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Scientifically based framework for conserving and monitoring the Eritrean coral-reefs

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Executive Summary

The objectives of this project were to develop a reef-conservation program for the Eritrean reefs. Specifically, our goals were (a) to study the community features of the corals and their recruitment, (b) to develop a monitoring system for these reefs, (c) to study the biodiversity of a variety of corals and fishes, and (d) to establish a scientific reference collection of these organisms and develop identification keys and field guides. These goals have been achieved through collaboration between the Eritrean and Israeli researchers and students in a joint research cruise to the Dahlak Archipelago, Eritrea (5-22 February 2005) using the R/V Mediterranean Explorer. The R/V set sail from Israel on its way to Eritrea. The participants from both countries used the R/V as a platform from which to conduct research on various sites, and also held an onboard "live" workshop and training activities. We found a variety of reef types at the Archipelago, ranging from rich reefs, to scarcely occupied ones with low live cover and poor diversity. We revealed three main categories of reef states: (1) reefs dominated by stony corals; (2) algal-dominated reefs; and (3) reefs rich in filter feeders, dominated by e.g., soft corals and sponges. The presence of algal "reefs" was an interesting and unique phenomenon. In order to monitor the appearance of juvenile corals, we deployed settlement plates on the reef, which need to be removed once a year for examination later in our project. Ca. 200 specimens, encompassing a variety of reef organisms, were photographed underwater and then collected including the south-eastern part of the Archipelago, which had been barely surveyed to date. The material has been deposited in Asmara University and constitutes the seed for scientific collections there. So far our activities have established a comprehensive expertise and facilities for reef research in Eritrea. This has been achieved via enhancing the skills of the Eritrean personnel and the acquisition of facilities and equipment for the marine station in Massawa. These will substantially contribute to the future abilities of the Eritreans to conduct independent reef research. The formation of digitized identification keys of the reef organisms will also facilitate reef studies there. Our activities have laid professional grounds for a continuous monitoring program of the reefs there, and for the determination of strategies for their sustainable use.

Section I: Technical Progress

From 5-22 February 2005 a joint research cruise to the Dahlak Archipelago was conducted. Sections **1** and **2** in this report provide the details of: (A) Research Objectives and Research, and (B) Accomplishments for the two respective subjects corresponding to the original proposal. This is followed by (C) Scientific Impact of Collaboration, (D) Description of Project Impact, (E) Strengthening of Developing-Country Institutions and (F) Future Work.

1. Developing a reef-conservation program for Dahlak Archipelago

A) Research Objectives:

The objectives of this part of the activity were to develop a reef-conservation program for the Eritrean reefs. Specifically, our goals were (a) to study the community features of stony corals and their recruitment on the Eritrean reefs and (b) to develop a monitoring system for the Eritrean reefs, including selection of bio-indicating and bio-monitoring species and methods for indication of ecosystem alterations. The obtained data are intended to lead to development of an applicable conservation-oriented program for the Eritrean coral reefs, which in turn will serve as a platform for Coastal Zone Management. During the cruise attention was also focused on the marine macroalgae and seagrasses of the Dahlak Archipelago in order to assess their role in occupying the reef substratum.

Methods

During this part of the project we focused our work on the north-western sites of the Dahlak Archipelago. The study sites represent different reef types (Table 1)

Table 1: The study sites

Site	Location	Dates	Structures	Transects	Comments
Dur-Ghella	15° 46.713' N 039° 47.635' E	7, 11/02/05	3 * 12 tiles (6 PVC + 6 Ceramic)	3	Shallow reef
Dar-Otun	15° 53' 32.78" N 039° 56' 42.21" E	8/02/05	-	-	"*Sargassum* Reef"
Seil-Betta	16° 00' 01.34" N 039° 55' 22.06" E	8, 10/02/05	3 * 12 tiles (6 PVC + 6 Ceramic)	3	"*Sargassum* Reef"
Isratu	16° 18' 38.28" N 039° 54' 53.08" E	9, 10/02/05	3 * 12 tiles (6 PVC + 6 Ceramic)	3	Deep reef
Nokra	15° 42' 24.21" N 039° 59' 33.65" E	11,12/02/05	-	-	Shallow reef; largest colonies

Data acquisition. Community features of stony corals were studied at three of the sites (Table 1). Data on community and population structure were obtained through a series of belt transects, using SCUBA. Transects (10 m each), placed randomly on the reefs, were run parallel to the shore and to each other. The surveyed area along each transect consisted of a 25 cm at each side of the line, thus forming a belt transect of 10 x 0.5 m. This disposition increased the probability of recording data from hard substratum. All stony coral species intercepting the belt transect were recorded and their maximal projected length was measured to the nearest cm. An individual stony coral colony was identified as any colony growing independently of its neighbors.

Recruitment. Our approach in studying coral recruitment is based on deployment of experimental settlement plates. For this purpose we have deployed 3 steel racks at the study sites (5-8 m deep). The racks were positioned among reef patches, each with 6 unglazed 10 x 10 cm ceramic tiles and 6 PVC plates. The tiles will be removed once a year for examination and replaced by new ones during successive expeditions. This procedure will allow assessment of spatial and temporal variations in the rate of coral recruitment.

Data analysis: Community and Population state. The acquired data from the reef surveys were used for monitoring the reef community state (i.e. Size Frequency Distribution, SFD; Deterioration Index, DI). The SFD is used for various purposes and in our study is used to evaluate the recruitment rate prior to the study and also to obtain information on the largest-size cohorts. The concept of DI is based on the idea that coral reef state is an outcome of constructive versus destructive processes. Therefore, the DI is calculated as the ratio between the mortality and recruitment rates of reef-building corals:

that is: $DI = \frac{DC}{TC} : \frac{SC}{TLC}$ where the recruitment rate is given by the ratio between the number of the smallest detectable living corals (up to 3 cm; SC) and the total number of all living corals (TLC), and the mortality rate is the proportion of dead colonies (DC) out of the total number of living and dead corals. The basic concept of the DI is that distinct reefs may experience different mortality and recruitment rates, and yet apparently reveal a stable state. However, when high mortality and low recruitment rates coincide at the same reef, the community is likely to be undergoing deterioration.

B) Research Accomplishments:

Community and Population state. The surveys and the preliminary quantitative censuses have indicated the presence of a variety of reef types at the Dahlak Archipelago, ranging from highly developed reefs possessing high live cover and species richness, to scarcely occupied ones with low live cover and poor species richness. Our observations suggest poor recruitment at the latter sites as could be inferred from the relatively low frequency of juvenile corals (Figs. 2, 3). Likewise, most of the observed reefs demonstrated relatively small coral colony sizes, as indicated by the skewed histograms to the small-size groups and the very small size of the largest corals.

The presence of algal "*Sargassum* reefs" (see ahead) was an interesting phenomenon, which we observed e.g. in the vicinity of Eucus, Dalcus and Duliacus (Table 1). These reefs are characterized by smaller coral colony sizes, relatively poor recruitment and very high cover of brown macro-algae, notably *Sargassum* sp. and *Turbinaria* sp.

The low DI values for the examined sites (Dur Ghella - 0.24, Seil-Betta – 0.78, and Isratu - 0.44) are due to the presence of a few dead coral colonies, which appeared in the transect.

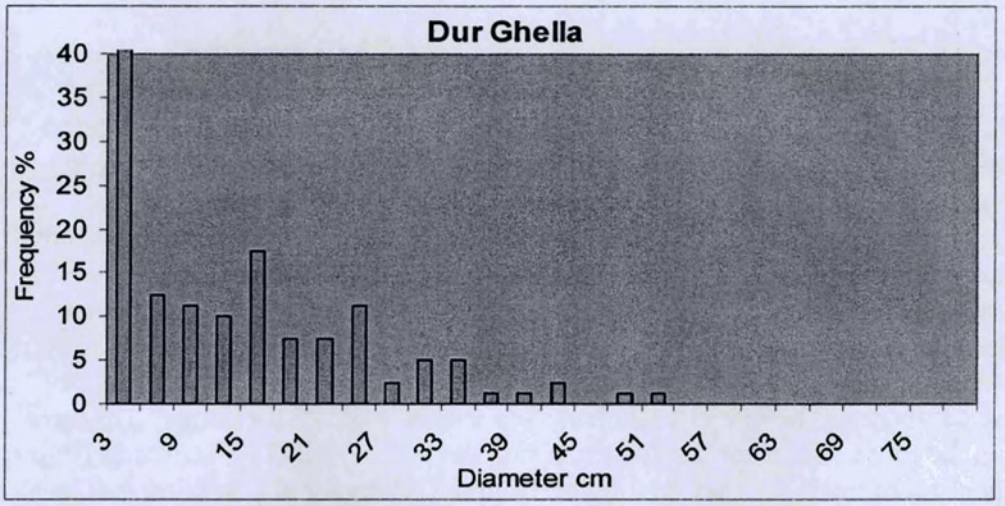

Fig. 1: SFD of branching stony corals in Dur Ghella

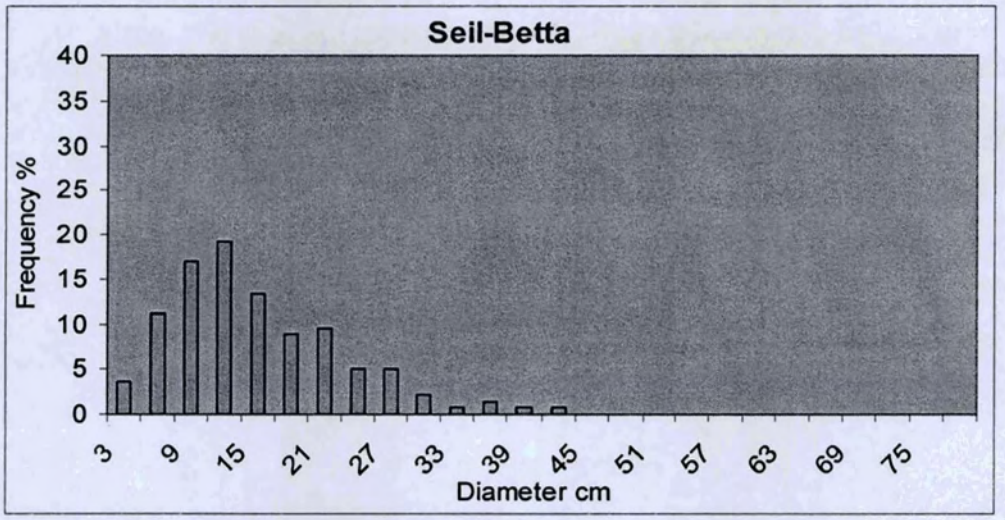

Fig. 2: SFD of branching stony corals in Seil-Betta

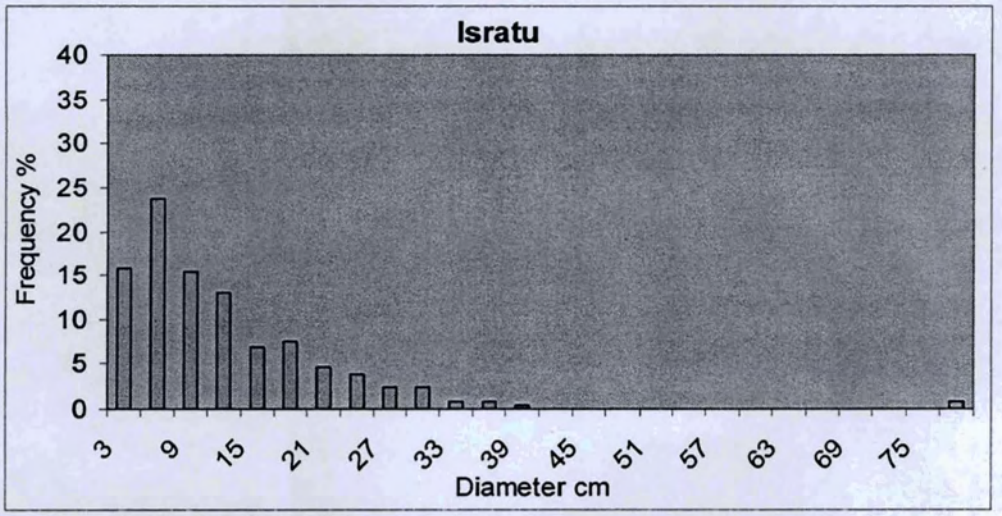

Fig. 3: SFD of branching stony corals in Isratu

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Our cruise was dedicated mainly to a qualitative survey of the Dahlak Archipelago reefs. Likewise, we conducted belt transects for acquisition of quantitative data on population and community indices of reef-building corals, notably SFD and DI, and on establishing a monitoring system for coral recruitment. This revealed three main categories of reef states on the north-western part of the Dahlak Archipelago: (1) reefs dominated by stony corals, which are the mainframe reef-builders; (2) algal-dominated reefs; and (3) reefs rich with filter feeders, scarcely occupied by stony corals, but dominated by soft corals, sponges and tunicates. Among the latter reefs we observed different levels of live cover, but none of the reefs have high live coral cover, or large coral colonies. The relatively low cover of corals might be due to a relatively low survival rate of the corals. This gets support from the low average coral colony size, and the lack of truly large colonies (Figs. 1-3). The poor recruitment, as may be inferred from the relatively low frequency of small corals, and the relatively small sizes of the largest ones, may be indicative of environmental conditions that reduce their survivorship and may inhibit their growth. The flourishing algae on the "*Sargassum* reefs" may suggest a phase shift from coral-dominated reefs to algal-dominated ones. Such a phenomenon has been previously described for several geographic regions, but not tod ate in the Red-Sea. The potential governing factors responsible for this phase shift in the Dahlak Archipelago remain for future studies.

Macroalgae. The major part of the macroalgae present in the Dahlak Archipelago was constituted by Phaeophyta (brown algae). The massive genera *Sargassum* and *Turbinaria* and the smaller genus *Padina* were especially abundant. Also present were the green algae *Ulva* and *Caulerpa*, and several smaller genera of red algae. Most striking was the presence of *Sargassum* and *Turbinaria* around the islands. We often observed a fringing reef like- structure from the R/V, but upon closer examination this frequently turned out to be a belt of benthic, strongly anchored, *Sargassum* and *Turbinaria* fronds. These algae were often up to 2 meters long, and growing in dense stands resembling kelp forests.

Fig. 1 *Sargassum* fronds of up to 2 m length form an underwater "forest"

While diving within these algal "forests" many fish were observed. It thus seems that these algae are important breeding grounds for fish and/or provide shelter for fish fry. No fish were seen foraging on the algae, and it is thus not known to what degree these algae are a nutritional source. The surprising presence of these unusually large brown algae indicates their importance in the ecosystems surrounding many of the archipelago's islands.

Seagrasses. Seagrasses (marine angiosperms) were surprisingly sparse throughout. The presence of algal "*Sargassum* reefs" (see ahead) was an interesting phenomenon, which we observed e.g. in the vicinity of Eucus, Dalcus and Duliacus (Table 1). These reefs are characterized by smaller coral colony sizes, relatively poor recruitment and very high cover of brown macro-algae, notably *Sargassum* sp. and *Turbinaria* sp.
Dahlak Archipelago. The only seagrass species encountered was *Thalassia testudinum*. This rather robust species grew at 3-10 m depth on soft, rather sandy bottoms between the islands, especially in the southern part of the archipelago.

In conclusion, the density of very large brown algae surrounding many islands and the sparseness of seagrasses were surprising and did not fit earlier reports. Undoubtedly, further research is needed in order to evaluate their ecological importance.

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2. Biodiversity and community structure features

A) Research Objectives:

The goals of this part of the joint project were (1) to study the biodiversity of benthic organisms (stony and soft corals) and fishes and their community features on the Eritrean reefs and (2) to establish a scientific reference collection of the reef organisms and to develop identification keys and underwater field guides.

Methods

Biodiversty studies. Collection of benthic organisms was conducted during the cruise at 7 sites, including the outer reefs of the Dahlak Archipelago located in the south-easten part of the region, which have been barely surveyed in the past. The reef sites were reached by rubber boat launched from the R/V Mediterranean Explorer. Collections were made on lagoon and fringing reefs down to 12 m, and careful examination of a variety of niches at the different sites was carried out by SCUBA diving. Underwater abundance estimates of the genera were made visually and divided into 4 categories: rare, sporadic, abundant and dominant. Data concerning the habitat of collection of the different taxa were recorded and included depth, reef type (lagoon *vs.* reef slope), bottom type (hard *vs.* soft substratum) and its orientation (horizontal *vs.* vertical). Prior to collection most of the colonies were photographed *in situ.* Samples of benthic organisms were fixed in 70% ethyl alcohol and sub-samples were removed for future molecular (DNA) analysis and preserved in 100% ETHOH or DMSO. All samples were immediately labeled and divided on board into two parts to be deposited in Asmara and Tel Aviv University respectively.

The following sites were surveyed:

1. Southern entrance to the channel between Nocra and Dahlak N 154136, E 0395608
2. Southern entrance to the channel between Nocra and Dahlak N 154160, E 0395640
3. Nokra Deset N 15 42 50, E 039 57 50
4. Shuma N 15 32 50, E 040 00 00
5. Museri N 15 28 50 E 040 21 00
6. Hatitau N 15 34 00, E 040 42 50
7. Green Island N 15 35 34, E 039 29 05

Community structure. Data on the benthic communities at each site were obtained through aby series of 10 m line transects. For this purpose we randomly selected the sites on the Dahlak Archipelago in areas characterized by hard substratum and reasonable coral coverage. This approach was adopted to avoid selection of sites with bare rocks and/or sandy or muddy bottoms. The transects were placed randomly on the reefs running parallel to the shore and to each other at fixed intervals of 2-3 m depth, with 2-3 replicates at each depth as dictated by the reef structure. The surveyed area along the transects consisted of a 5 cm belt at each side of the line, thus forming a belt transect of 10 x 0.1 m (referred to below as "line transect"). This disposition increases the probability of recording data from hard substratum. All stony and soft corals, sponges and tunicates intercepting the line transect were recorded and their maximal projected length was measured to the nearest cm. An individual stony coral colony was generally identified as any colony growing independently of its neighbors (i.e., whenever a gap exists between two adjacent colonies). This definition is not always applicable to soft corals, sponges or tunicates since many of them present areas covered by a large number of densely growing colonies that are indistinguishable from one another. Therefore, in

these cases, the intercepted length was measured without recording the number of colonies. In case of doubt concerning the species of a certain organism, a close-up photo was taken using an underwater NIKONOS V camera or a digital U/W camera, and a small piece of the colony was sampled into a numbered plastic bag for identification in the laboratory.

Visual fish censuses were conducted at the above-mentioned reef sites. This non-destructive technique has been found to be very useful for most fish species, albeit resulting in a certain underestimation of both the cryptic and the most abundant species. At each study site, the fish censuses were carried out in 5 x 5 quadrates along belt transects, 50 m long and 5 m wide, placed parallel to the shore line and were repeated for 3 depth zones as dictated by the reef structure. All fishes were counted up to 4 m above the bottom, therefore forming a total volume of 180 m^3 along the transects. The diver first counted the more conspicuous fishes from a distance of 2-3 m and the size of large schools was estimated to the nearest 50 individuals. Next, the diver approached the reef and closely examined it for more cryptic species. Only resident and visitor (transient) species with a clear association to the reef were included in the counts. Fish species were identified underwater, and in case of uncertainty a photograph was taken and later compared to fish guides.

B) Research Accomplishments:

Approximately 200 samples were collected encompassing the variety of soft corals, stony corals, sponges and tunicates growing on the reefs. The southern entrance to the channel between Nocra and Dahlak, and Nokra Deset and Shuma were found to have the richest benthic and fish fauna. On these reefs two types of benthic communities were recognized, comprising either mostly soft corals or a mixture of a rich stony coral community with a rather low soft coral coverage. The former community type comprised mainly soft corals of the family Xeniidae, notably with several species of *Xenia*. Each species tends to cover large reef areas in the form of large mono specific aggregates, covering >50% of the substrata. This was particularly apparent in the seascape at Shuma reef, which exhibited diverse benthic communities. At sites where stony corals were dominant, the most abundant genera were *Stylophora, Acropora* and *Seriatopora* accompanied by large stands of *Porites*. In such areas soft corals were much less abundant.

The reefs of Museri and Hatitau, the outer reefs of the Dahlak Archipelago, are much more impoverished and characterized by a lower live coverage compared to the other reefs (see above). It seems that a high sedimentation rate in this part of the archipelago may result in these biotic features. The soft coral diversity on these reefs is low and most of the live coverage comprises stony corals of the genera *Pavona, Galaxea, Lobophylia* and *Seriatopora*. Of special interest are the mangrove trees that grow adjacent to these reefs. However, this habitat was not explored by us. Green Island reef is quite rich, although its shallow formation has led to a rather low-medium diversity of benthic organisms highly affected by sedimentation.

Approximately 50 10 m line transects were carried out on the reef sites. The data will be analyzed following proper identification of the reference collection of stony and soft corals by Y. Benayahu. The fish data will be processed and analyzed by Z.A. Zekeria.

The field work yielded numerous underwater photographs of excellent quality showing the reef biota, including digital video footage of fish and benthic communities. Digital copies of all photographic material have been left with the Eritrean collaborators. It is anticipated to produce identification keys, underwater field guides and educational material at a later stage of the project.

C) Scientific Impact of Collaboration:
The collaborating scientists planned, coordinated and actively participated in the joint research cruise to Dahlak Archipelago. During the period prior to the research cruise all the PIs and co-PIs continuously interacted, via conference phone calls and exchange of drafts of the mode of scientific collaboration and of execution of the project. Both parties followed the goals and work plan as they appear in the proposal and considered together any need for adaptations and last minute changes. During the cruise both teams worked together and stayed on board the R/V for a two-week period. Each side contributed to the practical aspects and exchanged views while carrying out the work. We held a "live" workshop and scientific discussions while conducting the scientific assignments. Each pair of divers comprised an Eritrean and an Israeli partner. Undoubtedly, this mode of operation greatly contributed to the Eritrean side by building their capacity to continue scientific work along the same research lines and to develop other activities in the future.

D) Description of the project impact:
Our activities during the first year of the project have established comprehensive expertise and facilities for reef research in the South Red Sea. This has been achieved via enhancing the skills of the Eritrean scientists, training their students, and the acquisition of facilities and equipment for the Department of Marine Biology and Fisheries at the University of Asmara and its field station in Massawa. These will substantially contribute to the future abilities of the Eritrean personnel to conduct independent reef research along the lines of the proposal. The reference collections and formation of digitized identification keys of the main reef organisms will facilitate reef studies in Eritrea. The first year has laid solid and professional grounds for a continuous advanced monitoring program of the reefs there and the determination of strategies for sustainable use of this resource.

E) Strengthening of Eritrean Institutions:
During the first year of the project we established reference collections in Eritrea, improved taxonomic and curatorial expertise and formed identification keys for the main reef organisms of the region. This facilitated quantitative and accurate analysis of reef communities, of population richness and of species determination as bio-indicators of environmental stress. The training activity included the application of field survey methodologies for monitoring fish and benthic communities. Both sides benefited through joint fieldwork, and "live" workshop and training activities. The training of the Eritrean personnel, together with the acquisition of curatorial and management methodologies will ensure the continuity of achievements in both practical (e.g. monitoring and management) and research work in the field and at the University of Asmara. The reference collections and training materials will provide a long-term tool for reef management to the Eritreans. The Israeli PI brought from the Zoological Collections of Tel Aviv University to Eritrea identified specimens of fish and corals as well as photographs from previous expeditions. This material enriches the reference collections

in Asmara. Furthermore, we purchased for the field station in Massawa a large variety of containers and jars for storage of specimens, collection equipment and ethanol to be used for future work on their reefs. In addition, we purchased in Israel diving equipment for the Eritrean personnel upon their request.

F) Future Work:
The time chart that appears in the original proposal clearly indicates the further tasks to be carried out in years 2 and 3 of the project. The training of M.Sc and a Ph.D students is a major challenge that should be fulfilled. Regardless of the halt of the project, Y.B. will continue to work on the identification of the benthic organisms collected during the cruise. These are extremely valuable samples with enormous scientific importance.

Section II: Project Management and Cooperation

A) Managerial issues:
In general, most managerial issues went smoothly. The Eritreans issued all necessary permits and letters of invitation. The one serious administrative barrier was the refusal of the Director of Research of the University of Asmara to issue invoices in order to enable electronic transfer of funds from TAU. In addition, there was severe bureaucracy involved in issuing permits to the Eritrean students in order to initiate their graduate studies in Israel. These serious problems have already been raised and discussed with the USAID-CDR officials.

B) Collaboration, Travel and Training:
From 5-22 February 2005 a joint research cruise to Dahlak Archipelago was conducted.
The Israeli participants included:
1. Prof. Y. Benayahu - PI
2. Dr. A. Abelson – co- PI
3. Prof. S. Beer – Botanist
4. Ms. Shimrit Perkol-Finkel - student
5. Mr. Mati Halperin – student
6. Mr. Ido Sella – student
7. Mr. Assaf Zvuloni – student
8. Mr. Shai Nimrod Saroussi – student

The Eritrean participants included:
1. Dr. Z.A. Zekeria – PI
2. Y. Afelwerki - student
3. Y. Bokhre - student
4. Dr. Y. Gebri – Botanist

The R/V Mediterranean Explorer was made available for the purposes of the project (see appended letter in original proposal). The R/V set sail from the Herzeliya marina late January 2005 on its way to the port city of Massawa in Eritrea, off the Dahlak Archipelago. The one-week cruise from Herzeliya sailed through the Suez Canal along the Red Sea with 5 Israeli crew members (skipper –D. Shaffer, A. D. Weil, I. Katzman, G. Anker, diving officer – O. Ben Shaprot) and the research and logistic equipment, including food for the entire period. Most of the Israeli team flew to Asmara via Rome and then traveled by land to Massawa where they boarded the R/V Mediterranean Explorer. The Israeli participants split the ship time on the R/V into two periods, 5-12

February and 12-19 February 2005. Abelson and Benayahu acted as chief scientists respectively. The Eritreans stayed on board throughout the entire period (5-19 February).

The immediate actions that are required are (1) training of Eritrean students as detailed in the proposal and (2) planning another joint field trip to the Dahlak Archipelago. To the best of my knowledge (Y.B) the Eritreans have chosen Mr. Y. Bokhre as a Ph.D, candidate and I certainly consider him as a very good choice. He came to Israel last year as a MASHAB fellow, we met here and discussed issues related to his academic plans. The monitoring work on the Dahlak Archipelago should be carried out with no delay for this purpose funds should be made avaiable.

C) Summary of Requests for CDR Program Action:
The only request that we have at this stage is to allow us to continue of the project with the hope that the political difficulties will not be a cause for interruptions.