Study of the biological communities of the potential MPAs for the Ankilibe Bay, Southwest of Madagascar

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INTRODUCTION

Madagascar is the fourth biggest island in the world with a shoreline of 6000 km including 3500 km of coral reefs (Gabrié *et al.* 2000) : 1130 km are fringing reefs, 557 km are patch reefs surrounding ilets, 52 km are barrier reefs (all located in the Toliara region) and 1711 km are submerged bank reefs (Cooke *et al*. 2000). Those coral reefs are of the richest in the Western Indian Ocean in therm of biodiversity, with more than 6000 biological species, including 752 species of fish and 340 coral species (McKenna & Allen, 2003).

However, those complex ecosystems are among the most threatened. Wilkinson (2004) estimated 20 % of the coral reefs in the world already destroyed, 24 % are in imminent danger and 26 % are endangered on the long-run. The main threat is a constant increase in human pressure. Indeed, the coral reefs are directly affected by overfishing, by extensive shell collecting, by trampling which destroys the coral or by its use as building material (Vasseur, 1988). In addition, the exploitation of the wood from the forests located on the shore to make charcoal or to use as building material increases sedimentation, salinity and suspense mater load of the marine waters, which directly and indirectly affects the health of the coral reefs (Rodgers, 1990 ; Ryan *et al.*, 2008). Finally, as the industrial and farming activities and the urban trash load increase, the pollution affect more and more the fragile balance of the coral reef ecosystem (Vasseur, 1988).

In addition to the threats due to a high human pressure, natural events can stress the reefs (Wilkinson 1998). Storms and wave action can destroy the most fragile corals. Shallow water warming, phenomenon amplified by the increase of green gazes, may lead to global bleaching (Hughes *et al.* 2003). Wilkinson (2002) estimated that 16% of the coral of the world died during the general bleaching events of 1998. Warmer waters also become more acid, which increase the tenderness of coral carbonate skeleton (Hughes *et al.* 2003).

Since the 60's, the scientists having studied the coral reefs of the region of Toliara (reviewed by Thomassin, 1971) stressed on the increasing threats on this ecosystem, especially due to a strong human pressure (Vasseur, 1988). The *Toliara Land and Seascape Conservation Program for the Ranobe Complex & Lower Onilahy River Valley and Delta* started in June 2007 by the *WWF Madagascar and West Indian Ocean Program Office (MWIOPO)* has the objective to follow the Durban Vision[1] and the *Madagascar Action Plan (MAP)* published in 2006. Thus, a five-years workplan started in 2007. It includes seven principal components, of which the fifth has the aim to restore coral reefs biological health with the help of local populations and NGOs. This is why Reef Doctor, NGO based in Ifaty, 28 Km North of Toliara, was chosen to work on the accomplishment of the objectives defined to reach this goal:

- A participatory action with the local populations was initiated to defined the potential sites for the future Marine Protected Area.
- Workshop were organized for representatives of each village of the Ankilibe Bay to learn about marine conservation programs

[1] The Durban Vision was defined by the Malagasy president M. Ravalomanana in 2003, during the World Parks Conference in Durban, South Africa. He declared that Madagascar would triple the total superficie of the protected areas from 1.7 to 6.0 millions of hectares within the next decade.

➢ A four-weeks socio-economic study was achieved in the village of Ankilibe in November-December 2007.
➢ The present study was achieved in July 2008 to assess the coral reefs biological health of the proposed sites in the Ankilibe Bay.

METHODOLOGY

Physical environment of the Toliara region

Toliara shores have semi-diurnal tides of heights between 0.6 m and 3.6 m, with an average of 2.10 m (Pichon, 1964). The dominant winds of the region are South-West are often strong during the winter (June to November), especially in the afternoon (Clausade *et al.*, 1971) and create a swell of similar direction (Weydert, 1973). Those winds create a strong sea, even on the lagoons. When there is no wind, the coasts of Toliara region are subjected to a faraway surge of great amplitude that can be strong in function of the general meteorological system of the Mozambique Canal.

The region of Toliara and the Mahafaly coastal plain (South of the Onilahy delta) has the lowest rain system of Madagascar (less than 400 mm per year) because it is out of the influence of the monsoon (Battistini R. *et al*, 1975).

Description of the study zone

The Toliara Bay is crossed in its centre by the Capricorne tropic (23°27S). Its length is 20 Km, delimited in the North by the temporary river Fiherenana and in the South by the permanent river Onilahy. The width of the Bay is 1.3 Km in its North extremity, in front of the city of Toliara, and 4.4 Km in its South extremity, in front of the small village of Sarodrano. Its median part reaches 8.8 Km (
Figure 1). The Bay has an opening in the North to the Mozambique Channel and on the South, to the Saint-Augustin Bay.

The coral systems of the Bay of Toliara are of four types: outer reefs, inner reefs, coral banks and fringing reefs (Sarodrano) (Clausade *et al.*, 1971, Figure 1). The outer reefs include the “Grand Récif de Tuléar” to which can be added Nosy Tafara islet. Its length stretches over 18 Km and its width varies between 1.1 and 2.9 Km. The depth of the adjacent lagoon does not exceed 10 m, except for the channels of the North and South passes (Clausade *et al*, 1971). The inner reefs are composed of three units which are from South to North: Beloza, Dimadimatsy and Norinkazo. Those reefs are well separated from each other by passes of about 300 m large. The coral banks are located North from the inner reefs and emerge at low tide.

The area studied corresponds to the South part of the Bay, between the village of Anilibe and Sarodrano

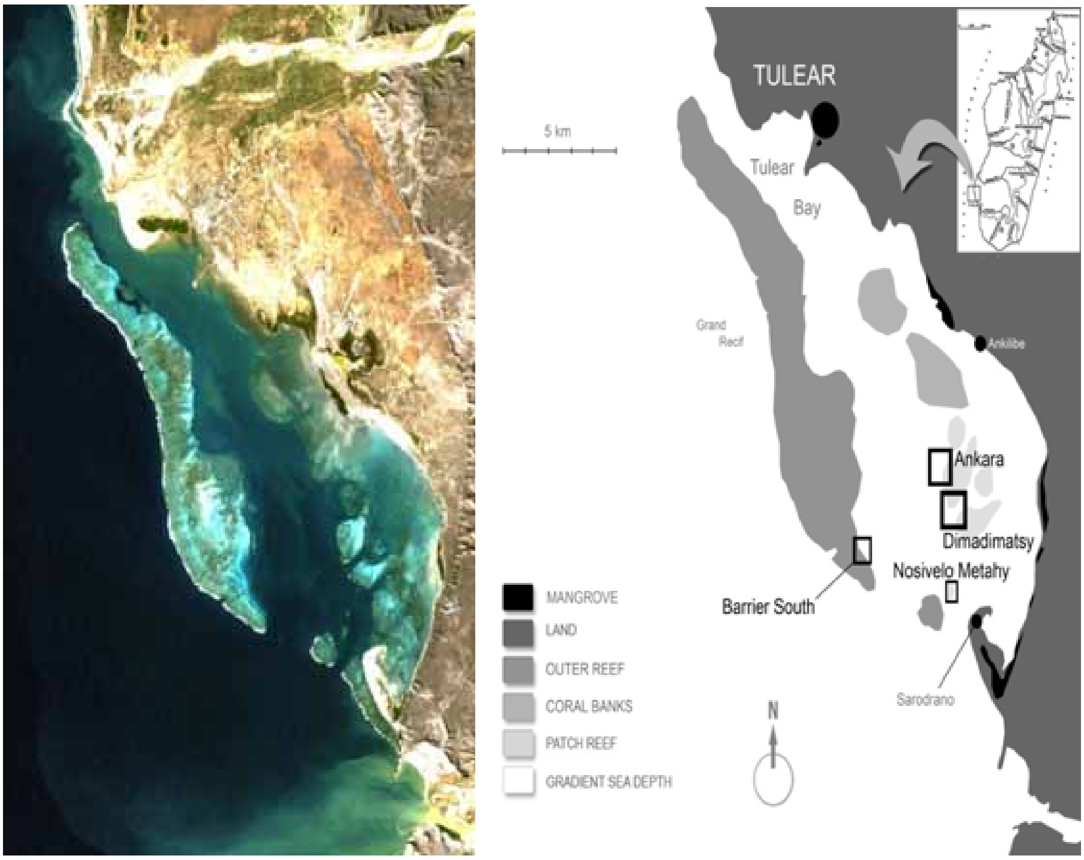

Figure 1. Study sites of the Ankilibe Bay.

Study sites

Site 1. South Barrier (SB)

South Barrier is the inner, lagoon side of the barrier reef system just north of the pass at Sarodrano (Figure 1). The GPS coordinates given (Appendix 1) illustrate the northern and southern limits of the survey area; the barrier system itself continues north until Tulear and south some several hundred metres before the pass. The barrier itself drops down from the reef flat in 2.5m depth at 9.45 on 24/07/2008 (high tide 8.40, 3.04m) to a flat sandy bottom at 9-10m that is strewn with many large coral calcareous bommies (Pichon 1964) covered with particularly high concentrations of soft corals and surrounded by diverse and concentrated fish populations. These bommies are seemingly the focus of life at this section of the inner barrier, and were the focus of the transects.

Site 2. Dimadimatsy (DD)

This site is part of the lagoon internal reefs complex located in the western part of the Bay. Dimadimatsy includes the south western area of the same reef system as Ankara, a wide sand channel and another fringing reef system continuing south. The western side of this whole system was indicated as the traditional fishing ground named Dimadimatsy. Its centre is made of a sandy channel running from the NE of the lagoon towards the SW. The western opening of the channel is just over 500m wide, at 10.00 on 23/07/2008 (high tide 8.00, 3.14m) the depth in the centre was 9m. The channel narrows and becomes shallower as it continues NE towards shore until petering out at the eastern side. The reef continues north from this channel until it is considered to be Ankara, though the exact delineation is necessarily unclear, while the southern section comprises another fringing reef aligned NW-SE running for 700m before becoming continually shallower and patchier. Our surveys were conducted in the channel itself, on north and south walls and on the western slope, both to north and south of the channel. The reef started at between 7 and 8m depth and continued to 1m below the surface as recorded at 9.30 the same day. It comprises large expanses of broken coral and rubble heavily overgrown by macro and turf algaes.

Site 3. Nosivelometahy (NV)

This is an oval-shaped area 1km northeast of Sarodrano, it is 680m in length N-S and 300m E-W. Just south of the centre is a sandy-bottomed roughly-circular hole of 30 m diameter at the top with shallow walls whose slope gradually descends to give a diameter at the sandy bottom of 10m. The depth in the centre of the hole was 9m at 9.00 on 22/07/2008 (high tide 7.30, 3.18m). The rest of the central area of Nosivelometahy is a flat zone of sand with patches of branching coral debris. Depths here were 2-3m as recorded minutes earlier the same day. The southern and western perimeters of the site slope down gently to join the sand flats at 5m; while the north and eastern slopes are steeper, dropping down to the sand at 11.5m at 9.45 the same day. These latter slopes were observed to have a higher live coral cover than those of the South-West, hence it was here that we focused our surveys, along with inside the hole.

Site 4. Ankara (AK)

Ankara is a long and narrow strip of bank reefs (Clausade, 1971) surrounded on its eastern and western sides by sand and seagrass. The reef area is 1.8km in length, running in a north, south orientation. The width east-west varies between 500 and 600m. The reef system is continuous with that of Dimadimatsy; Ankara is the northernmost part.

Ankara's eastern side consists mostly of very shallow sandy areas with patches of dead coral, rock and rubble interspersed with seagrass; while the western side facing the barrier slopes down more steeply from the reef top to a sandy bottom. At 11.45 on 28/07/2008 (high tide at 13.30, 2.61m) the top of the reef slope was barely covered with water, and in fact some places were exposed. The slope itself drops down to sand at 5m depth. This western side is undoubtedly the more diverse in terms of coral cover and fish life and it was here that we focused our survey efforts. Rock and coral bommies are interspersed with sandy patches in the deeper water, while the continuous reef structure of the shallows is a network of broken and dead branching coral held together by coraline algae.

Study of the biological communities

The methodologies used for this study to assess benthic, fish and invertebrates populations are a mixed of methodologies used by different institutes of research as COREMO3 (Coral Reef Management Program 3), Reef Check, AIMS (Australian Institute of Marine Science), FishBase.org and GCRMN (Global Coral Reef Monitoring Program Network).

First, it is important to give a clear definition of certain words and expressions that will be used all along this report:

Study site : area of the reef that is surveyed. In this study, four sites were surveyed (Figure 1).
Sample : data set collected during one transect in a study site (**station**). To allow a good variability of the biological population studied, it is necessary to do at least four transects on a study site. They are called **replicats**.
Transect line : tape measure along which an observer collects the data.

Sampling of benthic, fish and invertebrates population was done using non-permanent transects, randomly placed on the sites to study, preliminary divided in four different zones.

Each transect has been performed by divers buddy team swimming along the 50 m long tape measure. The first diver recorded the fish population while the second, swimming 5 m behind, was recording the benthos and the invertebrates. To keep the data independent, the observers ensured that the transects did not cross each other. All the survey were done between 9h et 16h30 during July 2008.

Fish community

The « Belt Transect » method was used to quantify the abundance and the composition of the fish population. Data are collected along a 50 m transect line, 5 m above and 5 m across. The total area covers a volume of 1250 m^3 (50 m x 5 m x 5 m). The diver swims at a constant speed and ensures that the duration of each data collection is almost the same. He also has to be sure that fishes are only counted once and that the depth is constant along the transect, to avoid any thorough change in the type of habitats encountered.

Once the transect line is set up, the buddy pair moves away for 5 minutes to allow the fish that were disturbed to settle back and behave normally again. The observer starts a first way along the transect line to record all the transient fishes which would leave the area after being disturbed. Then, on the way back, he records the resident and cryptic fishes which require more attention to be observed. All the fishes encountered are recorded to the species or genus level according to the knowledge of the observer.

The different trophic levels of the fish species observed were defined as followed: Carnivores, Herbivores, Planktivores, Coralivores and Omnivores using the FishBase.org database and the Lieske & Myers (2002) book. The trophic level of the species that are not specialist or Omnivores strict was defined from the main type of food they collect. The individuals that could only been defined to the family level were only used for the taxonomic analyses and not to assess the density of the site. Thus, the number of individuals may vary in function of the type of analyses. Finally, the juveniles whom diet differs from the adults were not used for the trophic analyses.

The list of all the species recorded during this study is shown in Appendix 2.

The communities of benthos fixed

The « Point Intercept Transect» (P.I.T.) method is used to sample the fixed benthic community. The second buddy pair of the observing team described above swims along the transect line, five meters behind the fishes observer and record every 50 cm the type of benthos directly found below the tape measure. According to the methodology used in COREMO 3, the benthos is recorded along two 20 m sections within the same transect, along the first 20 m and between the next 25-45m, leaving a 5 m gap at the end of each section. The data collected for the benthos are shown in Appendix 4.

The communities of invertebrates

The « Belt Transect » is used to sample the invertebrates population during a third way along the transect line that was already used to assess the fish and the benthos described above. As for the benthic, invertebrates are recorded on two 20 m sections along a 2 m width belt transect. Only indicators species defined by Reef Check were recorded (Appendix 5). Two species of Holothuridae were added to this list because they suffer a highly fished from people in Ifaty to be exported to the Asian market (personal observations).

RESULTS

Details of the data used for the analyses are shown in Appendix 5 for the invertebrates, in Appendix 6 for the benthos fixed and in Appendix 9 and Appendix 10 for fishes.

Study of the benthos

The benthos sessile

The total mean of hard coral cover for all the sites is 12.9 % ± 5.7 SE. It varies between 8 % ± 1.6 SE at Ankara, 8.5 % ± 3.6 SE at Barrier South and 22.9 % ± 14.4 SE at Nosivelometahy (Figure 2, Appendix 6). Coraline algae represent on average about 7 % ± 1 SE of the benthos among all the studied sites. It is quasi-null at Dimadimatsy (0.5 % ± 0.4 SE) and maximum at Nosivelometahy (17.1% ± 5.7 SE). Thus, on three sites out of four, less than 15 % of the benthos is formed by living carbonate skeleton organisms (living coral and coraline algae) which take part of the elaboration of the hard substrate of the coral reefs (Yap & Gomez, 1998). Nosivelometahy shows a higher percentage with almost 40 % of these substrate builders. The total cover of soft coral is very low with 0.8 % ± 0.5 SE cover on average.

The total average of dead coral and rubbles are respectively 1.2 % ± 0.6 SE and 35 % ± 5 SE. This rate is very similar among all the sites and may give a clue on a generalized event of coral death in the past within the bay. The low cover of living coral may not explain such a high percentage of rubble from a natural turn-over from coral death.

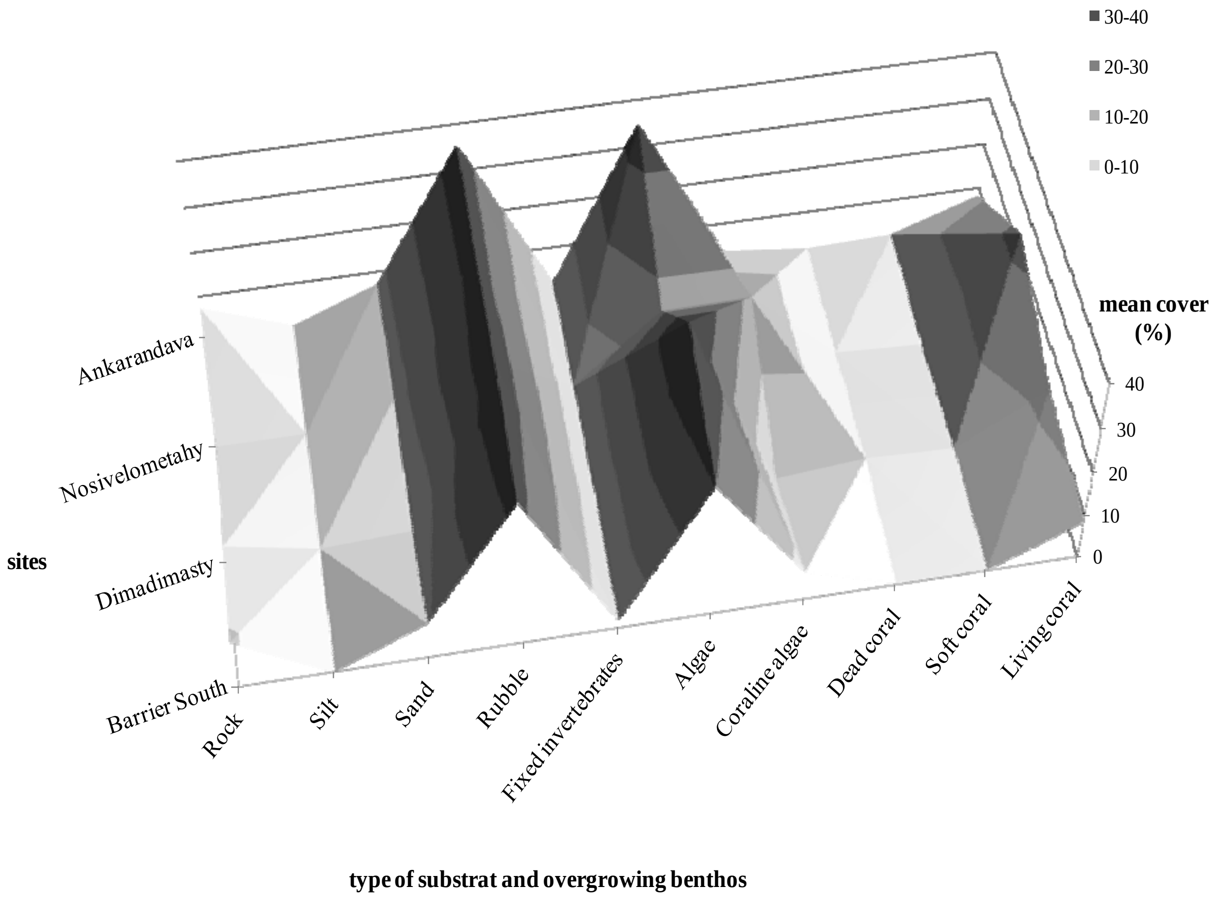

Figure 2. Mean cover of substrate and benthos among all the sites.

Algae represent on average 30.3 % ± 4.8 SE of the benthos of all the sites. Nosivelometahy shows the minimum proportion (16.9 % ± 4.6 SE) whereas they are dominant at Dimadimatsy (39.5 % ± 5.4 SE).

Most of the substrat was covered by overgrowing benthos; it was mainly made of rock and sand (respectively 5.5 % ± 2.8 SE and 5.4 % ±0.9 SE as an average of all the sites).

The coral composition

The corals non-Acropora massive, encrusting and submassive have the highest average cover among the sites (respectively 28.6 % ± 6.7 SE, 23.7 % ± 7.6 SE and 22.4 % ± 8.9 SE, Figure 3). The former are majoritary at Dimadimatsy (44.8 % ± 12.6 SE) while the second have the highest average cover at Barrier South, Ankara and Dimadimatsy (respectively 43.2 % ± 22.2 SE, 42.5 % ±7.7 SE and 29.3 % ± 16 SE). The latter represent almost half the living coral cover of Nosivelometahy (48.2 % ± 22.8 SE). Only the two types of Acropora branching and digitated corals were found at low percentage among all the sites (respectively 4.5 % ± 0.6 SE and 2 % ± 0.7 SE). The former were most present in Nosivelometahy (7.3 % ± 10.4 SE) which shows the highest taxonomic diversity with height different type of living coral out of eleven observed in total. Many free-living corals of the genuses *Fungia*, *Herpolitha* and *Halomitra* were observed at Nosivelometahy (10.9 % ± 5.8 SE), Dimadimatsy (6.9 % ± 5.8 SE) and Ankara (5 % ± 2.8 SE). Soft corals were only found at Dimadimatsy (10.3 ± 6.1 SE) and Ankara (17.5 % 16.7 SE) that belong to the same reef system (Figure 1).

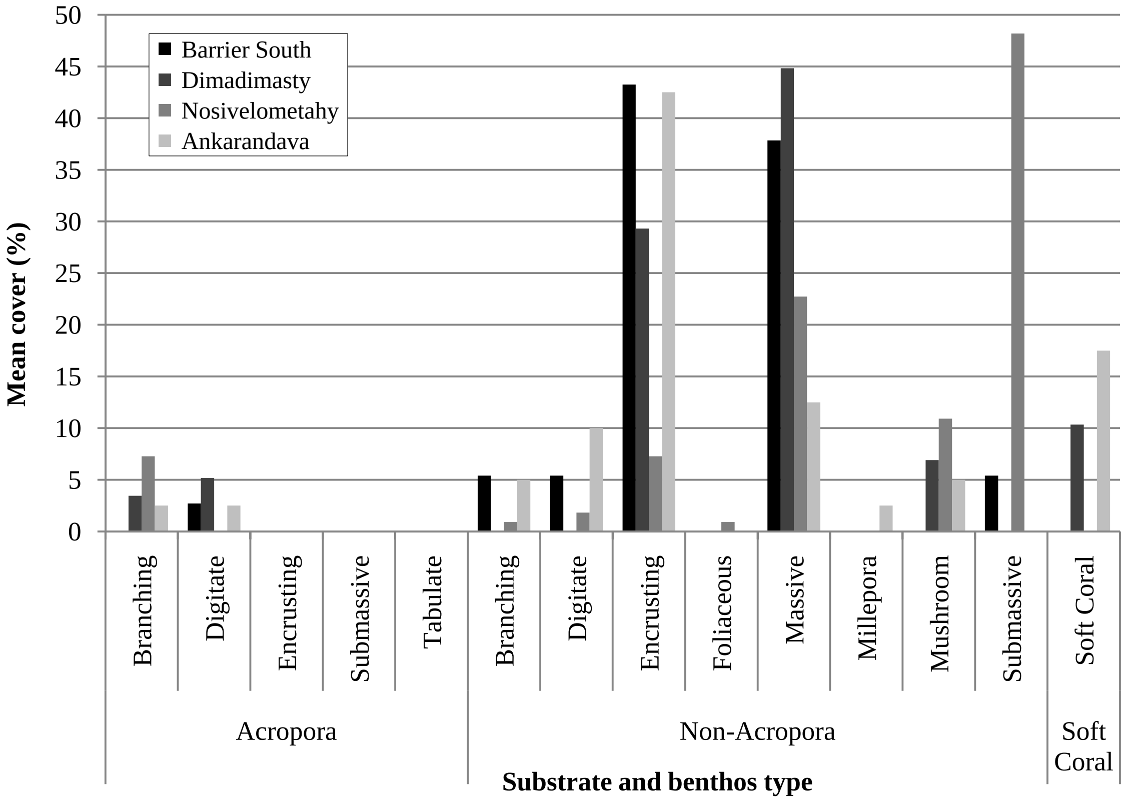

Figure 3. Percentage cover of substrate and benthos among all the studied sites

The invertebrates

Except for *Echinotrix diadema* which density was on average 16.2 ± 6.4 SE individuals per 50 m², the density of invertebrates was very low among the sites (Appendix 5). No *Charonia tritonis, Panulirus sp., Tridacna maxima, Holothuria scabra* nor *Acanthaster planci* was observed during this survey. In total, one *Tridacna squamosa*, two *Holothuria nobilis* and three *H. edulis* were observed. On average, less than one individual per 50 m² of *Diadema setosum* and *D. savignyi* was observed among the sites.

Study of the fish community

The fish biodiversity

The average density of fish among all the sites was 270.6 ± 54.8 SE individuals per 50 m² (Figure 4 and Appendix 9), with the highest average at Ankara (441.3 ± 157.2 SE). This number was pushed up by the presence of big schools of juveniles Apogonidae and *Caesio sp.* (Caesionidae) composed of respectively more than 300 and 200 individuals. Fish density was the second highest at Barrier South (397.5 ± 122.2 SE), mainly due to the presence of large groups of *Chromis dimidiata* (Pomacentridae), *Pempheris schwenkii* (Pempheridae) and *Dascyllus trimaculatus* (Pomacentridae) (Appendix 8). The density of fish was lower at Dimadimatsy (148.8 ± 37.4 SE), and Nosivelometahy (137.5 ± 18.7 SE). The dominant specie was *Plectroglyphydodon lacrymatus* (Pomacentridae) for the former and *Plotosus lineatus* (Plotosidae) for the latter.

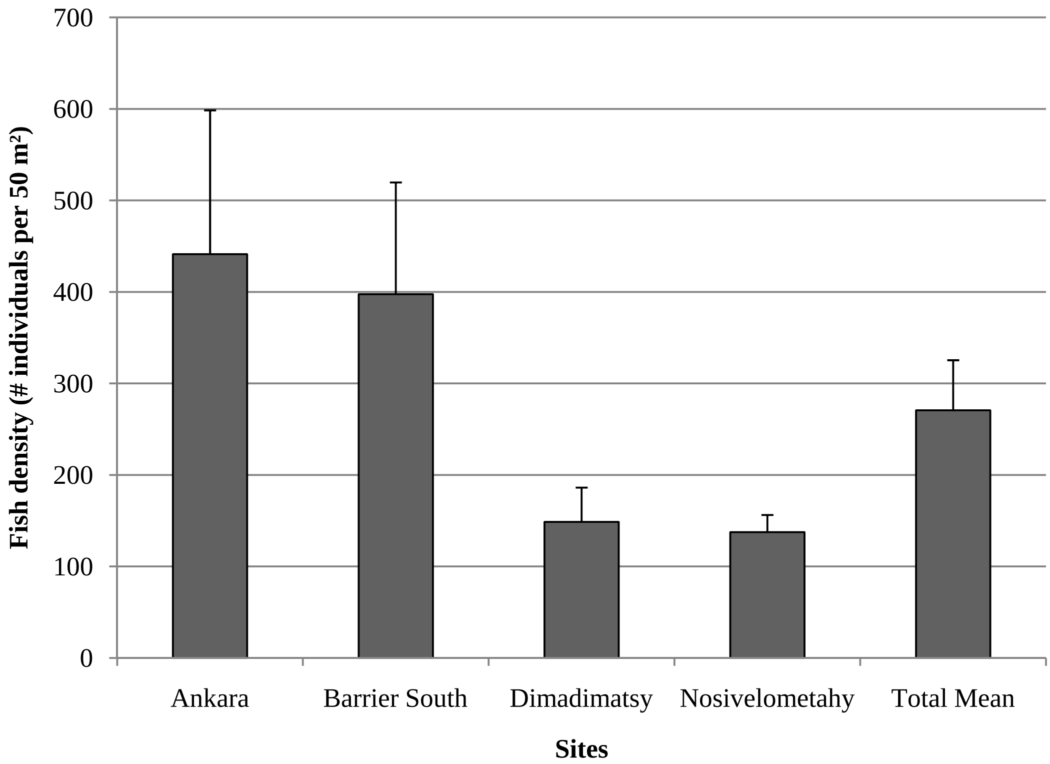

Figure 4. Density of fish per sites (mean ± SE)

A total of 170 species and 35 families were recorded during this study (Figure 5 and Appendix 9) with an average of 35.4 ± 3.4 SE and 14.1 ± 1 SE respectively. The highest diversity of fish species was found at Dimadimatsy (99 in total, 29.3 ± 3.3 SE on average per transect) while the lowest diversity was found at Ankara (71 in total, 38 ± 8.1 SE). The highest number of different families was found at Barrier South (28) while the lowest was found at Ankara (23) where, however, the highest average of families per transect was recorded (15.7 ± 4.4 SE).

The 20 families with the most individuals recorded per transect were: Pomacentridae (95.5 ± 21.5 SE), Labridae (25.9 ± 6.1 SE), Apogonidae (24.6 ± 11.3 SE), Caesionidae (21.3 ± 15.9 SE), Pempheridae (13.8 ± 11.9 SE) (Appendix 8).

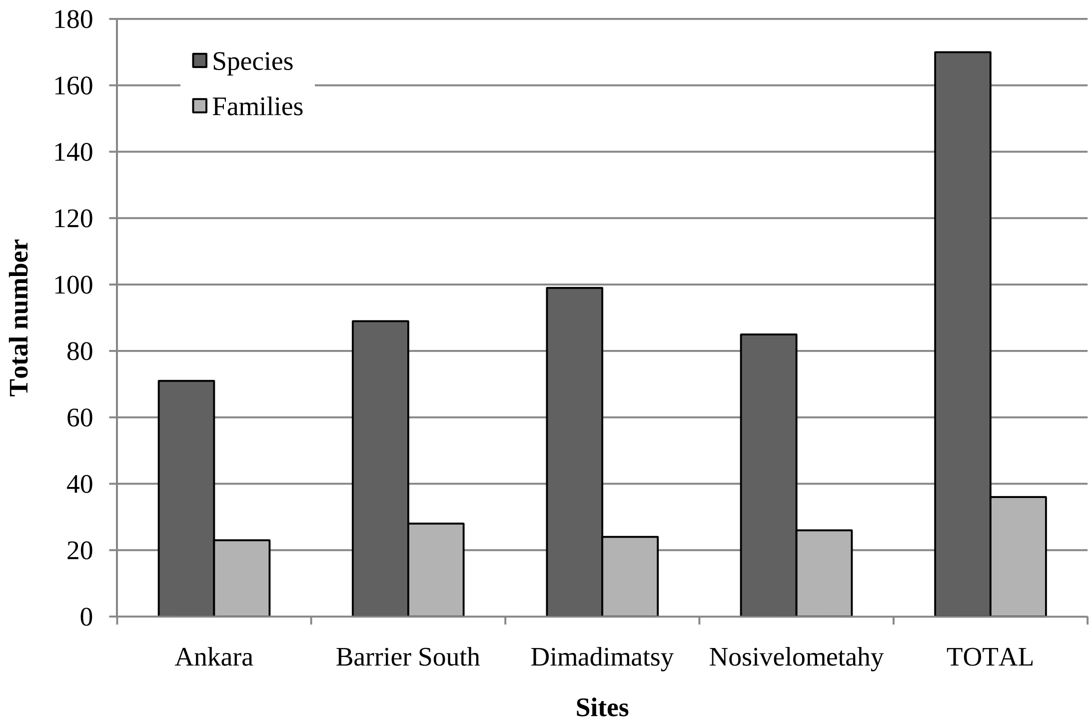

Figure 5. Total number of species and families recorded among and for all the sites.

The fish trophic levels

The fish population of the studied sites was constituted of 55 Carnivores species (36 % ± 1.6 SE on average per transect), 33 species of planktivorous (21 % ± 1.1 SE on average per transect), 25 omnivores species (23.9 % ± 0.7 SE on average per transect), 18 species of herbivores (15.6 % ± 1 SE on average per transect) and 2 species of coralivores (3.5 % ± 0.1 SE on average per transect) (Appendix 10).

Figure 6 and Appendix 10 shows that the planktivorous species had the highest percentage of individuals among all the sites (31.4 % ± 8.4 SE) despite the fact that they did not show the highest average number of species (21 ± 1.1 SE). The fish community of Barrier South was greatly dominated by the planktivorous (59.6 % ± 6.8 SE), certainly due to the location of this site close the south pass of the bay, zone where the currents carry the plankton they feed on (Hobson, 1991). This high percentage was mainly due to the presence of large groups of *Chromis dimidiata*, *C. ternatensis*, *Dascyllus trimaculatus* (Pomacentridae) and

Pempheris schwenkii (Pempheridae). The planktivorous represented almost ¼ of the community of all the other sites. This dominance

The carnivores showed the highest species diversity among all the sites (36 ± 1.6 SE) and the second highest density on average among all the sites (25.3 % ± 7.1 SE). They were dominant in number of individuals at Ankara (48.2 % ± 11.4 SE) and minimum at Barrier South (15.9 % ± 1.5 SE) and Dimadimatsy (14 % ± 7.7 SE). The dominant Carnivores species were *Labroides dimidiatus*, *Thalassoma hardwicke* (Labridae) and *Apogon cyanosoma* (Apogonidae). The great majority of the Carnivores recorded during this study were small invertebrates browsers and none of the families of the great predators of coral reefs (Carcharhinidae, Stegostomidae, Ginglymostomatidae, Sphyraenidae, Serranidae) were recorded, which may show the very high fishing pressure in the Bay of Ankilibe.

The total mean of coralivores fish individuals is the lowest (4.5 % ± 3 SE) of all the diet type. This is mainly due to the low number of species of this very specialized diet recorded during this study (3.5 ± 0.1 SE). Almost no coralivores were recorded at Barrier South (0.6 ± 0.1 species and 0.3 % ± 0.3 SE individuals). However, Nosivelometahy showed a much higher percentage of Coralivores (12.9 % ± 10.4 SE) than the other sites, due to a great number of *Chaetodon trifasciatus* (Chaetodontidae) (6.0 individuals per 50 m^2 ± 2.4 SE) which were recorded within all the transects performed. This result can be compared with the highest percentage of living coral cover observed at Nosivelometahy (Figure 2).

The herbivores constituted 21.4 % ± 7.9 SE of all the individuals recorded and had the second lowest species diversity on average among all the sites (15.6 ± 1 SE). They were dominated in term of density by the Acanthuridae, dominated by the species *Plectroglyphidodon lacrymatus* (21.4 individuals per 50 m^2 ± 7.9 SE) and the Scaridae, dominated by the species *Chlorurus sordidus* (8.3 individuals per 50 m^2 ± 3.5 SE). An important part of the ichtyofauna of Dimadimatsy was constituted by herbivores (34 % ± 15.9 SE). This proportion is the lowest at Ankara (12.6 % ± 5.1 SE) and Barrier South (11.9 % ± 2.9 SE).

The average number of omnivore fishes varied between 12.3 % ± 3 SE at Barrier South and 23.1 % 5.2 SE at Dimadimatsy, with an average of 17.4 % 4 SE among all the sites. Their number of species is the second highest and is very constant among the sites (23.9 species on average ± 0.7 SE). The omnivores were dominated by the Tetraodontidae, especially the species *Canthigaster solandri* (7.0 individuals per 50 m^2 ± 2.5 SE) and *Canthigaster valentini* (5.7 individuals per 50 m^2± 1.2 SE).

The most fished fish species

Only 7 species from the most fished in Ankilibe were recorded among all the sites (

Appendix 3). An average of 18.7 ± 1 SE and 18.3 ± 2.8 SE individuals per 50 m² were recorded at Barrier South and Nosivelometahy respectively (Figure 7).Only 2.75 ± 0.2 SE individuals per 50 m² were recorded at Dimadimatsy and none at Ankara. None of the individuals observed were bigger than 20 cm in total length, which gives a clue about the high fishing pressure that may exist in the Bay (McManus, 2000).

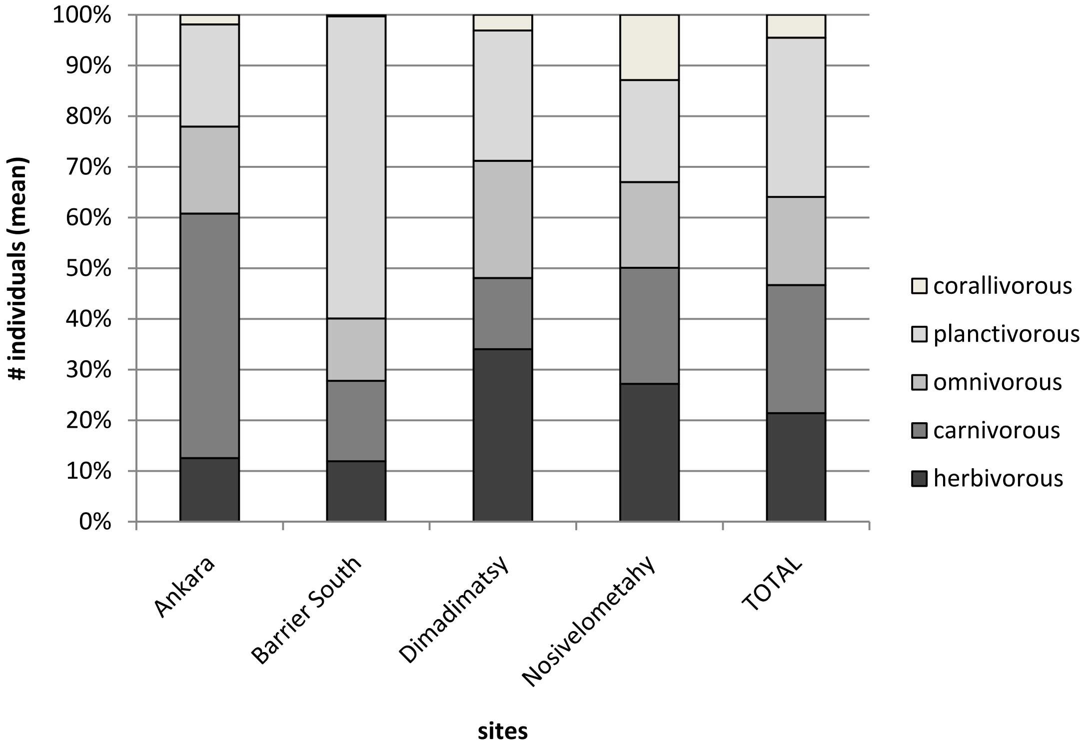

Figure 6. Mean (%) of the number of individuals in function of their trophic levels per and for all the site.

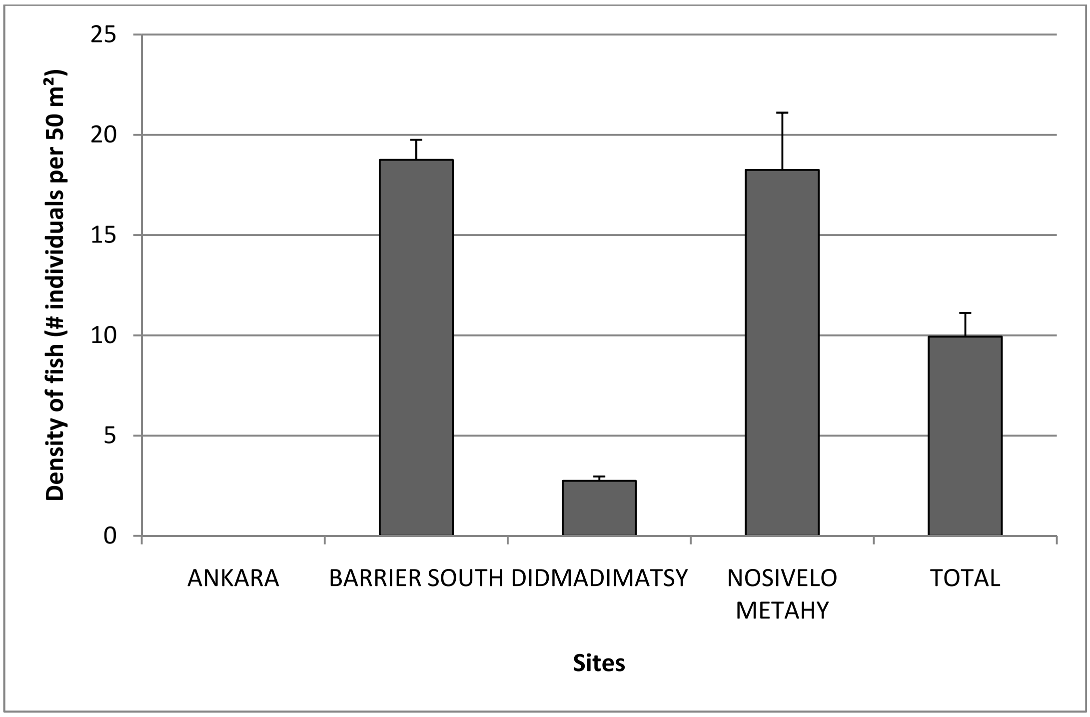

Figure 7. Total number of individuals belonging to the most fished species at Ankilibe (

Appendix 3) recorded among all the surveyed sites.

DISCUSSION

A study achieved in 2006 in the South of the Bay of Tulear showed a living coral cover of 23.5 % (Tableau 1, references of the studies cited in caption). The sampling stations were located outside the Bay (deep zone, outer slope) and inside the Bay, among the reef flat of the barrier reef where the living coral cover was the lowest (22.0 %). These results pointed out the fact that the percentage of living coral was lower for the inner than the outer sites. In the present study, the coral cover among all the sites, which were all located inside the Bay, was lower (12.9 % ± 5.7 SE) than for the interior sites of the 2006 study, except for Nosivelometahy which had a similar living coral cover. The higher coral cover found in Nosivelometahy was still almost two times lower than for the non-protected sites of the Bay of Ranobe monitored one month before (Ory, unpublished). As well, the coral cover recorded on sites of the Bay of Ankilibe for the present study was lower than in the other regions of Madagascar (42 % in the purpose of reating an MPA , between 53 % and 36.5 % in the North-Ouest, 25.8 % in Salary Nord or 45.7 % in the East coast) (Tableau 1). The conclusion is the same for a comparison of sites within the western Indian Ocean; the coral cover was higher in La Réunion, the Comoros, Mauritius, Mozambicus, Kenya, even in Tanzania which showed the lowest percentage of living coral within the whole region. So, the living coral cover observed among the four sites was one of the lowest of the whole western Indian Ocean.

The average algae cover was lower than in the Bay of Ranobe and in Kenya but higher than the sites surveyed in Andavadoaka, North-West of Madagascar, Tanzania or Mauritius (Tableau 1). However, it is less important than in the Bay of Ranobe or in Kenya.

The high percentage of rubble found at all the sites may indicate that a major event could have negatively affected the coal reef health; this may be the result of the major coral bleaching event recorded in the region in 1998, 2002 and 2005 (Obura, 2005). However, Ahamada *et al.* (2002) noticed that most of the sites had recovered within several months. But, this was the case for none of the four sites we surveyed. The high percentage of algae coupled with the very low coral cover could indicate that these sites may suffer of a low recovering capacity of its coral community after a great disturbance. Unfortunately, no data on algae cover are available from the study done in 2006 ain Toliara South that could have allowed a study of its evolution within the last years.

The high algae cover is higher within the sites that have less herbivores fish. The latter are constituted in majority of small territorial grazers (Acanthuridae, Pomacentridae) which may control the algae population and give the coral an advantage to gain its competition with algae. Indeed, herbivores represent almost 1/4 of the total individuals in Ankilibe (21.4 % ± 7.9 SE); this result is similar to this from the study performed in Ranobe in 2008 (27.8 % ± 2.1 SE) (Reef Doctor, unpublished) and shows that the population of herbivores fish may control the spread of algae.

The fish diversity of the studied sites is, on average, similar than for other sites surveyed in the South-West of Madagascar (Tableau 1). The total number of species is lower but this is due to a lower sampling effort with only four transect performed per site.

On a healthy coral reef ecosystem, the percentage of carnivores (piscivorous and predators of small invertebrates) is generally comprised between 45 % and 65 % of the whole fish population (Jones *et al.*, 1991). Few of the great predators of coral reefs belonging to families like sharks, Sphyraenidae, Serranidae (Epinephelinae), Lutjanidae or Lethrinidae were observed during this study and all their individuals were less than 25 cm in total length. This result gives a good clue about the high fishing pressure observed in the Bay (McManus, 2000; Ahamada *et al.* 2002). Similar observations were made for most of the sites surveyed within the western Indian Ocean (e.g. Reef Doctor, unpublished; Ahamada *et al.* 2004; Nadon *et al.*, 2007).

Due to their specialised diet, coralivores species represent a lower part of the total percentage of the species found among coral reefs but are very important indicators of its good ecological health. During our study, their number was comparable with this found on sites considered in good health in Andavadoaka (Nadon *et al.* 2007) or in the Bay of Ranobe (Reef Doctor, unpublished). Furthermore, the percentage of coralivores was very high at Nosivelometahy, which is well correlated with the highest living coral cover found on this site (Figure 2) and may indicate a better health of its coral reef community than on any other surveyed sites.

Tableau 1. Comparison of the fish diversity and the benthos cover at Madagascar and in the western Indian Ocean between 2002 and 2008 at shallow and moderate depth (< 18 m) coral reefs sites. References : [1] Reef Doctor (2008, unpublished), [2] Nadon *& al.* 2007, [3] Ahamada *& al.* 2004, [4] WWF (unpublished), [5] McKenna & Allen 2003, [6] Webster & McMahon 2002, [7] Obura *et al.* 2002, [8] McClanahan *et al.*, 2005, [9] Graham *et al.*, 2005.

Location	Site	Year of the study	Fish diversity (species number)				Benthos mean cover (% per site, max-min)	
			Total	Max	Min	Mean per site	Hard living coral	Algae
SW Madagascar[1]	Ankilibe (NP)	2008	170	99	71	35.4	12.9 (5.7)	30.3 (4.8)
SW Madagascar[1]	Ranobe(NP)	2006	219	126	82	60	4	43
	Ranobe(P)	2006					36.4	46
SW Madagascar[1]	Ranobe(NP)	2008	245	103	60	35.7	41 (12-59.4)	32.6 (53.9-29.7)
	Ranobe(P)	2008		100			44.1	39.7
SW Madagascar[2]	Andavadoaka (NP)	2005				12.3*	42 (49-11.8)	19.2
SW Madagascar[3]	Récif Tuléar (NP)	2004					49.8	
SW Madagascar[4]	Salary Nord (NP)	2006	261	75	25	48.5	25.8 (40-10)	
	Tuléar Sud (NP)	2006	234	59	10	40.8	23.5	
NW Madagascar[5]		2002	463	166	33	117	36.5 (70.6-11.2)	26 (42.5-1.2)
NW Madagascar[6]	Nosy Ve	2002					40 (53-27)	
NW Madagascar[3]	Dzamandjar & Tanikely	2004					53	15
East Madagascar[3]	Foulpointe	2004					45.7	
La Réunion[3]		2004					42	
Comoros[3]		2004					47	8
Mauricius[3]		2004					38	4
Mauricius[9]		2005	101				~ 40	
Tanzania[7]		2002					26.1 (37.9-16.3)	20.7
Mozambicus[7]		2002					35.4 (65-7)	
Kenya[8]	Kisite(P)	2004				47.4**	32.5	40.5

P : Protected sites, NP : non-protected sites. * a list of 150 fish was used for the sampling ** : 8 indicator families used (Acanthuridae, Balistidae, Chaetodontidae, Labridae, Pomacanthidae, Pomacentridae, Scaridae)

Planktivores individuals were the most numerous among all the sites of the Ankilibe Bay despite their low number of species. This result can be explain by the fact that planktivores often aggregate in large schools close to the reef to feed on the plankton carried by the current (Hobson 1991). This is probably why the number of planktivores was the highest at Barrier South, which is located close the South Pass where currents are strong and may carry a lot of plankton. On the other sites, the percentage of planktivores was similar to those found in La Réunion (Ahamada *et al.* 2002) or in Andavadoaka (Nadon *et al.* 2007).

Few invertebrates different species were observed during our study in the Bay of Ankilibe. The density of the herbivorous urchin *Echinothrix diadema* was greatly higher than any other invertebrates. This higher density may be due to the high algae cover found on all the sites. Another factor that may have affect *E. Diadema* density was the total absence of its main predator, the triggerfish *Balistapus undulatus* (Balistidae) (McClanahan *et al.*, 2005). This high number may also be due to the fact that this species is not very valuable for fishermen in the region compared with *Tripneuste gratilla* that is more consumed by restaurants and which was never observed along the transects. None of the other species of urchin that were found in Andavadoaka (*Nadon et al.*, 2007) was either observed during this study. In addition, none of the indicator species of Holothuridae (Appendix 5) was recorded. These results may give arguments in favour of a very high fishing pressure that occurs in the Ankilibe Bay even if we also can argue about the methodology used here that was maybe not perfectly adapted for an exhaustive assessment of such species.

No individual of *Acanthaster planci* was recorded during our survey while it was observed in 20 % of the sites in the North-West of Madagascar (McKenna, 2003). On the first hand, the absence of the major predator of living coral may give another clue about how low the coral cover is among the sites. On the other hand, the lack of such a threat may be beneficial for coral to recover.

Potential sites for the creation of a Marine Protected Area

Nosivelometahy

Nosivelometahy, like all the studied sites, consisted of a high cover of coral rubble. However, there were some extensive patches of living coral and this site is from far, in the best ecological health of all the sites in regard with its living coral and coraline algae cover as well as its low cover in algae. Beside the lowest fish density observed at Nosivelometahy, this site showed a good diversity in term of fish families and species, with an important community of herbivores which may have a positive impact on living coral extension.

Nosivelometahy is a shallow site well adapted for diving and snorkelling activities and, despite its location close the south pass, it does not show strong currents in virtue of the protection of the Nosy Tafara islet from the South-West swell.

In conclusion, our survey defined Nosivelometahy as the best site to be protected by a Marine Protected Area in regard with its highest ecological quality and its physical environment compatible with an activity of tourism.

Dimadimatsy

The living coral cover and diversity at Dimadimatsy were low and this site was mainly constituted of rubble covered by turf algae. Its density of fish was lower than at Barrier South or Ankara (see discussion above), but its fish diversity was the highest.

The socio-economic study performed in 2008 in the village of Ankilibe showed that Dimadimatsy was one of the most fished sites within the Bay, with a daily fishing activity that represents 11.5 % of the total (WWF, unpublished). However, our survey showed that few species of commercial interest were present, and those found were of small size. This could mean that Dimadimatsy biological population is under a strong stress and may become even worse in the future if it is not protected. This would be the interest to protect this site more than a touristic importance.

Barrier South

The living coral community at Barrier South was one of the lowest, but one of the best in term of diversity. This was mainly due to the presence of big "bummies" among the sandy bottom, at the base of the inner slope. Each of these rocky structures was well covered by coral which offered good refuges for fish and invertebrates. Thus, despite the fact that our surveys showed a biological community in poor condition - mainly due to the inner slope of the barrier system that was strongly degradated, - Barrier South presents a real ecological interest.

However, this site is one of the hardest to dive, because its location close the South Pass creates strong currents which, coupled with waves that break close, often induce a poor underwater visibility not very well adapted for diving activities.

Ankara

Ankara was one of the most degradated sites with a low carbonate organisms cover, a high rubble percentage and an important algae community. Despite a high density of fish discussed above, its species and families diversity is the lowest.

Ankara presents few interests for the purpose of the creation of a Marine Protected Area.

CONCLUSIONS

The studied sites were in poor ecological condition and seem to be under high stresses that led to a diminution of their benthic and fish communities. Fine particules covered very often the substrat and the benthos which may indicate a high sedimentation rate in the Bay. Indeed, mangroves were very patchy along the coast of the Bay and may be an explanation to a high amount of land particles drained by the rain and small streams. The Bay is under a strong fishing pressure because of the big city of Toliara in the North. We can assume that this high fishing pressure has a strong effect on the coral reefs degradation because of the use of destructive techniques (e.g. use of metal bares to remove coral blocks and find octopus hidden below, use of small mesh nets non-selective in regard with the animals caught).

This technical assessment of the ecological community of the Ankilibe Bay performed by Reef Doctor responds to one of the objectives of the *Toliara Land and Seascape*

C*onservation Program* proposed by WWF for the *Lower Onilahy River Valley and Delta.*The purpose of this work was to give technical advices about the interest for the future MPA of the sites proposed by the villagers of the Bay during preliminary meetings, in a participatory action required by the program.

A Marine Protected Area is created to protect coral ecosystems and marine resources associated to it. It also proposes an alternative money income for the local populations with the development of eco-tourism and the creation of new jobs like boat divers, guides or hotels and restaurants works. The MPA is also a good tool to control the development of this tourism that could become destructive for the environment if too intensive. The MPA "Massif des Roses" created in June 2007 by the association FI.MI.HA.RA and the NGO Reef Doctor in the Bay of Ranobe is a real success that permitted the creation of many new jobs and an income of several millions MGA with the tourism activity of more than one year. This success led to the creation of three new MPA the 1st of December 2008 decided by the local populations themselves. It is now important that the Bay of Toliara-Ankilibe possesses its first MPA to increase an eco-tourism activity still poorly developed and to show the local population the very positive impact of such structures.

Another alternative activity to the traditional fishery done by the *Vezo* populations of the South-West of Madagascar may be the farming of sea-cucumbers. This activity is already well developed in Andavadoaka by the NGO Blue Ventures. This activity does not require large money investments either a strong knowledge, and may provide great incomes to the local populations while reducing the fishing pressure on the Bay.

Finally, a reduction of the human impact on the Bay may be the creation of Fish Aggregation Devices (FAD). Those floating structures are set-up several miles outside the lagoon and aim to attract fish providing shelter and food from algae and invertebrates fixed on. This solution could lead the fishermen to go and fish outside the Bay, in areas open to the ocean where fish population recovering is higher. Nevertheless, this solution can only be efficient if it is coupled with a program of help for the fishermen, providing them technical formation and modern equipments. It is however important that the side effects of such a new fishing activity is well controlled to not negatively affect the ecosystems.

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APPENDIX

Appendix 1. Sites and samples parameters.

Site et GPS coordonates	Reef Type	Average depth (m)	Replicats		
			Index	**Direction**	**Zone of the site**
South Barrier North: S23°29.470’ E043°41.063’ South: S23°29.995’ E043°41.545’	Inner slope of Outer Reef (Barrier)	8	1	N	South
			2	NE	Middle
			3	N	Middle
			4	NW	North
Dimadimatsy NW corner of Channel: S23°28.698’ E043°43.425’ SW corner of Channel: S23°28.961’ E043°43.529’	Inner Reef	6.5	1	W	North slope
			2	N	North slope
			3	W	South slope
			4	N	South slope
Nosivelometahy North: S23°29.961’ E043°43.411’ South: S23°30.326’ E043°43.421’ East: S23°30.088’ E043°43.538’ West: S23°30.238’ E043°43.338’	Inner Reef	6	1	E	Middle
			2	W	Middle
			3	N	NW slope
			4	S	NW slope
Ankara North: S23°27.733’ E043°.426’ South: S23°28.698’ E043°43.425’	Inner Reef	5.5	1	N	W slope
			2	E	NW slope
			3	SW	NE slope
			4	SW	Middle

Appendix 2. List of all the families and species recorded among all the sites.

	Genus and species
	1. ACANTHURIDAE
1	*Acanthurus blochii*
2	*Acanthurus nigrofuscus*
3	*Acanthurus thompsoni*
4	*Acanthurus triostegus*
5	*Ctenochaetus binotatus*
6	*Ctenochaetus striatus*
7	*Zebrasoma desjardinii*
8	*Zebrasoma scopas*
9	*Zebrasoma veliferum*
	2. APOGONIDAE
10	*Apogon cookii*
11	*Apogon cyanosoma*
12	*Apogon kiensis*
13	*APOGONIDAE spp.*
14	*APOGONIDAE spp. juvenile*
15	*Archamia fucata*
16	*Cheilodipterus artus*
17	*Cheilodipterus quinquelineatus*
	3. AULOSTOMIDAE
18	*Aulostomus chinensis*
	4. BLENNIDAE
19	*BLENIIDAE spp.*
20	*Meiacanthus mossambicus*
21	*Meiacanthus spp.*
22	*Plagiotremus rhinorhynchus*
23	*Plagiotremus tapeinosoma*
	5. CAESIONIDAE
24	*Caesio lunaris*
25	*Caesio spp,*
26	*Caesio xanthonota*
27	*Pterocaesio chrysozona*
	6. CENTRISCIDAE
28	*Aeoliscus punctulatus*
29	*Aeoliscus strigatus*
	7. CHAETODONTIDAE
30	*Chaetodon auriga*
31	*Chaetodon blackburni*
32	*Chaetodon falcula*
33	*Chaetodon guttatissimus*
34	*Chaetodon lineatus*
35	*Chaetodon lunula*
36	*Chaetodon madagascariensis*
37	*Chaetodon spp.*
38	*Chaetodon trifascialis*
39	*Chaetodon trifasciatus*
40	*Chaetodon vagabundus*
41	*Heniochus acuminatus*
42	*Heniochus diphreutes*
43	*Heniochus monoceros*
	8. CIRRHITIDAE
44	*Cirrhitichthys oxycephalus*
45	*Paracirrhites forsteri*
	9. DASYATIDAE
46	*Taeniura lymma*
	10. GOBIIDAE
47	*Amblyeleotris spp.*
48	*Amblyeleotris spp.*
49	*GOBIIDAE spp.*
50	*Istigobius decoratus*
	11. HAEMULIDAE
51	*Plectorhinchus flavomaculatus*
52	*Plectorhinchus orientalis*
	12. HOLOCENTRIDAE
53	*Myripristis berndti*
54	*Myripristis murdjan*
55	*Neoniphon sammara*
56	*Sargocentron caudimaculatum*
57	*Sargocentron diadema*
58	*Sargocentron seychellense*
59	*Sargocentron spp,*
	13. LABRIDAE
60	*Anampses lineatus*
61	*Anampses twistii*
62	*Bodianus axillaris*
63	*Bodianus diana*
64	*Bodianus opercularis*
65	*Bodianus spp.*
66	*Cheilinus chlorourus*
67	*Gomphosus caeruleus*
68	*Halichoeres hortulanus*
69	*Halichoeres marginatus*
70	*Halichoeres scapularis*
71	*Halichoeres spp.*
72	*Hemigymnus fasciatus*
73	*Hemigymnus melapterus*
74	*Labrichthys unilineatus*
75	*LABRIDAE spp.*
76	*Labridae spp.*
77	*Labridae spp.*
78	*Labridae spp.*
79	*Labridae spp.*
80	*Labridae spp.*
81	*Labroides bicolor*
82	*Labroides dimidiatus*

83	*Macropharyngodon bipartitus*
84	*Oxycheilinus sp.*
85	*Pseudocheilinus evanidus*
86	*Pseudocheilinus hexataenia*
87	*Pseudocheilinus octotaenia*
88	*Pseudocoris yamashiroi*
89	*Stethojulis albovittata*
90	*Stethojulis interrupta*
91	*Stethojulis spp.*
92	*Stethojulis strigiventer*
93	*Thalassoma hardwicke*
94	*Thalassoma hebraicum*
95	*Thalassoma lunare*
96	*Thalassoma lutescens*
97	*Thalassoma sp.*
98	*Thalassoma trilobatum*
	14. LETHRINIDAE
99	*LETHRINIDAE sp.*
	15. LUTJANIDAE
100	*Lutjanus ehrenbergi*
101	*Macolor niger*
	16. MICRODESMIDAE
102	*Ptereleotris evides*
	17. MONACANTHIDAE
103	*Pervagor janthinosoma*
	18. MULLIDAE
104	*Parupeneus barberinus*
105	*Parupeneus macronema*
106	*Parupeneus rubescens*
	19. MURAENIDAE
107	*Gymnothorax javanicus*
	20. NEMIPTERIDAE
108	*Scolopsis ghanam*
	21. OSTRACIIDAE
109	*Ostracion cubicus*
	22. PEMPHERIDAE
110	*Pempheris schwenkii*
	23. PINGUIPEDIDAE
111	*Parapercis hexophtalma*
	24. PLOTOSIDAE
112	*Plotosus lineatus*
	25. POMACANTHIDAE
113	*Centropyge multispinis*
114	*Pomacanthus semicirculatus*
	26. POMACENTRIDAE
115	*Abudefduf sexfasciatus*
116	*Abudefduf spparoides*
117	*Abudefduf vaigiensis*
118	*Amblyglyphidodon leucogaster*
119	*Amphiprion akallopisos*
120	*Amphiprion latifasciatus*
121	*Amphiprion latifasciatus*
122	*Chromis agilis*
123	*Chromis atripectoralis*
124	*Chromis dimidiata*
125	*Chromis lepidolepis*
126	*Chromis opercularis*
127	*Chromis ternatensis*
128	*Chromis weberi*
129	*Chrysiptera biocellata*
130	*Chrysiptera glauca*
131	*Chrysiptera leucopoma*
132	*Chrysiptera leucopoma*
133	*Dascyllus aruanus*
134	*Dascyllus trimaculatus*
135	*Neopomacentrus azysron*
136	*Plectroglyphidodon lacrymatus*
137	*POMACENTRIDAE spp.*
138	*Pomacentrus baenschi*
139	*Pomacentrus caeruleus*
140	*Pomacentrus indicus*
141	*Pomacentrus pavo*
142	*Pomacentrus sulfureus*
143	*Pomacentrus trichrous*
144	*Pomacentrus trilineatus*
145	*Stegastes nigricans*
	27. SCARIDAE
146	*Chlorurus capistratoides*
147	*Chlorurus sordidus*
148	*Chlorurus viridifucatus*
149	*Scarus caudofasciatus*
150	*Scarus ghobban*
151	*Scarus rubroviolaceus*
152	*Scarus spp.*
	28. SCORPAENIDAE
153	*Pterois antennata*
154	*Pterois miles/volitans*
155	*Scorpaenopsis oxycephala*
	29. SERRANIDAE
156	*Epinephelus merra*
157	*Epinephelus rivulatus*
158	*Epinephelus spp.*
159	*Pseudanthias squamipinnis*
	30. SIGANIDAE
160	*Siganus luridus*
	31. SYNGNATHIDAE
161	*Corythoichthys intestinalis*
	32. SYNODONTIDAE
162	*Saurida gracilis*
163	*Synodus jaculum*

164	*Synodus spp.*
	33. TETRAODONTIDAE
165	*Arothron nigropunctatus*
166	*Canthigaster solandri*
167	*Canthigaster tyleri*
168	*Canthigaster valentini*

	34. TORPEDINIDAE
169	*Hypnos monopterygium*
	35. ZANCLIDAE
170	*Zanclus cornutus*

Appendix 3. Species most fished in Ankilibe (data from a socio-economic survey done between November and December 2007 in the village of Ankilibe. Source WWF, unpublished). The species in bold are those recorded for the present study.

Family	Genus	Species	Common name
Acanthuridae	***Acanthurus***	***triostegus***	**Andrarame**
Acanthuridae	*Naso*	*unicornis*	Fiantsifa
Acanthuridae	*Surgeonfish*	*sp.*	Angy
Apogonodae	*Cheilodipterus*	*sp.*	Bemaso
Ballistidae	*Balistoides*	*viridescens*	Votsanja
Carangidae	*Caranx*	*sp.*	Lanora
Clupeidae	*Herklotsichtys*	*quadrimaculatus*	Geba
Dasyatidae	***Taeniura***	***lymna***	**Fay foty**
Gerreidae	*Gerres*	*cinereus*	Ambariake
Haemulidae	***Plectorhinchus***	***flavomaculatus***	**Tsimareny**
Haemulidae	*Plectorhinchus*	*sp.*	Angarera
Kyphosidae	*Kyphosus*	*sp.*	Kifalaotse
Labridae	*Cheilinus*	*trilobatus*	Fiambonjo
Labridae	*Novaculichthys*	*taeniourus*	Lemeleme
Lethrinidae	*Lethrinus*	*harak*	Anakantsisy
Lethrinidae	*Lethrinus*	*lentjan*	Tsabeaky
Lethrinidae	*Lethrinus*	*nebulosus*	Ambitsy
Lethrinidae	*Monotaxis*	*grandoculis*	Ongike
Lutjanidae	*Lutjanus*	*gibbus*	Salabaro
Lutjanidae	*Lutjanus*	*rivulatus*	Voitso
Lutjanidae	*Lutjanus*	*sp.*	Amporama
Mullidae	*Mulloidichtys*	*sp.*	Tsoy
Mullidae	*Mulloidichtys*	*vanicolensis*	Fiantsomotse
Ostracidae	*Arothron*	*mappa*	Botana
Platycephalidae	*Papilloculiceps*	*longiceps*	Tohompase
Plotosidae	***Plotosus***	***lineatus***	**Gogo**
Rhinobatidae	*Rhynchobatus*	*djiddensis*	Soroboa
Scaridae	***Chlorurus***	***viridifucatus***	**Bodoloha**
Scaridae	*Leptoscarus*	*vaigiensis*	Moloto
Scombridae	*Scombridae*	*sp.*	Lamatra
Serranidae	*Epinephelus*	*fasciatus*	Lovo
Siganidae	***Siganus***	***sp.***	**Amboramasake**
Sphyraenidae	*Sphyraena*	*acutipinnis*	Mandreandovoke
Sphyraenidae	*Sphyraena*	*barracuda*	Aloalo
Synodontidae	***Synodus***	***sp.***	**Volomboto**

Appendix 4. Type of benthos recorded and their corresponding code.

Code	Benthos type
SUBSTRATE	
RC	Rock
RB	Rubble
SD	Sand
SI	Silt
DC	Dead Coral
LIVING CORAL	
ACB	Acropora Branching
ACD	Acropora Digitate
ACE	Acropora Encrusting
ACS	Acropora Submassive
ACT	Acropora Tabulate
CB	Non-Acropora Branching
CD	Non-Acropora Digitated
CE	Non-Acropora Encrusting
CF	Non-Acropora Foliaceous
M	Non-Acropora Massive
CS	Non-Acropora Submassiv
CMR	Non-Acropora Mushroom
CHL	Heliopora
CME	Millepora
CTU	Tubipora
SC	Soft Coral
OVERGROWING BENTHOS	
TA	Turf Algae
FMA	Fleshy Macroalgae
HMA	Hard Macroalgae
CA	Coraline Algae
OT	Other (Hydroids, Anemones, Tunicates, Corallimorphs, Bryozoans, Sponge, Zoanthids)

Appendix 5. Mean individuals ± SE of invertebrates of economical interest for the Ifaty zone (data Reef Doctor) used as indicator for Ankilibe Bay.

FAMILY SPECIES	Barrier South	Dimadi-matsy	Nosivelo-metahy	Ankaran-dava	Total individuals	Density per 50 m²
PANULIRIDAE						
Panulirus longipes	0	0	0	0	0	0 (0)
Panulirus versicolor	0	0	0	0	0	0 (0)
STENOPODIDAE						
Stenopus hispidus	0	0	2	0	2	0.1 (0.1)
RANELLIDAE						
Charonia tritonis	0	0	0	0	0	0 (0)
TRIDACNIDAE						
Tridacna maxima	0	0	0	0	0	0 (0)
Tridacna squamosa	0	0	1	0	1	0.1 (0.1)
CIDARIDAE						
Echinothrix diadema	30	67	54	8	159	16.2 (6.4)
ACANTHASTERIDAE						
Acanthaster planci	0	0	0	0	0	0 (0)
TOXOPNEUSTIDAE						
Tripneustes gratilla	0	0	0	0	0	0 (0)
ECHINOMETRIDAE						
Echinometra gratiosa	0	0	0	0	0	0 (0)
DIADEMATIDAE						
Diadema setosum	2	4	0	0	6	0.7 (0.5)
Diadema savignyi	2	5	0	0	7	0.8 (0.6)
HOLOTHURIIDAE						
Holothuria nobilis	2	0	0	0	2	0.2 (0.2)
Holothuria scabra	0	0	0	0	0	0 (0)
Holothuria edulis	1	0	0	2	3	0.3 (0.2)

Appendix 6. Mean cover (%) ± SE of the substrate and the benthos.

Type of Benthos	Barrier South	Dimadimatsy	Nosivelometahy	Ankara	Total mean
Sample size (N)	4	4	4	4	16
Living coral	**8.5 (3.6)**	**12.2 (4.4)**	**22.9 (14.2)**	**8 (1.6)**	**12.9 (5.7)**
Acropora Branching	0 (0)	3.4 (2)	7.3 (10.4)	2.5 (2.2)	4.5 (0.6)
Acropora Digitate	2.7 (1.4)	5.2 (2.9)	0 (0)	2.5 (2.2)	2 (0.7)
Non-Acropora Branching	5.4 (9.5)	0 (0)	0.9 (2.8)	5 (6.1)	2 (3.1)
Non-Acropora Digitated	5.4 (2.8)	0 (0)	1.8 (1.7)	10 (8.9)	3.3 (1)
Non-Acropora Encrusting	43.2 (22.2)	29.3 (16)	7.3 (7.7)	42.5 (7.7)	23.7 (7.6)
Non-Acropora Foliaceous	0 (0)	0 (0)	0.9 (1.9)	0 (0)	0.4 (0)
Non-Acropora Massive	37.8 (18.1)	44.8 (12.6)	22.7 (14.3)	12.5 (1.6)	28.6 (6.7)
Millepora	0 (0)	0 (0)	0 (0)	2.5 (3)	0.4 (0.9)
Non-Acropora Mushroom	0 (0)	6.9 (5.8)	10.9 (5.8)	5 (2.8)	7.3 (2.9)
Non-Acropora Submassive	5.4 (5.2)	0 (0)	48.2 (22.8)	0 (0)	22.4 (8.9)
Soft Coral	0 (0)	10.3 (6.1)	0 (0)	17.5 (16.7)	5.3 (5)
Dead coral	**0.5 (0.2)**	**2.1 (1.5)**	**1 (1.1)**	**1.2 (0.9)**	**1.2 (0.6)**
Coraline algae	**6.6 (3.7)**	**0.5 (0.4)**	**17.1 (5.7)**	**3.4 (1.1)**	**6.9 (1)**
Algae	**30.2 (7)**	**39.5 (5.4)**	**16.9 (4.6)**	**34.7 (1.5)**	**30.3 (4.8)**
Fixed invertebrates	**1.8 (0.5)**	**2.6 (2.9)**	**2.1 (1.6)**	**1.5 (0.6)**	**2 (0.9)**
Rubble	**33.2 (10.1)**	**36.7 (6.6)**	**34.6 (8.9)**	**35.4 (3.3)**	**35 (5)**
Sand	**8.2 (5.7)**	**0.9 (0.6)**	**5.4 (1.5)**	**7 (1.6)**	**5.4 (0.9)**
Rock	**11 (10.3)**	**4 (4.4)**	**0 (0)**	**7 (1.2)**	**5.5 (2.8)**

Appendix 7. Name of the fish families recorded.

	ANKARA	BARRIER SOUTH	DIDMADIMATSY	NOSIVELO METAHY
1	ACANTHURIDAE	ACANTHURIDAE	ACANTHURIDAE	ACANTHURIDAE
2	APOGONIDAE	APOGONIDAE	APOGONIDAE	APOGONIDAE
3	BLENNIDAE	AULOSTOMIDAE	BLENNIDAE	AULOSTOMIDAE
4	CAESIONIDAE	BLENNIDAE	CAESIONIDAE	CHAETODONTIDAE
5	CENTRISCIDAE	CAESIONIDAE	CENTRISCIDAE	CIRRHITIDAE
6	CHAETODONTIDAE	CHAETODONTIDAE	CHAETODONTIDAE	DASYATIDAE
7	CIRRHITIDAE	CIRRHITIDAE	CIRRHITIDAE	GOBIIDAE
8	GOBIIDAE	GOBIIDAE	GOBIIDAE	HOLOCENTRIDAE
9	HOLOCENTRIDAE	HOLOCENTRIDAE	HAEMULIDAE	LABRIDAE
10	LABRIDAE	LABRIDAE	HOLOCENTRIDAE	LUTJANIDAE
11	LUTJANIDAE	LETHRINIDAE	LABRIDAE	MULLIDAE
12	MICRODESMIDAE	MONACANTHIDAE	LUTJANIDAE	MURAENIDAE
13	OSTRACIIDAE	MULLIDAE	MULLIDAE	OSTRACIIDAE
14	PEMPHERIDAE	NEMIPTERIDAE	NEMIPTERIDAE	PINGUIPEDIDAE
15	PINGUIPEDIDAE	PEMPHERIDAE	OSTRACIIDAE	PLOTOSIDAE
16	POMACANTHIDAE	PINGUIPEDIDAE	PEMPHERIDAE	POMACANTHIDAE
17	POMACENTRIDAE	PLOTOSIDAE	PINGUIPEDIDAE	POMACENTRIDAE
18	SCARIDAE	POMACANTHIDAE	PLOTOSIDAE	SCARIDAE
19	SCORPAENIDAE	POMACENTRIDAE	POMACANTHIDAE	SCORPAENIDAE
20	SYNGNATHIDAE	SCARIDAE	POMACENTRIDAE	SERRANIDAE
21	SYNODONTIDAE	SCORPAENIDAE	SCARIDAE	SIGANIDAE
22	TETRAODONTIDAE	SERRANIDAE	SERRANIDAE	SYNGNATHIDAE
23	ZANCLIDAE	SYNGNATHIDAE	TETRAODONTIDAE	SYNODONTIDAE
24		SYNODONTIDAE	ZANCLIDAE	TETRAODONTIDAE
25		TETRAODONTIDAE		TORPEDINIDAE
26		TORPEDINIDAE		ZANCLIDAE
27		ZANCLIDAE		

Appendix 8. The 20 families of fishes with the highest number total of individuals in and on average per transect (± SE). The dominant species are sorted from the left to the right in a decreasing order by their number of individuals per transect.

Families	Total of Individuals	Mean	Dominant species
POMACENTRIDAE	1432	95.5 (21.5)	*Chromis dimidiata, Plectroglyphidodon lacrymatus, Dascyllus trimaculatus, Chromis ternatensis, Chromis weberi*
LABRIDAE	388	25.9 (6.1)	*Labroides dimidiatus, Thalassoma Hardwicke, Anampses twistii*
APOGONIDAE	369	24.6 (11.3)	*APOGONIDAE sp., Archamia fucata, Apogon cyanosoma*
CAESIONIDAE	320	21.3 (15.9)	*Caesio sp., Pterocaesio chrysozona*
PEMPHERIDAE	207	13.8 (11.9)	*Pempheris schwenkii,*
TETRAODONTIDAE	176	11.7 (2)	*Canthigaster solandri, Canthigaster valentini*
SCARIDAE	154	10.3 (4.6)	*Chlorurus sordidus, Scarus sp.*
CHAETODONTIDAE	149	9.9 (1.2)	*Chaetodon trifasciatus,*
PLOTOSIDAE	136	9.1 (5.8)	*Plotosus lineatus*
ACANTHURIDAE	111	7.4 (1.3)	*Zebrasoma scopas, Ctenochaetus striatus*
CENTRISCIDAE	60	4 (2.5)	*Aeoliscus strigatus*
HOLOCENTRIDAE	47	3.1 (2.3)	*Sargocentron seychellense*
POMACANTHIDAE	25	1.7 (0.5)	*Centropyge multispinis, Pomacanthus semicirculatus*
BLENNIDAE	24	1.6 (0.5)	*Meiacanthus mossambicus, Plagiotremus rhinorhynchus*
ZANCLIDAE	23	1.5 (0.4)	*Zanclus cornutus*
GOBIIDAE	18	1.2 (0.7)	*GOBIIDAE sp., Istigobius decoratus*
LUTJANIDAE	18	1.2 (0.9)	*Lutjanus ehrenbergi, Macolor niger*
MULLIDAE	14	0.9 (0.4)	*Parupeneus rubescens, Parupeneus macronema*
SYNGNATHIDAE	14	0.9 (0.6)	*Corythoichthys intestinalis*
SERRANIDAE	11	0.7 (0.5)	*Pseudanthias squamipinnis, Epinephelus spp.*

Appendix 9. Descriptive statistics used for the analyse of the fish diversity (± SE).

	Ankara	Barrier South	Dimadimatsy	Nosivelometahy	TOTAL
Sample size (N)	4	4	4	4	16
Total of individuals	1324	1590	595	550	4059
Density (mean individuals per 50 m²)	441.3 (157.2)	397.5 (122.2)	148.8 (37.4)	137.5 (18.7)	270.6 (54.8)
Total species	71	89	99	85	170
Mean species	38 (8.1)	43.8 (5)	29.3 (3.3)	30.5 (3.6)	35.4 (3.4)
Total of families	23	28	24	26	36
Mean familles	15.7 (4.4)	15.5 (4)	12.5 (3.3)	13.3 (3.5)	14.1 (1)

Appendix 10. Descriptive statistics used for the analyses of the fish trophic levels. The numbers are the mean (± SE).

	Ankara	Barrier South	Dimadimatsy	Nosivelometahy	TOTAL
Sample size	4	4	4	4	16
Average number of species					
Herbivores	13.9 (1)	13.3 (0.6)	14.8 (0.9)	20.3 (1.4)	15.6 (1)
Carnivores	36.5 (1.8)	40.1 (0.9)	32.3 (1.6)	35 (2.3)	36 (1.6)
Omnivores	21.2 (0.6)	20.8 (0.4)	29.5 (0.7)	24.2 (1.1)	23.9 (0.7)
Planktivores	23.4 (1.8)	25.2 (0.5)	19.2 (1.8)	16.4 (0.4)	21 (1.1)
Coralivores	5 (0.3)	0.6 (0.1)	4.2 (0)	4.1 (0)	3.5 (0.1)
Average number of individuals					
Herbivores	27.7 (12.6)	36 (11.9)	41 (34)	33 (27.2)	34.4 (21.4)
Carnivores	158 (48.2)	52 (15.9)	15 (14)	28.5 (22.9)	63.4 (25.3)
Omnivores	41.3 (17.1)	35.5 (12.3)	27.8 (23.1)	19.3 (16.9)	31 (17.4)
Planktivores	58 (20.2)	231.3 (59.6)	44.5 (25.7)	21.8 (20.1)	88.9 (31.4)
Coralivores	5.3 (1.9)	0.8 (0.3)	3.5 (3.1)	13 (12.9)	5.6 (4.5)
Percentage of individuals					
Herbivores	12.6 (5.1)	11.9 (2.9)	34 (15.9)	27.2 (7.7)	21.4 (7.9)
Carnivores	48.2 (11.4)	15.9 (1.5)	14 (7.7)	22.9 (7.8)	25.3 (7.1)
Omnivores	17.1 (5.7)	12.3 (3)	23.1 (5.2)	16.9 (2.2)	17.4 (4)
Planktivores	20.2 (6.3)	59.6 (6.8)	25.7 (15.4)	20.1 (5)	31.4 (8.4)
Coralivores	1.9 (0.2)	0.3 (0.3)	3.1 (1.1)	12.9 (10.4)	4.5 (3)