ambaniaroe 1 and Ambaniaroe 2.

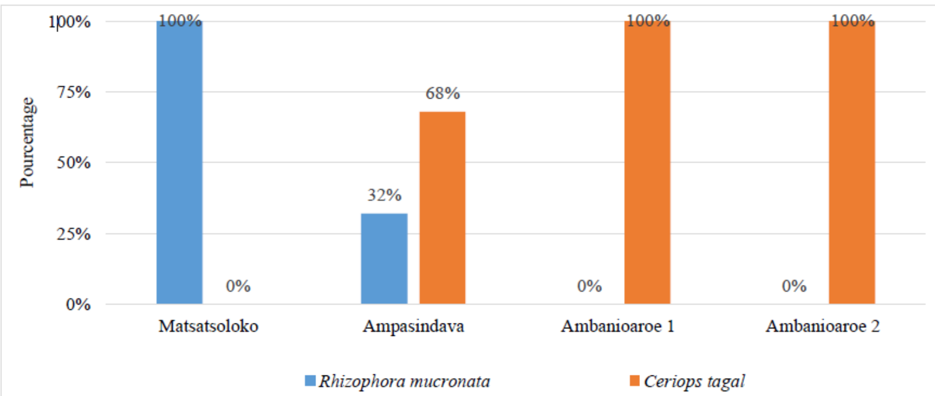

Figure 3. **Survival rate of *Rhizophora mucronata* and *Ceriops tagal* in four sites in Ambodivahibe**

Discussions and recommendations

The absence of *Ceriops tagal* in Matsatsoloko and of *Rhizophora mucronata* in Ambaniaroe 1 and Ambaniaroe 2 illustrates the implausibility of mangroves to regenerate in an area where these species were cleared of previously. In addition, habitat preference and the presence or absence of permanent water bodies might explain the fate of these species at a particular site. *Rhizophora mucronata* preferred muddier substrate, while *Ceriops tagal* favored muddy-sandy substrate. Furthermore, mangroves needed fresh water for the supply of minerals and to counteract the rate of excessive salinity of seawater during high tide. All the four sites had water bodies. It was seasonal at three sites (Matsatsoloako, Ampasindava and Ambaniaroe 2) and perennial in the other (Ambaniaroe 1). The seasonal water affected the sites at Matsatsoloko, Ampasindava and Ambanioaroe 2, and therefore the mangrove species could not withstand dry spells. On the other hand, at Ambanioaroe 1, water was present all year round, and this ensured the high survival rate of *Ceriops tagal.*

Matsatsoloko, Ampasindava and Ambanioaroe 2 were impacted by the nearby agricultural activities such as ploughing which leads to soil erosion and causes the mudflat to rise. This subsequently led to an increase in the submersion time of the propagules. Consequently, wilting of the plants occurred due to longer duration of submergence. Hence the *C. tagal* did not survive in Matsokotsoko. Likewise, *R. mucronata* in Ambaniaroe 1 and Ambaniaroe 2. Also, during our fieldwork, we observed pastoral activities within the restoration sites in Ampasindava and Ambanioaroe 2. These activities negatively impacted the restoration because the grazing zebus finished off all green growth.

In conclusion, degradation of habitat negatively affects the survival on the propagules of *Ceriops taga* and *Rhizophora mucronata* and the presence of water are important factors to consider to the survival rate of *Rhizophora mucronate* and *Ceriops tagal.* Our recommendations to the managers of protected area are: (1) Stakeholder coordination and working with the local communities is important to successful outcomes in mangrove restoration and (2) sites adjoining channels are highly priority for such restoration.

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