Report at a Glance

Source: A Rapid Marine Biodiversity Assessment of the Coral Reefs of Northeast Madagascar: 10

Published By: Conservation International

URL: https://doi.org/10.1896/054.061.0118

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INTRODUCTION

To fill the gap in biological information, both nationally for Madagascar and for the broader Western Indian Ocean (WIO) region, Conservation International conducted a marine Rapid Assessment Program (RAP) in the Northeastern Coast of Madagascar from the Bay of Ambodivahibe to Vohemar. This was a third initiative following two other marine RAPs. The first covered approximately 200 km of coastline from Nosy Be to Nosy Hara on the northwest coast in 2002 (McKenna et al. 2005). The second RAP covered approximately 50 km of coastline from Cap d'Ambre at the northern tip of Madagascar to Ambodivahibe, down the Northeast coast, in 2007 (Maharavo et al. in press). This survey covered approximately 130 km of coast. For a thorough review of the existing marine biodiversity studies in Madagascar, and the institutional and policy context for the three expeditions in support of MPA planning and selection, see McKenna et al. (2005).

Madagascar is the world's fourth largest island, covering 587,045 square kilometers, and with a coastline length exceeding 5,000 km and an estimated length of all reefs (including fringing reefs, islands, platforms, and both emergent and submerged barrier reefs) of 3,459 km (Cooke et al. 2000). Coastal marine habitats are predominantly mangroves, seagrasses and coral reefs, with an exposed rocky shore along the eastern ocean-facing coast. Past work has counted over 320 coral species, and over 750 reef-associated fish species (McKenna et al. 2005). In 1999, an ecoregional approach was proposed by the Association Nationale pour la Gestion des Aires Protégées (ANGAP 2001) for the establishment of Marine Protected Areas, later expanded on through the establishment in 2006 of an inter-ministerial body, the Commission Environnement-Peche (CEP). In partnership with international conservation NGOs, 20 potential MPAs were initially identified based on their extraordinary biodiversity or the presence of special organisms such as turtles, lemurs, and sea birds.

Existing threats to Madagascar's marine biodiversity include fishing, sedimentation from rivers, coastal development and pollution, and increasingly oil and gas exploration and mining (WWF 2010). Growth of coastal populations is taking place more rapidly than across the country as a whole, with women giving birth to an average of >6 children in coastal provinces. Most coastal communities are poor and highly dependent upon fisheries for survival and livelihoods. Large-scale development programs are being planned for oil and gas exploitation in the western Madagascar and Mozambique Channel, with exploration concessions already parceled out. Sedimentation from deforestation on land has long been recognized as a primary threat to marine resources. Since coastal and offshore marine resources are major contributors to the national economy, as a source of food for their people, and through tourism, commercial fishing agreements, and revenues from offshore oil and gas development, pressures are expected to increase with both population growth and increasing development, and the likely increase in inequitable distribution of wealth and resources.

Climate change has become an overarching concern for coral reefs globally (Hoegh-Gulberg et al. 2007). In 1998, the WIO showed the highest levels of coral bleaching in response to climate change globally (Wilkinson 2004). Madagascar's coral reefs bleached during the Indian

Ocean-wide event of 1998 as well as in smaller episodes in the last 3-5 years (Linden et al. 2002, Wilkinson 2004). However the pattern of bleaching has varied, with high levels of bleaching and mortality in the southwest, but low or variable mortality recorded in the northwest and northeast (Quod et al. 2002, Webster et al. 2002). A reef susceptibility model that broadly matches patterns of coral bleaching in other parts of the WIO (Maina et al. 2008, McClanahan et al. 2009), predicting lower bleaching susceptibility in cooler waters to the south is contrary to the pattern found in Madagascar. There are several possible reasons for this disagreement as many factors influence multiple stages of the bleaching process (Obura 2005). Two key ones that may be important to this region are a) reefs in the southwest were already more highly degraded than reefs in the northwest from local anthropogenic stresses, which can increase vulnerability to bleaching, and b) while sea surface temperatures (SST) closer to the equator are higher than those in subtropical latitudes, corals acclimate locally (Coles and Brown 2003), hence the absolute temperature may be less important than short term variability in temperature.

In 2008 a series of initiatives oriented around the impacts to marine protected area (MPA) planning for climate change were conducted (CI 2009, Maina and Obura 2008). At the same time the second marine RAP (Maharavo et al. in press) identified a site potentially protected from warming sea surface temperatures by strong upwelling, at Ambodivahibe Bay, south of Antsiranana Bay (Diego Suarez) on the Northeast coast. Billed as a 'climate park', it promoted further incentive for this RAP to not only further inventory and assess Madagascar's marine biodiversity, but also to determine if natural climate resilience is a general condition for the northwest coast, with upwelling (West and Salm 2003, Obura 2005) providing a refuge for corals under climate change.

This RAP survey had the following objectives:

1) Highlight the richness of marine biodiversity along the northeast Madagascar to raise awareness among the local communities as well as the global general public,

2) Collect biodiversity data to assist in guiding conservation actions and marine priority sites identification in the region,

3) Assess the vulnerability of coral reefs in this part of Madagascar to warming sea surface temperatures, and to understand the connectivity with other marine ecosystems (e.g. seagrass),

4) Enhance scientific capacity in Madagascar by developing collaborations between international and local scientists.

This expedition deployed a multi-disciplinary team of 9 marine scientists and coastal resource experts to survey selected areas, and was in the field from 28 March to 14 April 2010. Surveys were focused in bay and island systems along the northeast coast, at Ambodivahibe Bay, Loky Bay, Nosy Ankao, Andravina Bay and Vohemar.

Survey sites

The study region is approximately 130 km from north to south, along the northern end of the northeast coast of Madagascar. A total of 24 study sites were surveyed for coral reef fauna with an additional 2-3 reef flat surveys for echinoderms. Algae and seagrass assessments were conducted at some 15 sites adjacent to the coral reef survey sites (Table 1). The sites grouped naturally into 5 geographic locations along the coast, from north to south:

Ambodivahibe Bay is a narrow bay in the form of a deep canyon, penetrating into the land about 3 km. Its sides are steeply sloping, and the bottom varies from about 200m deep at the mouth, to 40 m just before its end. Mangroves and seagrasses are found along both sides of the bay. One small village is located within the bay.

Loky Bay is a large deep bay, over 10 km in length with extensive fringing reefs and islands at its mouth, and extensive mangrove fringe and seagrass meadows at various locations. The main river flowing into the bay drains a large catchment and many additional small rivers add up to a highly sediment-influenced area. There are several villages in the bay and temporary fishing camps.

Nosy Ankao is part of a set of islands and patch reefs on a bank (Leven Bank), highly exposed to ocean waves and with low influence from rivers. The islands and reefs are leased to an algae aquaculture company that has several hundred workers living on the islands. Limited fishing occurs and external fishers are discouraged from accessing the reef areas.

Andravina Bay is a small shallow circular bay with two small river emptying into it. It shows very high influence of sediments, with coral communities on limited hard substrate around the mouth and a central islet. The extensive sandy bottom likely has seagrass beds where the depth and water clarity is appropriate. A small village and fishing camp(s) are located in the bay.

Vohemar is a large bay almost completely taken up by an extensive shallow and intertidal reef bank, a well developed exposed fore reef with spur and groove development, and relatively limited lagoon and channel reefs near the town in the south. A large river drains into the bay. Clear human impacts are visible in the bay and sheltered reefs, from eutrophication and fishing.

PRINCIPAL FINDINGS AND RECOMMENDATIONS

Reef areas

Of the five locations, three are heavily sediment-affected bay systems: Ambodivahibe Bay, Loky Bay and Andravina. Of these, the first two are large enough to have areas within them that are less sediment-affected and allow for complex reef structure (i.e. A02/A04 in Ambodivahibe, A06/A11A

in Loky Bay) while the small size of Andravina resulted in a very heavily sediment-affected system with low coral abundance and small corals. The southern end of our survey, Vohemar, has a very exposed fore-reef and heavily sediment- and human-influenced back-reef. Finally, Nosy Ankao is found on a seaward bank bathed by cleaner water and less influenced by sedimentation, which is also the site for an intensive seaweed farming operation.

All components of the RAP found sediment influence and fishing to be overwhelming factors affecting the reefs. Thus, while conservation tactics may vary among the locations, we recommend first, limiting fishing pressure in priority sites to maintain a strong community of grazing fish, and second, managing upstream watersheds to minimize sediment delivery to the reefs. These strategic goals will both maintain existing reef structures, and maintain and/or improve coral recruitment, a key process for sustaining a reef's ability to recover from disturbance.

Corals

281 hard corals were identified during the surveys, which using Michaelis-Menten equations to predict a total species number resulted in an estimate of 313 species. This is slightly lower than the highest diversity sites in Northwest Madagascar including Nosy Be and Nosy Mitsio (323, by McKenna et al. 2005, Veron and Turak 2005), but higher than the Nosy Hara area just W of Diego on the Northwest coast (217, Obura 2009).

At a regional scale, Northeast Madagascar groups with the highest diversity sites in Northwest Madagascar, N Mozambique and S Tanzania, lending support to the existence of a high diversity center for the WIO in this region.

Key species of interest for Northeast Madagascar include the following:

– the regional endemic monospecific genera – *Craterastrea laevis, Anomastrea irregularis, Horastrea indica* and *Gyrosmilia interrupta*

– Significant range extensions of Indonesian species are reported in this survey, of *Anacropora pillai* and *Turbinaria irregularis* (previously recorded in Northwest Madagascar, Veron & Turak 2005).

– A recently described rare species, *Psammocora albopicta* was found here, as well as a potentially undescribed species of *Echinopora*.

Ambodivahibe and Loky Bay have the highest level of coral diversity of the locations surveyed due to their depth and complexity, so have the highest value for habitat and species conservation. However individual sites in all 5 locations were important for some of the above key species, suggesting broad-based conservation across the entire region, with focal protection sites and strategies is necessary.

The two sites in Andravina had the lowest species diversity of all the sites sampled, showing high influence of sedimentation. However, they had the most unusual species assemblage of corals, including the only sites with *Anomastrea irregularis*, reasonably common *Craterastrea laevis* and common *Horastrea indica.*

Fish

The diversity of reef fishes was relatively high but abundance was low – a total of 271 species (from just 19 families) were seen on this Northeast coastline, 74% of the 367 species reported for Madagascar since 1891 (Allen 2005). A total count of 296 species was recorded.

The deep bays of Loky Bay and Ambodivahibe Bay had the highest fish diversity, likely due to habitat diversity, together with sites at Nosy Ankao where reefs had more complex structure and relatively high coral cover and water clarity. Multiple-zone conservation areas in these bays offer a good opportunity for maximizing conservation of fish species.

The absence of highly vulnerable species (shark species, bumphead parrots – *Bolbometapon muricatum*) as well as low densities of common reef fisheries species (snappers and groupers) and herbivorous fishes, which are important in maintaining resilient reefs (scrapers – parrot fish and grazers – surgeon fish), was noticeable. Although this may in part reflect the low relief reefs of the region, the low abundance of target fishery species is indicative of fishing impacts. The presence of small villages, the regional centers at Vohemar and Diego Suarez, and activity by seasonal migrant fishers,are all likely to impose moderate to high levels of pressure even on seemingly remote locations. Targeted species/resource management plans with local communities are recommended to facilitate fish recovery. On a positive note, the Napoleon wrasse (*Cheilinus undulatus*) was seen at several sites, though none were large terminal phase males.

The presence of a commercial algae farm at Nosy Ankao, which discourages fishing in the area, had resulted in a noticeably higher species diversity and higher abundance of fishery target species (omnivores) than seen in the other locations. Though partly attributed to natural differences in the reefs of Nosy Ankao (low sediment, high relief), this example provides an alternative management option e.g. with villages in the other locations surveyed, that can be considered for conservation application.

Algae/seagrasses

Ninety one species of algae and ten species of seagrass were found along the northeastern Madagascar. Algal diversity was dominated by reds, followed by green and browns (44, 32 and 11 species, respectively). The seagrass species were typical of East Africa, namely *Thalassodendron ciliatum, Thalassia hemprichii, Syringodium isoetifolium, Cymodocea rotundata* and *C. serrulata, Halodule uninervis* and *H. wrightii, Halophila ovalis* and *H. stipulacea, Zostera*

capensis. In deeper water (i.e. on the outer edge of coral reefs) in light limited conditions, only *Halophila* species were found.

Due to the absence of coastal development, limited boating operations and other anthropogenic stressors, seagrass beds were mostly in good conditions along this coastline. The only exceptions were found in proximity of sewage outfalls or larger human settlements, particularly Vohemar. In these areas, the high organic matter content in the sediment and water turbidity increases epiphyte growth and growth of macroalgal forms.

Although healthy, seagrass ecosystems may be affected by changing climatic conditions in the WIO, through increase in sea surface temperature (expected to rise up to 0.6°C) and sea level rise (predicted up to 50cm by 2100) and changes in storms/cyclone patterns, frequency and intensity.

Echinoderms

Sixty eight species of echinoderms belonging to five classes were recorded: 3 species of crinoid, 18 holothurians, 27 ophiuroids, 10 echinoids and 10 asteroids, which with an additional 2 species previously recorded from the area gives a total richness of 70 species for the survey area.

The highest diversity of echinderms was found in deep bays (e.g. Loky Bay) where habitat diversity was highest, but also in impacts sites (e.g. Vohemar) where opportunistic species typical of degraded conditions were dominant. As echinoderm species are good ecological indicators,their patterns of abundance are good indicators of the condition of the reefs. The predatory seastar *Acanthaster planci* was not observed during the survey.

The patterns of echinoderm species distributions strongly support other findings of the RAP and the need for biodiversity/ resource conservation in the most diverse sites and remedial action in the most degraded sites.

Coral exosymbionts

On preliminary analysis, 67 exosymbiont taxa from approximately 48 structural species were sampled. A number of the exosymbionts showed characteristics not known from

Table 1. Study sites visited during the RAP. Site codes correspond to the main map on page 25.

Location	Code	Site name	Latitute (S)	Longitude (E)	Depth (m)
Ambodihavibe	A01	Ambodivahibe Inner	12°22.275	49°26.425	10
	A02	Ambodivahibe S	12°21.52	49°27.689	10
	A03	"	12°22.34	49°26.972	9
	A04	Ambodivahibe S, channel	12°21.07	49°27.893	15
	A05	Ambodivahibe N	12°20.32	49°26.166	10
Loky	A06	Loky S	12°43.82	49°41.792	10
	A07	"	12°44.943	49°40.743	10
	A08	Loky North West	12°43.452	49°40.04	9
	A09	"	12°42.119	49°39.921	10
	A10	Loky North	12°39.448	49°36.699	9
	A11A	Loky Acropora gardens	12°39.774	49°36.486	2
	A11B	Loky inner reef	12°43.104	49°39.109	0.5
	A12	Loky West	12°44.39	49°39.662	4
	A19	Loky Inner	12°45.188	49°40.278	12
Ankao	A20	Ankao North	12°47.484	49°48.731	6
	A21	Ankao South	12°49.648	49°48.713	6
	A22	Ankao North-East	12°46.004	49°49.351	10
	A23	Ankao North	12°46.911	49°48.658	5
	A24	Ankao Bay	12°48.174	49°47.536	5
Andravina	A17	Andravina Bay S pt	12°56.463	49°52.096	6
	A18	Andravina rock	12°55.955	49°51.246	6
Vohemar	A13	Vohemar North	13°19.585	50°0.807	8
	A14	Vohemar Inner	13°20.881	50°0.279	6
	A15	Vohemar North	13°20.089	50°0.899	11
	A16	Vohemar South	13°21.083	50°1.177	11

existing species, giving a possibility of several new species. Even based on such preliminary findings, the suggestion for so far un-measured regional diversity is strong, emphasizing the need for further sampling in this area and effective conservation actions to prevent losses before species can be documented and described.

Reef health and coral bleaching

Overall the region showed high coral cover (mean of 48%), and coral populations that spanned the expected size range for each genus, including large, mature colonies. The northern three locations (Ambodivahibe Bay, Nosy Ankao, Loky Bay) showed greater coral cover, larger corals and fewer bleached colonies than the southern two sites (Andravina, and Vohemar).

From February to April 2010 a warm pool of water affected reefs throughout the western Indian Ocean, causing bleaching in several locations. In the study area however, coral bleaching was relatively low, showing a mean ~5% of colonies affected. This finding, together with the low impact detected from the 1998 mass bleaching event, suggests that the corals in this region have largely resisted the negative effects of heating events, and supports the hypothesis that these reefs are thermally resistant.

The recruitment of corals in the areas surveyed was present but generally low. This may be due to a number of factors, including: (1) few sources of coral larvae: most reefs in this region have a narrow and shallow reef profile, limiting the total area of reef community and potential source colonies for reproduction, and the few upstream sources of larvae in the central Indian Ocean are quite distant; (2) low retention of dispersing larvae: strong currents that accelerate northwestward around the tip of Madagascar may deliver dispersing larvae to the East African mainland instead of retaining them locally; and (3) little good settlement substrate: most reefs showed a relatively low abundance of bare, hard substrate free of sediment, turf, soft coral or sponges. We recommend conservation actions to enhance coral recruitment, a key factor for ecological resilience, through watershed management to limit/reduce sedimentation

GENERAL RECOMMENDATIONS

Of the five locations, three are heavily sediment-affected bay systems: Ambodivahibe Bay, Loky Bay and Andravina. Of these, the first two are large enough to have areas within them that are less sediment-affected and allow for complex reef structure (i.e. A02/A04 in Ambodivahibe, A06/A11A in Loky Bay) while the small size of Andravina resulted in a very heavily sediment-affected system with low coral abundance and small corals. The southern end of our survey, Vohemar, has a very exposed fore-reef; the lagoon and back-reef are very heavily sediment- and human-influenced to the extent that coral community development is low. Finally, Nosy Ankao is on a seaward bank bathed by cleaner oceanic water and less influenced by sedimentation, and is also the site for an intensive seaweed farming operation.

The findings of this RAP support the recommendations proposed in previous surveys (see box below) and propose additional actions for the management and conservation of marine resources in Northeast Madagascar and the WIO Region:.

1) **ESTABLISH new Marine Protected Areas**. A number of opportunities and priority areas can be identified on this coastline for protection, through partnerships with different institutions and communities to achieve the most effective protection of biodiversity and natural resources, and sustenance of local livelihoods.

   Ambodivahibe – high priority 'climate park' with existing activities for conservation planning, and nested within a broader conservation initiative including Ivovona, Ramena and Diego Bay to the north.

   Loky Bay – highest diversity of corals and fish due to complex habitats and large area. Replicate upwelling/climate protection site to Ambodivahibe

   Ankao – unusual island system with clear water, and with the best fish populations due to de facto protection by concession owner of the islands.

   Andravina – low diversity but highly unique regional endemic coral populations.

   Vohemar – high diversity and highly developed fore reef system, but with heavy use and impact of the bay and reefs from urban and port development and sedimentation.

2) **ENHANCE fisheries management**. The impact of local and migrant fishing, for food and commercial markets, were clear even in the most remote and least accessible locations on the survey. It is essential to maintain fish populations to ensure their ecosystem services are realized, in particular a strong community of grazing fishes. Maintaining or boosting the population of grazers will likely aid the maintenance of existing adult corals (i.e. sources of coral larvae), and has strong effects on maintaining the availability of bare, grazed settlement substrate. Fish abundance was generally low relative to other sites in the region, with some key species absent. Specific fishery management plans will be required to encourage fish population recovery. Though fish species diversity was relatively high overall, certain families and sites had notably low diversity. While much of the region appears sparsely populated, we repeatedly noticed temporary fishing camps, and often these were equipped with effective gear such as out-board motors. Further socio-economic research should look specifically at the effects of migrant fishers.

3) **PROMOTE watershed management to reduce sediment impacts on marine systems**. Urgent steps are needed to control sediment delivery into the reef

system. A moderate level of sediment is not necessarily detrimental for reefs, and this region faces naturally high levels of sedimentation, evidenced by many sediment-adapted coral communities, with high abundance of more sediment-tolerant species. In fact, many of the regional endemics, e.g. *Horastrea* and *Gyrosmillia*, are well adapted to sediment heavy ecosystems. However, in many sites reef development was apparently limited by sedimentation, either through direct burial or through light limitation in the turbid water. Given the history of rapid deforestation in Madagascar, and the continued heavy reliance of the growing coastal population on mangrove stands for building material and charcoal cooking fires, sediment delivery has likely increased recently and, without intervention, will continue to increase. Some of the watersheds affecting the reefs, e.g. Loky Bay, have existing forest conservation initiatives in which CI is a partner, and these can be leveraged to broaden the focus of work to a ridge-to-reefs framework.

4) **IMPLEMENT species conservation plans.** Flagship species for protection (e.g. sharks, sea turtles, Napoleon wrasse, Bumphead parrotfish and large groupers) will all benefit from species conservation plans if they can be established in this area, or nationally in Madagascar. The potential for species plans for unusual species may also be powerful tools for broader goals, such as for evolutionarily distinct corals endemic to the western Indian Ocean (*Craterastrea laevis, Anomastrea irregularis, Horastrea indica* and *Gyrosmilia interrupta*). These can serve as flagship species for implementation of other recommendations (e.g. MPAs and watershed management).

5) **INSTIGATE effective partnerships for conservation.** With the highly dispersed and marine-resource-dependent local communities and population, partnerships will be the cornerstone for effective conservation and marine management. This has been clearly shown by experience since the 2nd RAP and the development of conservation activities in the Ambodivahibe-Ivovna-Ramena-Diego Bay system to the north. Three types of partnerships may be possible, depending on the location and the balance of local stakeholders:

Local government: In our meetings with the local government in Vohemar, they expressed great interest in conservation efforts for their area, but were quite candid about the current lack of such efforts. Coastal zone management, watershed management and pollution/municipal management are critical areas for intervention in all locations, but particularly Vohemar and Loky Bay.

Local communities: many of the villages in the region are quite remote, with poor access by land and limited infrastructure for travel by sea. Community-based initiatives for conservation, paired with income generation and improving standards of living will be necessary in these locations. Integrated projects incorporating health and education, two areas clearly lacking in some of the remote villages, may be necessary.

Private Partnerships: private investors and industries (e.e. seaweed farming) have been active in the region for over a decade. Nosy Ankao's reefs, for example, remain the least affected reefs in our survey by both sedimentation and fishing as seaweed farmers are actively discouraging fishing on the reefs. The private sector may also provide local fishers with an alternative livelihood through algal farming, thereby reducing fishing pressure. Effective partnership with private partners can be key in achieving effective conservation targets.

6) **CONDUCT further biological assessments**. This survey represents the third of six surveys recommended following the first RAP (McKenna et al. 2005). Priority sites for additional RAPs can be identified. Based on the presence of the highly succesfual Masoala Marine Park about 200 km south of Vohemar, several MPA initiatives on the Northwest coast from Nosy Hara to Sahamalaza, and extensive work on the southwest coast (the region ecompassing Andavadoaka to Tulear) a clear gap is the coastline south of Sahamalaza down the Northwest coast, around the 'hump' of the island in

Conservation Recommendations, RAP 31 (2005):

1) Pursue a vigorous program of **biological assessment.**
2) Review and **consolidate previous knowledge** of Madagascar's marine biota.
3) Collection of **additional data and long-term monitoring** programs essential for marine conservation planning and implementation.
4) Establish a **network of marine protected areas.**
5) Enact more effective laws to **regulate fishing activities.**
6) Promote and develop **conservation-oriented marine tourism** for the benefit of local communities.
7) Provide **dive training** for staff of local universities and conservation organizations.
8) Set up **outreach and public awareness** programs on marine resources to all local stakeholders.
9) Promote **community participation** in conservation planning and management.
10) Strengthen **species conservation programs** for rare and endangered marine wildlife.

the Mozambique channel, to the Barren Islands. This represents a coastline of close to 1,000 km, and the least known of reef environments in the country.

7) **DESIGN guidelines and best practices for coastal and foreshore development planning.** As coastal development and population growth increases along this coastline, coral reefs, mangroves and seagrasses will face growing pressures such as mechanical disturbance for infrastructure development (hotels, marinas, etc) and from boating, increasing sediment runoff due to deforestation, and extraction for food and commerce. At present, the Northeast coast is relatively remote, and is protected by the very rough seas and highly exposed nature of the shorelines. Strategies to manage and limit threats as population increases will be necessary, to replace the natural protection as incentives increase to exploit the area. Additionally, "climate-smart" development should be promoted, which takes into account the potential for increased storm activity, salt water intrusion, and other climate change impacts. This best-practice development is particularly timely as Madagascar's national Integrated Coastal Zone Management (Gestion Intégrée des Zones Côtères – GIZC) process is gaining policy traction at the national level.

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