Assessment of the impact on the marine biodiversity of the power plant planned by EEHC in Nuweiba, southern Sinai, Egypt

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The objective of the field mission was to examine, with a team of experts, in Nuweiba, South Sinai (Egypt), the site of a 750MWe natural gas-fired combined-cycle power generation plant planned by the Egyptian Electricity Holding Company (EEHC) and the East Delta Electricity Production Company, under the aegis of the Ministry of Electricity and Energy.

The objective of this expertise concerns the assessment of the impact on the marine environment of a 750MWe natural gas-fired combined-cycle power generation plant planned by the Egyptian Electricity Holding Company (EEHC) and the East Delta Electricity Production Company, under the aegis of the Ministry of Electricity and Energy. This assessment is based on:

- a review of the documents produced for the Environmental Impact Assessment drafted by the Power Generation Engineering and Services Company,

-a review of available information on the topic and the site in the Gulf of Aqaba,

- a field survey of the coastal and marine environment concerned by the power plant project,

- interviews with EIB relevant services in Luxembourg and with the EIB team on the field,

- interviews with project promoter officials and relevant Egyptian authorities, in Cairo and in the Gulf of Aqaba,

- interviews with local stakeholders, including complainants, concerned by the use of coastal and marine resources at this site and its immediate surroundings.

This report succeeds to a preliminary evaluation which was open to discussion. The participatory approach enabled to better draw a final assessment and propose recommendations.

Executive summary

This review of the Environmental Impact Assessment of a 750 MWe power plant in Nuweiba, Gulf of Aqaba (Egypt) drafted by the Power Generation Engineering and Services Company highlights the main characteristics of the marine context and a detailed description and mapping of the planned location which were not emphasized in the Environmental Impact Assessment.

The coastal and marine environment of Nuweiba is still relatively pristine. The coral reef and seagrass communities are assessed as healthy, diverse and highly resilient having adapted to periodic natural stressors (wadi floods, earthquakes, bleaching events, invasions of corallivorous organisms, diseases..). These qualities characterize “hotspots” of biodiversity in the realm of protection of an ecosystem integrity and the management of natural resources. Such a hotspot would could serve as gene bank facing the decline of coral communities in the region and in the world.

However if impacts, such as planned in the power-plant project, are continuous, and above a certain threshold, they would destroy these communities even if these are highly resilient and endowed with such ecologically adaptive characteristics**.**

The presence of endangered species of the IUCN - World Conservation Union has been recorded in the area, the internationally important and endangered species of the IUCN - World Conservation Union, mainly green turtles *Chelonia mydas* and hawksbill turtles *Eretmochelys imbricata.*

A scientific and touristic scoop comes with the presence on the Nuweiba site of a mimic octopus *Thaumoctopus mimicus* (Norman and Hochberg, 2005) which has never been recorded in the Red Sea. There is also the confirmation of the discovery of a new species of clam, *Tridacna costata*.

Presently local activities in Nuweiba seem adapted to the carrying capacities of the marine ecosystems. Thus the site, in the context of expanding urbanization and recreational uses of the coastal and marine environment of the egyptian Gulf of Aqaba, is of national and regional importance in terms of conservation and sustainable development.

The terrestrial environment in Sinai is of high value with the creation by the Government of Egypt of a network of 5 protected areas covering the desert, coastal, and marine ecosystems and remaining available for traditional uses by the local population of Bedouins. This network includes the full marine environment of the Gulf of Aqaba and a length of about 30km in the Gulf of Suez, including the coastal setback, up to 200m inland.

The responsibility for the management and the control of these protected areas, covering about 50% of the South Sinai Governorate, lies in the Nature Conservation Sector of the Egyptian Environmental Affairs Agency and is ruled by law 102 on Protectorates and law 4 on Environment.

Accordingly, for the marine environment is subject to a zero discharge policy and none of the coastal activities related to tourism has an impact on the marine environment: sewage water is collected and treated inland and desalination brine is normally re-injected inland at depth avoiding impact on the marine environment.

Fisheries are allowed only for Bedouins and the catches are recorded and management is a responsibility of the NCS in coordination with the loacal Bedouin authorities.

According to the lack of accurate data provided by the EIA concerning the impact on the marine environment at the planned site, the location of the powerplant cannot be accepted until sufficient detailed information on the baseline data and assessed impacts based on scientific evidence are provided.

As the site for pumping and discharging is located in the marine area under the responsibility of EEAA Nature Conservation Sector as part of the National Park of Egypt dedicated to conservation and supporting tourism and local populations, the precautionary principle should be applied and a detailed EIA provided otherwise the project should be relocated at a less sensitive area.

In addition, the EIA will have to include a monitoring plan for all relevant parameters, on land and at sea and to prepare an emergency plan for all situations related to the land and sea aspects as the area of Nuweiba is a tourism centre with numerous visitors in increasing numbers from Egypt and abroad eager to visit a pristine place of Sinai still in harmony with the nature.

General conclusions on the marine environment of the planned site in Nuweiba

1. The marine environment of the Egyptian part of the northern Gulf of Aqaba is considered as still pristine in comparison with the present status in Israel and Jordan. This is due to the classification as a marine protected area by the NCS/EEAA as part of the protected areas of South Sinai. This protection is implanted through a strong management and controlled by the staff of the National Parks of Egypt and the environmental police.

2. Except in Ras Mohamed National Park, located at the southern tip of the Sinai peninsula where fishing is totally forbidden, this activity is allowed for Bedouins of the coastal tribe and in particular in front of Nuweiba area.

3. This pristine environment and the quality and clarity of its waters is also supporting the coastal and marine tourism in the Gulf of Aqaba, with a close to Nature approach, including swimming, snorkeling and diving. Presently local activities in Nuweiba seem adapted to the carrying capacities of the marine ecosystems. Thus the site, in the context of expanding urbanization and recreational uses of the coastal and marine environment of the Gulf of Aqaba, is of national and regional importance in terms of conservation and sustainable development.

4. The coral reef and seagrass communities of Nuweiba, and of the planned site in particular, are assessed as healthy, diverse, including the presence of endangered species and new species to the region, and highly resilient having adapted to periodic natural stressors (wadi floods, earthquakes, bleaching events, invasions of corallivorous organisms, diseases..). These qualities characterize “hotspots” of biodiversity, highly valued for conservation and recolonisation purposes face to the decline of coral communities in the region and in the world. However although their great adaptability and resilience, these species would not survive to anthropic mpacts over certain physical thresholds and continuously.

4. The bathymetry in the vicinity of the Nuweiba site is shallower than elsewhere in the Gulf of Aqaba (except in the straits of Tiran), corresponding to a sill due the bottom topography of the Gulf at this site and to the input in sediment over centuries of wadi Watir. This factor is not in favor of the installation of inlet and outlet pipes that should preferably be set at great depth to impact the less marine communities.

5. The site is subject to periodic flash floods from the Watir catchment with peak flows at 91.9m^3/s; it is also close to the epicenter of extensive and severe seismic activity for the gulf of Aqaba, located in the rift area. Both factors represent an added risk for the planned power plant.

6. The lack of precise and comprehensive data provided in the EIA on the power plan technical aspects and on the impacts on the quality of the discharged waters in the marine environment does not allow a proper evaluation of the impact of the planned power plant. Using existing surveys in other parts of the region and in similar conditions with outlets of hot water from power-plants or other infrastructures, it is possible to provide elements on the importance of the impacts on the area surrounding the inlet and outlet waters, concerning in particular the impact of water temperature and of acidification of local waters; other parameters are described in the report but need more technical information and environmental data from field surveys, data sampling for a proper evaluation.

7. The maximum of seawater temperature in the Gulf of Aqaba in summer reaching 27 Celsius Degrees, with in shallow waters higher values at lower tide periods, is the threshold for the survival of marine species, in particular for the benthic fauna and flora. It has been recorded that an increase of 2 to 3 Celsius degrees for a period of one to three days would result in the death of all benthic organisms and the death or departure of pelagic fauna. As the power plant in Nuweiba is planned to discharge permanently waters with an increase of the temperature of 9 Celsius degrees, it would cause the death of all marine life in the vicinity of the outlet and would impact marine life over a thousand meters or more according to the flow, the directions of the currents and the capacity of the environment.

8. The impact would be greater in summer as local conditions of circulation and renewal of seawater seem to be very limited. Thus, the water discharged with an increase of 9℃ would be pumped again into the station. In a medium range from the impact, the rise in temperature would induce algal blooms, decline and trophic shifts in fish communities and flora and faunal assemblages with, in some cases, eutrophication of the waters which would be detrimental to marine life, artisanal fisheries and touristic activities.

9. As the water salinity can change during the cooling process, the impact could be expected to be lethal to marine organisms at the discharge as species are reluctant to increase or decrease in salinity.

10. The ph in the outlet flow would be more acid than at the inflow and this impact would add to the global impact of acidification of oceans, which induces the weakening and, at higher levels, the disappearance of calcareous parts or skeletons of living animals. This phenomenon is increased with higher water temperatures.

11. The change in water circulation, in particular with the need of 13.6 m3/sec of seawater for the cooling system, will cause a major impact on benthic and pelagic communities, in particular for spawning and in the settlement pattern of numerous marine benthic organisms with planktonic stages in their life cycle. It would also induce vertical mixing and thus increase the primary productivity which consequently would change planktonic community structures and diversity. Finally, it would increase the loading of fine sediments in the water column and therefore increase turbidity. These processes would seriously damage marine sensitive habitats such as coral reef communities and associated habitats and be lethal for most marine life especially close to the pumping sites.

12. When both temperature and the presence of chlorine are increased, the cumulated effects can concern an area of at least 1km radius. As the planned locations of the inlet and outlet are separated by 500m only, the impact would be more severe.

13. It is therefore recommended, based on the precautionary principle, to suspend the authorization for the selected site and to look for alternative sites in less sensitive areas. For these, it would be important to improve the field surveys, e.g. data sampling for the modelling for the EIA in particular concerning the diffusion of the water outlet and its impacts on the surrounding environment during summer and winter extreme conditions. In addition, a complete monitoring programme for the marine environment would have to be defined and implemented during the construction and the operation of the power plant.

General assessment of different possible impacts on the marine environment:

The expected changes in the marine environment are not properly and precisely described in the EIA document. The first column indicates the parameters needed for a proper evaluation. The second column includes the information found in the EIA document, in particular in paragraph 103, 111 and 113. The third column gives indications from the literature.

Items	Description in EIA by PGESCo	Data of interest for impact assessment
Biological survey of the area	Lack of detailed information on the site concerning benthic, pelagic and planktonic species	Essential for the EIA, a complete survey has to be conducted at the different possible impacted sites within the area.
Temperature in winter and in summer	Paragraph 103 increase of 9 Celsius degrees	Extreme value acceptable is 2 to 3 degrees (Sheppard *et al.,* 1992) for most species; Impact on benthic, pelagic and planktonic species (Nour El Din, 2004)
Salinity in winter and in summer	No information	Necessary for evaluating the impact on species
Waves and swell (during storm)	No information	Necessary for the stability of underwater infrastructure and surrounding environment
Current at intake	No information	Important to evaluate the stability of infrastructure and the impact on fauna in particular benthic and pelagic species
Flow at intake	No information	To be provided for evaluation of impact on sediment and species
Current at outlet	No information	Important to calculate the plume and the extended impact that can usually reach at least 1 km and more in slow motion areas without remixing. Model to be prepared according to state of the art (Numerical model system Mike)
Flow at outlet	No information	Important for the evaluation of the impact on sediment and species in the vicinity (turbidity)
Chemicals in outlet	The presence of chlorine is indicated without value to reduce the fouling	Necessary as impact on fauna and flora can reach one kilometer
Ph of the outlet	Paragraph 103 is expected between 6 and 9	Acidification Ph6 can have an important impact on marine species and in particular on those with carbonate shells or skeletons. Numerous species are excluded by chlorine presence until more than 1km from the outlet (Nour El Din, 2004),
Turbidity of outlet waters	No information	Turbidity could be linked to the quality of the outlet or to the disturbance of the sea bottom by the outlet
Noise and vibrations	Information on noise and vibration on land but not on the propagation in marine environment	Noise and vibrations at sea can have an impact on marine mammals and other species and can be an issue on the fixation of larvae

Fixation of intake in the marine environment	No information	Necessary to evaluate the impact during construction and the operation. Need to calculate the stability according to existing currents and waves at the site
Fixation of the outlet in the marine environment	No information	Necessary to evaluate the impact during construction and the operation. Need to calculate the stability according to existing currents and waves at the site

Experience shows that the potential limiting factors of coral reefs are temperature extremes, high salinities, macroalgal competition, coral diseases, corallivorous epizooties, isolation, oil production and pollution. This is also substantiated in the literature.

Concerning the planned power-plant, the different impacting elements presented in the Table are discussed hereafter:

<u>Impact of water temperature increase</u>

The maximum seawater temperature as measured in the Gulf of Aqaba reaches in summer a maximum of 27 Celsius degrees with locally, for short times, usually at the lower tide period, higher values on the reef flat and in shallow waters. In the marine environment, this maximum value is the reference for the survival of marine species, in particular for the benthic fauna and flora (coral reefs, seagrasses, algae and other organisms) as the pelagic species can migrate to other places. It appears that an increase of 2 to 3 Celsius degrees can be lethal for most of the organisms when they are at their upper limit of acceptability (Sheppard *et a*l., 1992).

The power plant in Nuweiba is planned to discharge water permanently with an increase in temperature of 9 Celsius degrees compared to the inlet water. This means that during the first summer, all marine life will be destroyed around the outlet.

For pelagic species, the immediate reaction is to move away. However reef fishes are associated to reef habitats and are the dominant component of reef fauna. They play an important role in a number of reef processes by increased rates of carbon fixation and creating important pathways of nutrient transfer within reef habitats. Their withdrawal is a serious threat to the survival of reefs.

For benthic species, such a rise in water temperature for a period of one to three days, will result in the death of all benthic organisms around the outlet and changes in benthic composition up to long distances.

As an example, in a site in Qatar where the maximum increase of the sea water temperature is of 7.4 Celsius degrees (Nour El Din, 2004), the impact to most benthic species is lethal within a radius of 450m and still effective until a radius of 1,500 m, affecting in particular, the composition of species assemblages. In natural conditions, some extreme cases as e.g. in southern Oman where summer temperatures exceed 37℃ and salinity 50ppt, corals cover is <1% of the substrate which is dominated by phaenophytes algae which themselves could be replaced by chlorophytes algae.

The best range for coral reefs to flourish being 25-29℃ (Cole, 2003). Studies on Hawaii coral reefs *Pocillopora damicornis*, *Montipora verrucosa* and *Fungia scutaria*, that were grown in a temperature-regulated, continuous-flow, sea water system, demonstrated that the skeletal growth optimum occurred near 26℃, coinciding with the natural sum mer ambient temperature in Hawaii, and was lowest at 21° to 22℃, representing Hawaiian winter ambient. An increase in temperature of approximately 32℃ produced mortality of corals wit hin days. Prolonged exposure to temperatures of approximately 30℃ eventually caused the loss of ph otosynthetic pigments, increased mortality and reduced calcification (Pearse, 1977).

In the Red sea and the Persian Gulf, bleaching and death of coral reefs occur with a rise of temperature trespassing a threshold of around 34℃ over the maximum acceptable during the year (in summer) and for a continuous period of time trespassing the seasonal periodicity (Downing, 1993).

In Nuweiba, a similar impact could be at least expected as the increase of temperature is of 9 Celsius degrees. In addition, as local conditions of circulation and renewal of water seem to be very limited, in particular during summer months, the impact could be more important.

In a medium range from the impact, or during cooler months at close range, the rise in temperature could induce algal blooms, decline of fish communities and trophic shifts in faunal communities, coral diseases and outbreaks of corallivorous species (*Drupella sp., Acanthaster planci*) with, in some cases, an eutrophication of the waters which would be detrimental to marine life, artisanal fisheries and touristic activities. Impact on fisheries would be very important due also to the withdrawal of numerous pelagic species and the destruction of nursery grounds.

In numerous countries, coral bleaching has been reported when the water temperatures were only one degree above the maximum temperature. This implies that coral reefs are the most temperature-sensitive of all ecosystems, and cannot take a further warming of one Celsius degree.

In some very specific locations, coral reefs are normally adapted to higher thresholds, but an increase of 2 to 3 degrees above this temperature, and over a long period of time, would first provoke coral bleaching then death according to the duration of the event. Indeed, if the impact were only seasonal, as in the marine plateau of 100km in Eritrea where most of the 250 islands are located, the marine organisms, in particular coral reef communities prove to be highly resilient by adapting to the stress and recuperating after 2-3 months (Tilot *et al.,* 2008b).

Therefore, the impact of over several ℃ and a continuous period of time of the planned outlet flow in shallow waters would be lethal to most living organisms in the bay and over a distance from the impact up to 1 km or more according to the flow, the directions of the currents and the capacity of the environment. This impact is reduced as the extension of the thermal plume can be modified.

<u>Impact of change in salinity</u>

Coral reefs flourish best at salinities 34-36 parts per thousand (Cole, 2003). As the water salinity can change during the cooling process, an impact could be expected at the discharge as species are reluctant to increase or decrease in salinity. The consequence would be death of the existing communities which would be replaced, if ever, by other trophic guilds and/or more adapted species. A complete study is necessary in similar cases.

<u>Impact of change in pH</u>

Acidification of oceans is a phenomenon described as part of the existing impacts of climate change. The results of acidification is the weakening and the disappearance of calcareous components or skeletons of living animals. Coral reefs or mussels are organisms with calcareous parts, but numerous others could be listed. The outlet water could be in the ph range from 6 to 9 (7 being the neutral point). If acidification is the case, all calcareous organisms will start to suffer. In addition, impact of acidification is known to be more severe with higher water temperatures.

Even a miniscule change of the pH from momentarily 8,2 to 8 can significantly reduce coral growth. In case of a drop from 8 down to 6 (which is an increase of 100% of the proton concentration) whole reef areas would dissolve.

<u>Impact of modification of water circulation, high currents (at inlet and outlet)</u>

The knowledge of the water circulation in the area, in normal conditions and in the presence of extreme events (tide, currents, swell) is essential to evaluate the area impacted by the change of water temperature at the outlet and its diffusion. Such an evaluation is usually provided through a complete analysis of the site during summer and winter conditions and the modeling of hydraulic aspects of the circulation of cooling water in the marine environment from the outlet to the surrounding area. This could be done using an uni, bi or tri dimensional model of the type “Mike”, a standard model for outlets of cooling water discharges. As indicated in different documents (Nour El Din, 2004; Zahid Ahmed et al., 2001), the impact can reach important distances according to the flow of water at the outlet and has a temporary or permanent impact according to the local conditions up to a distance of 1500m.

The change in water circulation will cause a major impact on benthic communities, in particular in the settlement pattern of numerous marine benthic organisms with planktonic stages in their life cycle. It would also induce vertical mixing and thus increase the primary productivity which consequently would change planktonic community structures and diversity. Finally, it would increase the loading of fine sediments in the water column and therefore increase turbidity. These processes would seriously damage marine sensitive habitats such as coral reef communities and associated habitats. The impact would be more severe close to the pumping sites.

<u>Impact of change of water quality</u>

The EIA indicates the addition of chlorine for reducing the fouling by organisms at the outlet pipe and the occasional presence of other pollutants. There is no indication on the treatment of the intake pipe but it will be subject to the same risk of fouling. As for the temperature, the presence of chlorine can be lethal for numerous organisms and a reason for others to move from the area. As indicated in Nour el Din (2004), the impact of chlorine on benthic communities can be effective up to at least one kilometer from the outlet according to the local conditions.

When both temperature and the presence of chlorine are increased, the cumulated effects can concern an area of at least 1km radius and as the inlet and outlet are separated of 500m only, the impact would be more severe. In addition, there is a risk for the power plant that in summer, when water circulation is much slower in this part of the part, the water discharged with an increase of 9°C would be pumped again into the station.

In some sites, studies have shown that copper concentrations are toxic for corals, and the oil residues have a negative influence on coral reproduction.

<u>Impact of turbidity and sediment transport</u>

Turbidity (increase the sedimentation rate and the loading of fine sediments in the water column) could be of great importance as it would seriously damage the living processes of marine sensitive ecosystems such as coral reefs and associated habitats. Also sedimentation rate has major influences on coral community composition which in turn influences fish assemblages through deterministic habitat effects (Sale, 1980). Almost all reef fishes have a pelagic larval dispersal phase, feeding on plankton for days to weeks before settling onto the reef (Roberts, 1991). This pelagic phase is a decisive stage in the life history as larvae have small energy reserves and are extremely vulnerable to predators. Suspended inorganic particulate matter may reduce feeding efficiency of some species since larvae respond to food particles only over short distances. Therefore this phenomenon would increase larval mortality (Sheppard *et al.* 1992).

<u>Impact of noise and vibration</u>

In reference to the EIA report for the combined cycle power plant at Jertoved, Croatia, the existing power plant generates high levels of noise and vibration when in operation. The vicinity of the power plant is categorized by the regulatory authorities as Zone 2, for which the maximum permissible noise levels are 55 dB(A) during the day and 45 dB(A) during the night at the residences. Noise levels generated by the existing power plant operation range from 52 dB(A) in the centre of the Jertovec village to 60 dB(A) some 50 meters from the power plant fence. These values exceed the limits allowed by the regulations both in the day and at night time.

Concerning the planned site at Nuweiba, noise and vibrations would probably disturb the fauna in the coastal and marine environment and migrating birds. Marine wise, it could affect in particular marine mammals, such as dolphins, sea-turtles and pelagic fish as well as the life cycle of coral reefs and seagrass communities (e.g. spawning, nurseries).

Impact of the construction and the presence of infrastructures on the sea

There is no detailed data on the impact on the benthic/pelagic environment, currents and the circulation pattern in the area of the construction and the presence of the pipes and the offshore structures, including the diffusers. Their impact on navigation, nautical sports and on traditional fishing activities by the Bedouins is not predicted in the EIA. Neither is there any information on the impact of marine life on these structures (fooling can be very important in hot water). Most probably they would not have the purpose of artificial reefs, as put forward in the EIA, as the conditions of discharged water would be lethal to most organisms. All these elements have to be provided as these structures would most probably have a strong impact on the marine environment, underwater landscape and the economic activities taking place in the area.

Impact of the loss of the economic value of living marine resources and the deterioration of natural coastal habitats

The economical value of living marine resources and coastal habitats of the Egyptian coast of the Gulf of Aqaba, especially coral reefs, seagrass beds communities and beaches, is the backbone of tourism development in South Sinai and an important contribution to the national income. As former quoted e.g., an individual shark at the valuable diving site, in the offshore islands, exceeds $300,000, which represents more than 30 thousands time more than killed to sell on the market. Thus the economical value of the natural resources of the coastal and marine environment of the planned site of Nuweiba should be assessed.

Synergetic effects of combined impacts

There can be synergetic effects of combined impacts on the environment. The increase of temperature added to the presence of chlorine, to a low Ph, and the existing maxima in temperature recorded in the summer months, can create locally the conditions for the total destruction of marine life over important areas and the flight of pelagic fishes. When nutrient enrichment occurs, coral replacement by alga is observed with much smaller temperature and salinity extremes. These processes could be toxic to marine organisms and human beings.

Shallow reef flats which are subject to periodic exposure at low tide and water temperatures varying between 16℃ and 40℃ are more vulnerable to additi onal environmental stress (Sheppard *et al.,* 1992). Even low levels of turbulence may cause heavy sand scour in shallow water, reducing the growth of corals and other benthic organisms on which many fish depend.

The impact on the natural resources in shallow areas is relatively more important as the productivity and biodiversity in shallow reefs is higher. Algae are more productive in shallow waters due to higher levels of illumination, thus herbivorous species (surgeonfishes and parrotfishes) are more abundant in these shallows. Plankton is also more abundant in shallow waters (<10m) and planktivorous fishes tend to be located in upcurrent areas to exploit the resource prior to depletion by others (Hamner *et al.,* 1988). Reef habitats are also variable in productivity, in particular piscivores, the largest proportion of the biomass of fishes, are related to prey distribution, e.g., groupers are more abundant on the fore-reef where there is a peak in abundance of fish, especially planktivores. Most of reef fishes respond to predators by seeking refuge within the reef framework.

Shallow reefs, in particular concerning the fish inhabiting them, are also an important component of an ecosystem as foraging migrations constitute an important link between the outer-slope and lagoon zones (Meyer and Schultz, 1985), e.g., grunts and snappers which feed over sandy areas or seagrass beds by night and rest over large coral heads by days (Ogden and Quinn, 1984). Thus corals grow much faster where schools are stationed as these induce fertilization (transfert of nitrogen and phosphorus) by their faeces (Meyer *et al.,* 1983).

In addition, changes in the fish communities in the northern Gulf of Aqaba due to industrial activities combined with other impacts (coastal constructions, sedimentation, nutrient input, algal growth, coral destruction, heavy metal load) can cause: a reduction in fish abundance, a decrease in total abundance of invertebrates and fish feeders, a change in trophic composition with an increase in total abundance of herbivorous and detritus feeding fishes.

Main characteristics of the coastal and marine environment of the South Sinai peninsula

The following elements are developed with scientific evidence as they were not emphasized in the Environmental Impact Assessment drafted by the Power Generation Engineering and Services Company.

The **Gulf of Aqaba** is **internationally renown** by the scientific community for its **uniqueness**. It is the most northernmost tropical sea ecosystem. Its oxygen-rich water has a constant temperature of 21-24 C°. Its relative isolation, and physical conditions which range from nearshore shallows to depths of over 2,000 meters in the central rift (Edwards and Head, 1987) have given rise to an **extraordinary range of ecosystems and biological diversity** (Sheppard *et al*., 1992; Tilot *et al.,* 2008a; 2008b).

The **Gulf of Aqaba** is about 200 kilometers, longer and shorter than the Gulf of Suez, (5 to 26 km wide) and much deeper, reaching about **1,850 meters in the central basin** (conversely the Gulf of Suez is shallow with an average depth of only 40m in average). Its width ranges from 25 kilometers in the south to 16 kilometers in the northern parts. On almost the entire coastline of this gulf, the coastal fringing reef grows luxuriously, varying in width from 10 to 100 meters depending on the slope gradients at the shelf edge. The Egyptian coast of the Gulf of Aqaba (part of the Afro-Syrian Rift system) is formed mainly of uplifted fossilized corals followed by a sandy area varying in width and surrounded in most cases by mountains (mainly granite). In contrast, the Gulf of Suez coast is mainly sandy, composed of soft sediments interrupted in certain areas by small rocky formations. The bottom morphology is smooth in general and turbidity is higher due to frequent re-suspension of bottom sediment. These conditions combined to lower water temperatures restrict the development of coral reefs which have a different structure and benthic composition from the rest of the Red Sea (Edwards and Head, 1987).

The **air temperature** ranges between 9℃ to 44℃ in the **northern part** of the Gulf of Aqaba which receives about **25 millimeters of rain per year** between September and March, while the rest of the coast is virtually rainless, receiving an occasional shower of a few millimeters every several years. Such low rainfall is accompanied by low humidity for most of the year, except for periods in winter when it reaches about 70 percent in the south (Edwards and Head, 1987).

The **seawater temperature** remains constant with 21.5℃ below a depth of 200 m and varying from 20℃ in January to 27℃ in August at the surface. T ides are semi-diurnal with a range from 30 to 100 cm. Given the very high evaporation rates (200 centimeters per year in the Gulf of Aqaba and 235 centimeters per year in the south) and the lack of freshwater input, the Gulf of Aqaba could be considered the **most saline water body in direct contact with world oceans**. **Salinity** ranges from 43 ppt to 44 ppt from south to north, and reaches about 43 ppt in the Gulf of Suez due to high evaporation rates and the extensive salt layers below the bottom. **Currents** recorded as 15-20 cm/s follow in general the **north-western winds** which are at an average velocity of 7-12 km/h. However the flow is reversed in March and April when southern winds with storms (Azyab) occur during the Khamasin season (Edwards and Head, 1987; Paldor and Anati, 1979).

The Gulf of Aqaba supports a **dense faunal and floral population** of more than 100 species of corals, 800 species of fish and hundreds of species of crustaceans and molluscs in a **fragile environmental equilibrium**. It is considered as an **important repository of marine biodiversity** and contains **some of the world's most important coastal and marine habitats and resources** including representatives of several **endangered species**. Species **endemism** in the Gulf of Aqaba is extremely **high**, particularly among reef fishes and reef–associated invertebrates (Edwards and Head, 1987). All these elements constitute the international importance of the **conservation value of the marine and coastal habitats of the Gulf of Aqaba** (Jeudy de Grissac, 1999).

Among the most notable characteristics of the Gulf of Aqaba, is the **extraordinary range of ecosystems:** an arid coastal zone, coastal wetlands, mangroves, seagrasses and coral reefs. These ecosystems have also an **important role** in **protecting** and **stabilizing** the **coastline** and **serving as buffer** to **changes in water quality**.

A series of studies have described the structure and zonation of **coral communities** in the Gulf of Aqaba (Head, 1987; Loya and Slobodkin, 1971; Loya, 1972; Mergner and Schuhmacher, 1974; Kotb *et al.,* 1996, 2001; Tilot *et al.* 2001; 2008a; 2008b). The coral reef communities of the Gulf of Aqaba are composed of approximately 209 hard corals species (some 20 being endemic to the area) and 16 soft coral species representing the **highest diversity in any section of the Indian Ocean** (Wilkinson, 2008). The warm water and absence of freshwater input provide very suitable conditions for coral reef formation adjacent to the coastline. Coral reef communities provide space, food and shelter for a large and diverse fauna and flora population**.** In the northern part of the Gulf of Aqaba the coast is fringed by an almost continuous band of coral reefs which physically protects the nearby shoreline, except for wadi (temporary rivers) deltas, alluvial fans, where the input of sediment creates shallower habitats with bays favorable to seagrass beds and patch reefs. Further south, the coastal shelf becomes much broader and shallower and the fringing reefs gradually disappear to be replaced by shallow, sandy shorelines and mangroves. Coral reefs become more numerous offshore in this part of the Region and occur as offshore patch reefs and reefs fringing islands.

Various studies describe reef fish assemblages in the Red Sea and Gulf of Aqaba (Botros, 1971; Fishelson *et al.,* 1974; Head, 1987; Ormond and Edwards, 1987; Roberts and Ormond, 1987; Roberts *et al.,* 1992; Roberts and Polunin, 1992; Khalaf and Kochzius, 2002; Tilot *et al.,* 2001; 2008a; 2008b). From the **1280 fishes species** recorded in the Red Sea (Khalaf and Kochzius, 2002; Randall, 1994), only **around 200 species** are recorded in the northern part of the Gulf of Aqaba. A typical pattern is observed in the Gulf of Aqaba, species richness first increases from the shore to the reef-edge and continues to increase to depths of 10-15m before decreasing again. Abundance follows a similar pattern but peak abundances are generally found close to the reef-edge (often due to schooling planktivorous fishes) in shallower water than maximal species richness. Groupers tend to be located in the fore-reef whilst surgeon fishes are more common in shallow regions. Pomacentridae appear the more abundant and Labridae and Pomacentridae dominate in terms of species richness.

Fishes play an important role in a number of reef processes: defense of feeding territories by herbivorous species causing increased rates of carbon fixation, heavy grazing by fish and echinoderms resulting in dominance by nitrogen fixing blue-green algae and foraging migrations by fishes forming important pathways of nutrient transfer within and among reef habitats (Sheppard *et al.,* 1992). In the gulf of Aqaba, deep water species are found closer to the surface than elsewhere in the Red Sea, e.g. the flashlight fish *Photobleraphon palpebratus*, the angelfish *Holocanthus xanthotis*, the butterflyfish *Chaetodon paucifasciatus.* This characteristic has been attributed to temperature (Ormond *et al.,* 1984), it could be also due to a niche expansion in the absence of certain competitor species (Diamond, 1984). Many other species have vertically shifted distributions. Also some species are restricted to the Gulf of Aqaba such as the damselfish *Chromis pelloura.*

Concerning **echinoderms**, nearly 200 species have been recorded for the Red Sea among which 56 species in the northern part of the gulf of Aqaba (2 species of crinoids, 10 asteroids, 10 ophiuroids, 12 echinoids,).

Seagrass beds in the northern part of the gulf of Aqaba are located in shallow and sheltered waters such as lagoons, sharms (drowned wadi mouths), and mersas (shallow embayments) because of the soft-bottom sediments found in these areas. Of the 11 seagrass species in the entire Red Sea, the commonest species are *Halophila stipulacea, H. ovalis, Halodule uninervis, Thalassodendron ciliatum* and *Syringodium isoetifolium*. In the Gulf of Aqaba, five or six species may be found among which *Halophila stipulacea, H. ovalis* and *Halodule uninervis*. The productivity of seagrass beds is greater than comparable areas of both coral reefs and mangroves. Their abundance along the Red Sea is indicative of a highly productive ecosystem. Seagrass roots stabilize sediments, and in conjunction with associated ecosystems, protect the coastline.

The common inhabitants of seagrass beds of the Gulf of Aqaba are Mollusca (*Anadara antiquata , Botula cinnamomea, Cerithium rupelli, Circe calipyga, Circe corrugata, Conus arenatus, Conus tessulatus, Glycymeris pectunculus, Muricodrupa fiscellum, Nassarius concinnus, N. protrusidens, Natica gualteriana, Pinna muricata, Strombus fasciatus, Strombus gibberulus, Strombus mutibilis, Strombus tricornis)*, Crustacea (*Alphus sp., Clibanarius sp. , Paracleistostoma sp*.), Echinodermata (*Tripeneustis gratilla)* and Polychaeta *(Notopygos veriabilis).*

Water currents are reduced in the vicinity of seagrass beds leading to the deposition of fine sediments and the clarifying of surrounding waters. Many marine animals rely upon seagrass beds for shelter and food, including water birds, fish and crustaceans, and the internationally important and **endangered species** of the IUCN - World Conservation Union, dugongs and green turtles. Five species of marine turtles have been recorded in the red sea among which the green turtle *Chelonia mydas* and the hawksbill *Eretmochelys imbricata* are the most important. Commercially important fish and crustaceans use seagrass beds as nursery grounds, which are also mostly appreciated by juveniles for food and shelter.

There are also **strong connections between seagrass beds and nearby coral reefs**: nocturnally active fish migrate at night from the reefs to the seagrass beds to feed; dead seagrass leaves carried offshore in currents become food for pelagic and fauna inhabiting deeper marine habitats.

Concerning marine mammals, there are at least 9 **dolphin species** present in the Red Sea, the most common are spotted dolphins and bottlenose dolphins. Dolphins eat saltwater fish and cephalopods, such as squid or octopus. The false killer whale has been recorded as well but more South in the Red sea.

Another distinctive characteristic of the Gulf of Aqaba is the existence of an **arid coastal zone** which consists of a flat coastal plain of varying width which is often bordered by extensive mountain ranges. The coastal plain in many areas is dominated by large alluvial fans, such as in Nuweiba with Wadi Watir delta, characterized by a seasonal discharge of water in a limited series of flood flows. Close to the shore, the coastal zone is dominated by salt tolerant vegetation which grades into arid adapted plant associations.

Areas adjacent to springs or other sources of permanent water are traditionally characterized by **oasis type vegetation and fauna** which are unique in their adaptation to stressful environmental conditions. They are characterized by a biodiversity which far surpasses that of surrounding areas often including species endemic to the Region. Their areas of distribution are usually very limited and some of the species are relicts of taxa which were more widely distributed in the geological past. Open freshwater bodies are the breeding sites of insects and attract large numbers of reptiles, birds and mammals.

The shallow waters adjacent to reefs and islands and the wetlands (including mangroves) provide ideal habitat for a **large number of resident and migratory bird populations**. Some of the important resident species include the lesser flamingoes *Phoenicopterus mino*r and the yellow–vented bulbul *Pycnonotus xanthopygo*s, while important wintering species include the greater spotted eagle *Aquila clanga*, white–eyed gull *Larus leucophthalmu*s and the greater and lesser sand plover *Charadrius leschenault, C. mongolu*s. The Gulf of Aqaba is a flyway for many species of birds (about 2 million individuals) which seasonally migrate between Europe and Africa.

The natural resources of the Gulf of Aqaba are vital to the livelihood of coastal populations. They support them for thousands of years and nourish the development of a maritime and trading culture linking Arabia and Africa, Europa and Asia. The aridity of the coastal zone has historically concentrated human settlement near available water supplies and created a **traditionally heavy reliance on the marine environment** as a source of food.

Fisheries are an important source of employment in the Egyptian Red Sea. Artisanal fishermen use a range of gear including longlines, handlines, gillnets, trawls, trammel nets, tangle nets, set nets, traps and spears. More than 650 species are recorded among the 1280 red sea species, with 20 species recorded in commercial catches. Bedouin women traditionally harvest invertebrates (mostly octopus, and molluscs e.g. *Tridacna sp.* and *Strombus tricornis*) in shallow reefs using metal spears.

Although the Gulf of Aqaba is still one of the least ecologically disturbed marine areas compared to other enclosed water bodies, it is **under the rapidly growing pressure of urban, commercial and maritime activities, mainly for touristic and recreational purposes** in the southern Sinai Peninsula. Until the 1970s South Sinai lacked any large settlement, and these reefs were unexploited, save by a few Bedouin tribes who fish there mainly during the summer. Since then, however, the attractions of scuba diving and snorkeling have stimulated a dramatic expansion of the once Bedouin villages of Sharm El Sheikh, Nuweiba, Dahab and Taba into major tourist resorts. By 1990 South Sinai was receiving 160 000 tourists per year (Hawkins and Roberts, 1994; Jeudy de Grissac, 1999), but by 2002 this number had risen to 1.7 million per year, and by 2003 to 2 million per year, of whom most were concentrated in and around the coastal city of Sharm El Sheikh (Jeudy de Grissac, 1999; SEAM, 2004b; Jobbins, 2006).

Consequently the **Egyptian authorities have considered maintaining the quality of reefs as critical to the economic growth of the region**. They understood that living marine and coastal resources need to be managed effectively so that their long term sustainable use would be ensured. And that it should be done within an integrated approach and increased public awareness about the value of the marine environment promoting habitat and resource conservation. Accordingly a network of marine protected areas has been established on basis of Law 102/1983 and its accompanying decrees. This large marine protected area covers the whole of the Egyptian Gulf of Aqaba's reefs and coastline with the strict enforcement of zero discharge policies, the prohibition of coastal alterations, the regulation of artisanal fisheries and the achievement of consensus on management issues with resident communities and stakeholders. The network includes Ras Mohamed National park, Nabq Protectorate, Abu Galum Protectorate, Taba Protectorate and Saint Katherine Protectorate (Jeudy de Grissac, 1999; Pearson and Shehata, 1998; Galal et al., 2002; Tilot, 2007b).

Despite protective measures there has been concern that the rapid development of the coast is having both direct and indirect impacts to the area's marine environment. In particular, studies have recorded damage to corals by divers and snorkelers at the most popular sites (Hawkins and Roberts, 1992a,b, 1993, 1994; Medio and Ormond, 1995; Leujak, 2006). At Sharm El Sheikh the reef areas that are most heavily used by visitors have higher numbers of broken hard coral colonies, loose coral fragments and partly dead corals than do less heavily used areas (Hawkins and Roberts, 1992b; Medio, 1996; Leujak, 2006).

Over-fishing poses "a threat to Egyptian coral reefs through an increase in commercial fishing and heavy trawling in the Gulf of Aqaba, along with poaching in no-take zones. Fisheries in the Red Sea are predominantly seasonal and occur during the spawning seasons of the most valuable commercial fishes. Presently these stocks are under serious threat of depletion" (Kotb *et al.*, 2008). "**Destructive fishing** results from local fishermen, migratory fishermen from other provinces, and visiting fishers from the Nile Delta who use purse-seine nets during the fishing season and then return to their home villages. The traditional local fishers are increasingly abandoning fishing for more lucrative opportunities in the dive industry or in hotels. Newcomers who replace them have less knowledge about the local ecology and often use unsustainable fishing practices, resulting in an increase in habitat destruction from net damage. Also, traditional local fishing knowledge is being irreversibly lost" (Kotb et al., 2008). As priority is given to conservation and tourism activities, fisheries in the Gulf of Aqaba are limited to Bedouins using traditional tools. Catch are recorded and management decisions are taken jointly between the Local Bedouin representatives of each tribe and the Nature Conservation Sector local representation in Sharm El Sheikh.

Shark fishing and sea cucumber collection are more recent threats to Egyptian reefs." The insatiable market for shark fins has induced sharp increases in shark fishing which introduces a conflict with tourism. Sharks in the Egyptian Red Sea constitute a very high commercial resource for tourism as they represent the main attraction for divers (an individual shark at the valuable diving site of Brother Island exceeds $300,000). The Egyptian government issued a decree banning shark fishing on the Egyptian Red Sea coast in 2004" (Kotb et al., 2008). "After sea cucumbers were depleted in many other parts of the world a small-scale fishery began in Egypt in the late 1990s. By 2000 the sea cucumber fishery had increased greatly because of high prices. In April 2000 the Red Sea Governorate banned sea cucumber fishing in coastal areas under its jurisdiction, however, the sea cucumber fishery was re-opened in 2002 despite the efforts of Egyptian Environment Agency and the Governorate to retain the ban. Between 2001 and 2004 extensive fishing of sea cucumber resulted in serious depletion of the natural stocks and 5 commercial species have disappeared completely from many reefs. (139 tons in 2001, PERSGA/GEF, 2002). All Egyptian authorities agreed to completely ban sea cucumber fishing in 2004 (Kotb *et al.,* 2008).

In addition, natural stressors occurred recently in the area, including earthquakes (1993, 1995, 1997 (Abdel Fattah et al;, 1997; Shaked et al., 2004)), rainwater (wadi) floods carrying sediments (1971, 1972.1990, 1996, 2002, 2005), coral diseases (Antonius, 1995), sporadic coral bleaching events due the trespassing of certain thresholds of temperature of surface waters over a certain period of time combined with very low tides (2002, 2003, 2005), corallivorous crown-of-thorns (COTs) starfish *Acanthaster planci* outbreaks in 1994 and 1998 (Salem, 1999), corallivorous gastropod *Drupella cornis* invasions (Schuhmacher, 1992). The first COTs outbreak was relatively minor, whereas the 1998 outbreak was extensive and probably continued through 1999 and 2001 although major control programs were implemented (PERSGA, 2008). More generally, across the most popular tourist sites, the loss of live coral cover owing to the activities of visitors might have amounted to as much as 20% of original cover (SEAM, 2004a).

As marine and coastal ecosystems are **open systems**, being linked by water circulation, any decline in health of one ecosystem will affect the others, **even at distance**. **Physical destruction,** changes in water quality such as raised nutrient levels, and changes in salinity and temperature high levels of sedimentation, and changes in water currents can all **damage coral reefs and associated ecosystems**. Recovery, through new growth and larval settlement, requires a variable (1-5cm/year for hard corals in northern Gulf of Aqaba) amount of time and freedom from chronic stress.

International and regional conventions and national legislation concerning the preservation of the biodiversity

Before ratification of the UNCBD, Egypt ratified many agreements and conventions including:

- Convention on the preservation of fauna and flora in their natural state, London, 1933 (ratified in 1936).
- Agreement on establishing general fisheries council for the Mediterranean, Rome, 1951.
- International Plant Protection Convention, Rome, 1953.
- International Convention on preventing oil pollution into the seas, London, 1963.
- Phyto-sanitary Convention for Africa, Kinshasa, 1968.
- African Convention on the Conservation of Nature and Natural Resources, Algeria, 1968 (ratified in 1972).
- Convention for the Protection of the Mediterranean Sea against pollution, Barcelona, 1976 (ratified in 1978)
- Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), Washington, 1973.
- Protocol concerning Mediterranean , especially protected areas. Geneva, 1983 (ratified in 1986)
- Convention on Wetland of International Importance, especially Waterfowl Habitat (RAMSAR), (Rasmsar, Iran, 1972), (ratified in 1988)..
- Convention of the Conservation of the Migratory Species of Wild Animals (CMS), Bonn, 1979 (ratified,1982).
- United Nations Convention on the Law of the Sea. Montego Bay, Jamaica, 1982 (ratified in 1983)
- Regional Convention for the Protection the Environment of the Red Sea and Gulf of Aden. Jeddah, 1990.
- Convention on Biological Biodiversity, Rio de Janeiro, 1992. (ratified in 1994).

After ratification of the UNCBD Egypt involved in some other related agreements and conventions such as:

- Agreement on the Establishment of the Near East Plant Protection Organization, Rabat, Morocco, 1993 (ratified in 1995).
- International Tropical Timber Agreement. Geneva, 1994 (ratified in 1996).
- Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean, Barcelona, 1995.

The main national laws related to preserve biodiversity are the following:

-The agriculture law, Law No. 53/1966: It was the main legislation protecting the wildlife, especially, birds useful to agriculture and certain endangered mammals and reptiles (chapter 3).

-The fisheries law, Law No. 124/1983: Especially in the parts concerning sustainable fisheries. The General Authority for Fisheries Resources Development (GAFRD) is the responsible body to implement this law.

-Law 102/1983 for Establishment of Protected Areas*:* It is the most valuable law for conserving the nature in Egypt. This law established the legal framework for the creation and management of protected areas. Egyptian Environmental Affairs Agency (EEAA) is the competent authority responsible for implementing this law. Law 102/1983 and its accompanying decrees provide the Egyptian Environmental Affairs Agency with the necessary legal instruments to declare protected areas, equip these with suitable resource management and conservation measures and establish and enforce regulations to safeguard protected areas. "The declaration of networked Protectorates on the Gulf of Aqaba has in effect established **a large marine protected area (MPA),covering Egypt's Gulf of Aqaba littoral zone in its entirety** realising Government objectives with the full protection of coral reefs and associated marine ecosystems on the Gulf of Aqaba, the strict enforcement of zero discharge policies, the prohibition of coastal alterations, the regulation of artisanal fisheries and the achievement of consensus on management issues with resident communities and stakeholders. The Gulf of Aqaba Protectorates Development Programme owes its success to proper integrated coastal zone management, strong legislation, unwavering Government support and the establishment of functional partnerships with the local community" (Pearson and Shehata,1998; Shehata, 1998). **Presently, a total of 100% of the marine environment and the Egyptian shoreline of the Gulf of Aqaba** (the setback being 200m maximum according to the type of coasts) in addition to about **50% of the terrestrial** environment of the Southern Sinai Region is protected. The network of Protectorates encompasses : Ras Mohamed National park (Decrees 1068/1983 and 2035/1996), Nabq Protectorate (Decrees 1511/1992 and 33/1996), Abu Galum Protectorate (Decrees 1511/1992 and 33/1996), Taba Protectorate (Decree 316/1998) and Saint Katherine Protectorate (Decrees 613/1988 and 940/1996). Also 30km of the Gulf of Suez, are protected under this legislation (Fig 1). The International Maritime Organization (IMO) has plotted the boundaries of the marine protected areas on the navigation maps as areas to be avoided. In spite of these efforts, some accidents have happened resulting in damage to coral reefs. A damage evaluation system has been developed on an economic basis. The EEAA applies the principle 'polluter/owner pays' to all accidents (Shehata, 1998).

Moreover, the law 102/1983 specifically prohibits any action that may lead to the extermination, damage or alteration of any organism, system or formation considered as a habitat for the living terrestrial and marine resources of the protectorate. It also prohibits the introduction of exotic species and the removal of any organisms or materials found in the protected area. The law forbids any activities, actions or experiments in areas adjacent to a protected area that would affect the environment of the protected area or the processes within it without the express permission of the concerned administrative body.

-Law 4/1994 for Environment: It is supportive to Law 102/1983 especially in the areas out side the declared protected areas. Although Law 4/1994 is focused mainly on pollution issues in air, land and water, many provisions have implications for nature conservation and hunting management in Egypt as Article 26 which forbids hunting, shooting and catching of species listed by the Agriculture Law No. 53/1966 or by Egypt participated international conventions such as CITES and IUCN. The main articles concerning development and environment are those stipulating that an Environmental Impact Assessment (EIA) is obligatory to obtain a license for projects and establishments. The EIA should follow the guidelines determined by EEAA in agreement with the administrative authority.

On the Gulf of Aqaba, Law 102, which is a powerful executive law, is applied. The wide range of articles of Law 4, which is a coordinating law, are exploited. By enforcing the two laws, all the main coastal activities can be regulated and proper integrated coastal management objectives implemented.

- Other numerous local ministerial decrees related to the UNCBD are established and implemented. They deal with: regulating fishing activities, forbidding shark fishing, strengthening the environmental law enforcement, protection of coral reefs, environmental risk assessment, forbidding trade in coral reef fishes for aquarium, in shells and other coral reef organisms, forbidding sea cucumber fishing, minimizing the pollution…

Recent improvements of the Egyptian legislation have been achieved by:

- the revision of the Egyptian Constitution, in 2007, with the introduction of a new specific provision on environmental protection. In particular, Article 59 specifying that Environmental protection is a national duty and the Law shall regulate measures necessary to maintain good environment,

-in 2007, a decree of the minister of Justice establishing the institution of environment Benches in each Governorate of the Arab Republic of Egypt,

-in 2009, Environmental Law N°4/1994 (Promulgating the Environment Law and its Executive Regulation Law) is amended by Law N°9/2009 in which the Egyptian environmental legislation is strengthened and updated. In particular there is an increase of prohibited acts in Protected areas (Art. 29), such as trading and offering to sell all endangered living organisms of fauna and flora species and the strengthening of protection measures and penalities against any kind of violation in the territories of Protected Areas. The amended Environmental Law No. 9 of 2009 was the next step to keep pace with the new constitutional amendments by modification of the Environmental Law No. 4 of 1994.

Egypt is one of the first Arab and African countries that created a National Commission on Sustainable Development. The framework has been completed and it is currently under preparation for a strategy of sustainable development. At legislative level, a separate article in the Egyptian Constitution was included, stating that "Environmental Protection is a national duty".

Fig. 1 (Pearson and Shehata, 1998). The Southern Sinai Protectorates, Sector of the Egyptian Environmental Affairs Agency.

1: Ras Mohammed National Park.

2: Sharm el Sheikh Protected Coastline.

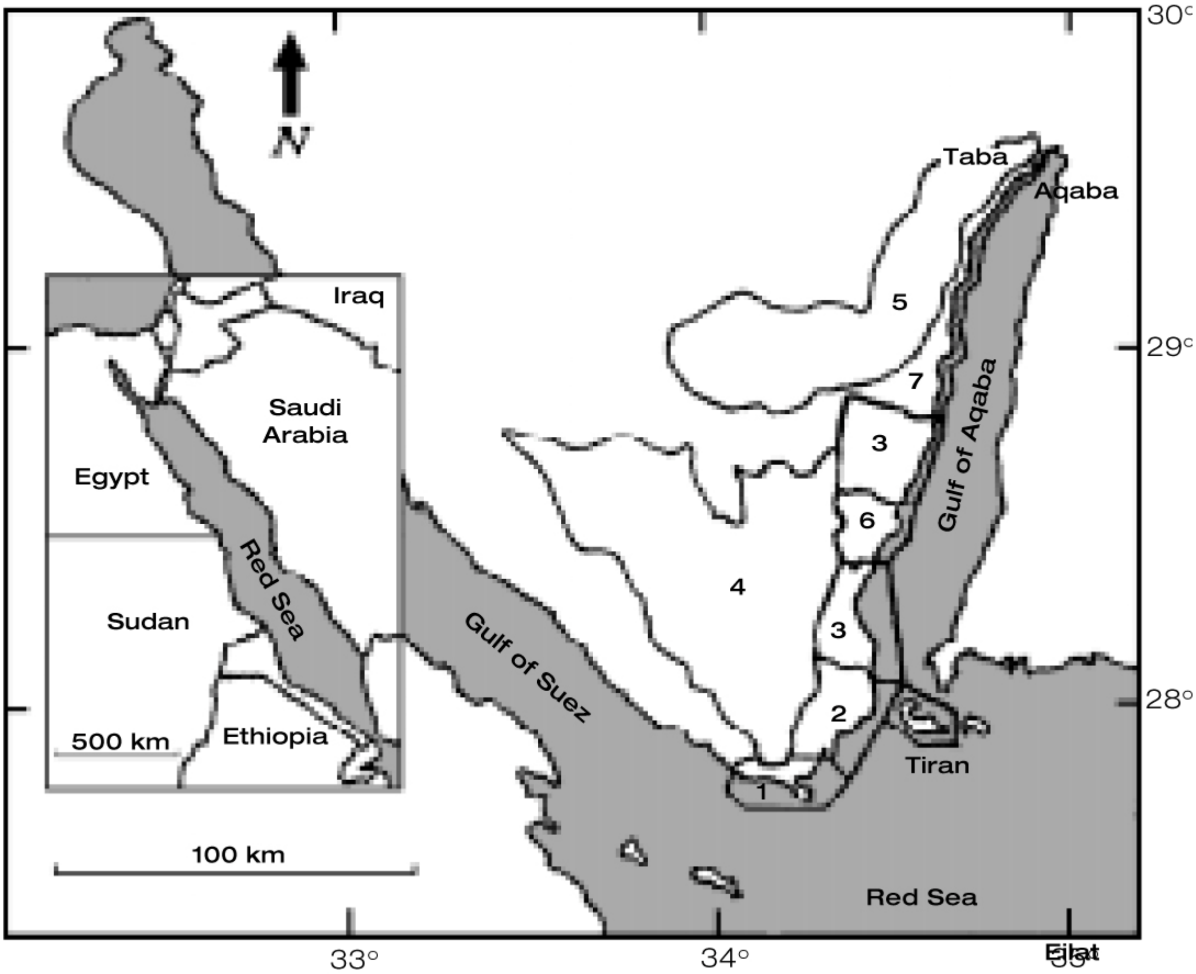
3: Nabq and Abu Galum Managed Resource Protected Areas.

4: St Katherine Protected Area.

5: Taba Natural Monument.

6: Dahab Protected Coastline.

7: Nuweiba-Taba Protected Coastline.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Saudi Arabia
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Sudan
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500 km
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5
7
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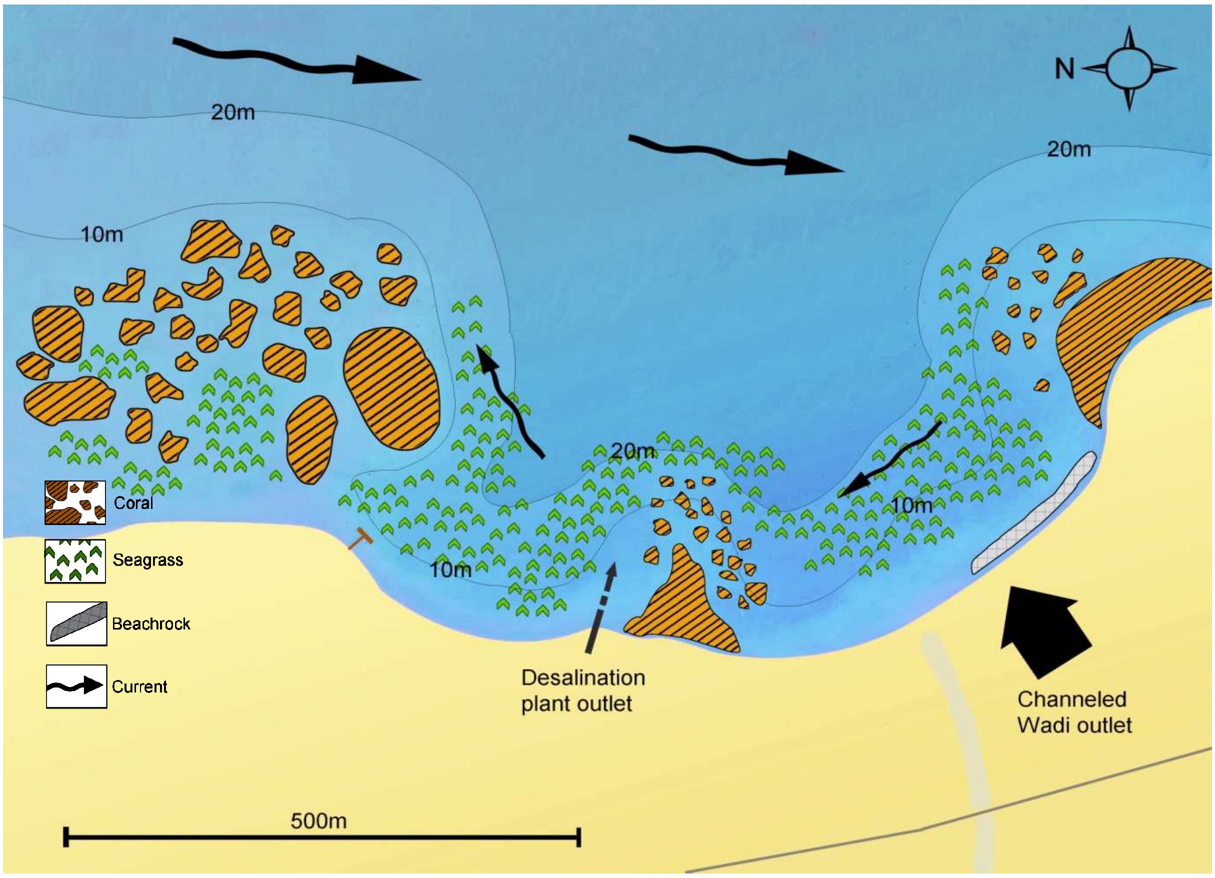
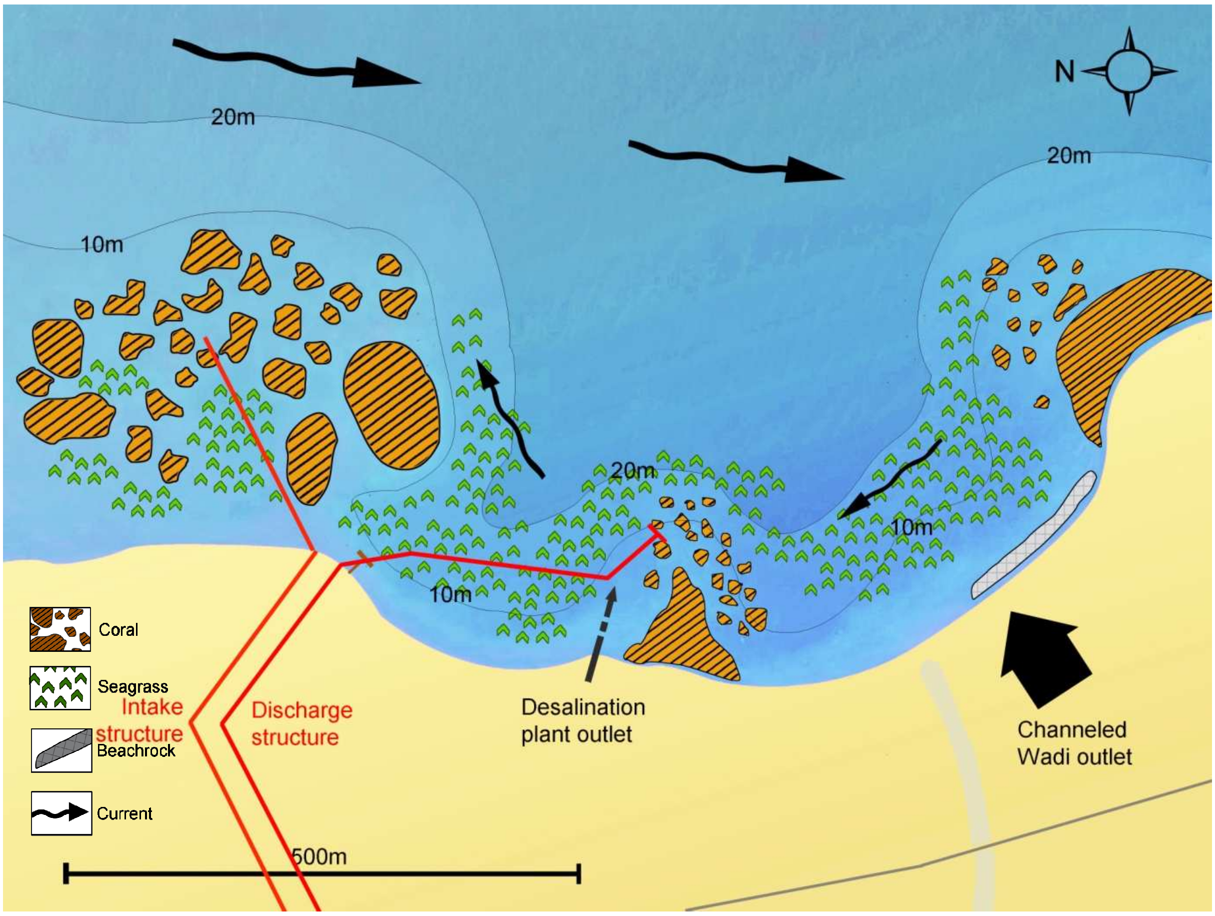
1
Gulf of Aqaba
Gulf of Suez
Tiran
Red Sea
Eilat
30°
29°
28°
33°
34°

Maps of the study site in Nuweiba

Maps of the study site with the location of the different marine habitats and the planned inlet and outlet maps (2 scenarios) in reference to 2 different documents presented by EEHC and

PGESCo. A third scenario, developed during the EIA performed by PGESCo, is analyzed during the dives (see description detailed further in the document)





N
20m
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Beachrock
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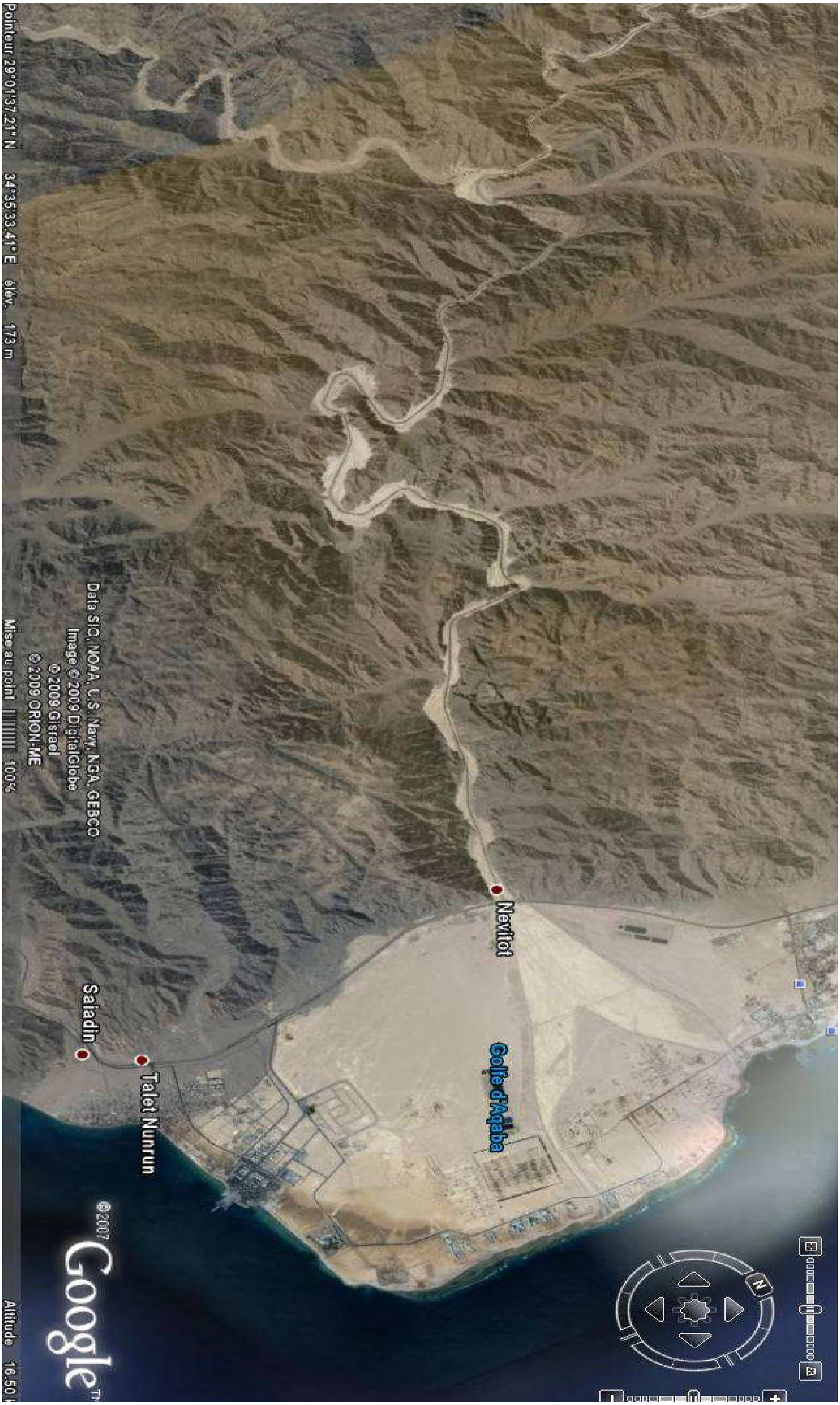
Channeled Wadi outlet
500m


Pointeur 29°01'37.21" N 34°35'33.41" E élév. 173 m
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2009 DigitalGlobe
© 2009 GIsrael
© 2009 ORION-ME
Mise au point 100%
Nevitot
Golfe d'Aqaba
Saladin
Talet Nunrun
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Altitude

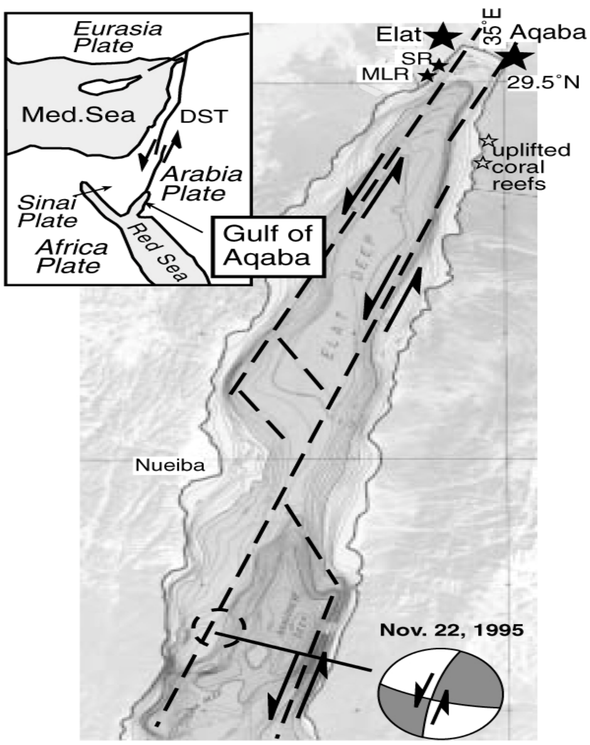
Description of Nuweiba marine environment

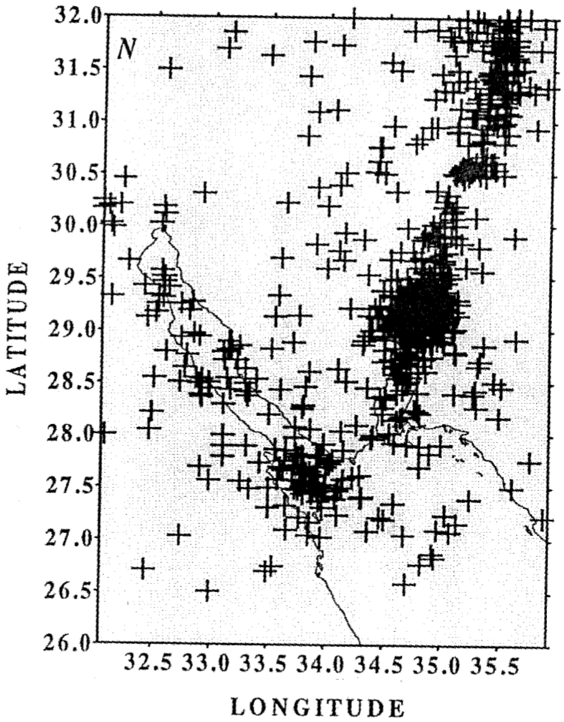
The coastal and marine environment of Nuweiba is still relatively pristine as the whole coast of the Sinai Peninsula apart areas where urbanization, tourism and recreational activities are more concentrated. This is the result of a decision of the government to prioritize in South Sinai **the protection of the environment and the sustainable development of tourism** and serves as model for the country, and the region, which has often fostered development to the detriment of environment especially in coastal areas.

Presently local activities in Nuweiba seem a**dapted to the carrying capacities of the marine ecosystems**. Thus the site, in the context of expanding urbanization and recreational uses of the coastal and marine environment of the Gulf of Aqaba, is of **national and regional importance in terms of conservation and sustainable development**.

Nuweiba area, in particular at the planned site area, is an exception to the general pattern observed along the northern part of the coast of the Gulf of Aqaba as it is a wadi delta, **alluvial fan of Wadi Watir**, where **flash floods** occur regularly. There the fringing reef is broken in a system of bays with sand bars, patch reefs on sand and large seagrass beds. A big beach rock bank lies parallel to the shore (see map). The fact that Nuweiba is located in a wadi bed and delta is a **risk factor for the installation of a power-plant.**

The **Watir catchment covers 3100 km^2** of very rugged mountainous terrain draining through a 20 km long canyonlike trunk stream to the Gulf of Aqaba. The floods in Wadi Mikeimin are typical of a geomorphologically efficient flood (Baker *et al.,* 1988; Schick *et al*., 1997). Wadi Mikeimin is a 12.9 km^2 tributary of the major drainage artery of southeastern Sinai-Wadi water. Detailed analyses of one typical big flood event in 1971 and 1972 have been achieved by Lekach (1974) in Baker *et al.,* 1988. **Major floods in 1990, 1996, 2002, 2005** were of the same type. Results can help debating on the risks and impacts of future floods. Thus in 1971, Wadi Mikeimin, after a highly localized rainstorm, deposited overnight a 6200 m^3 fan that completely obstructed the channel of Wadi Watir at their confluence. A flood reconstruction estimated **the peak flow at 91.9 m^3/s,** which dissipated completely into the sandy bed of the large Watir, whose catchment was unaffected by the event. A detailed analysis of high-water marks within the Mikeimin catchment indicated that one of its two main tributaries, drainage area 5.5 km^3, had a peak discharge of 83m^3/s. "Supercritical flows with surface velocities of about 5m/s, surges of 12m/s occurred about once a minute during high flow in the 1972 flood. Standing waves in rows of up to 8 and reaching at least 1m in amplitude above the average water surface were quite common. Distances between neighboring crests were 4-5m as these were sometimes moving very slowly downstream. The hydrograph of the event shows a series of very short flood peaks rising within 1-3 min from insignificant flow levels to peaks of 80-320m^2/s and a near-immediate abrupt recession. The total flow volume of the Watir was 5.5x106 m^3. Some of the flood peaks in the Watir must have been also due to nonsynchronous tributary input, an effect accentuated by the irregular pattern in time and space of the storm that generated the flood "(Lekach, 1974 in Baker *et al.,* 1988).





The gulf of Aqaba is the locus of **extensive seismic activity** (GII, 1996; Pinar and Turkelli, 1997). The epicentral distribution of the 1993 and 1995 sequences to tend to concentrate as a cluster around the area between, 28.5°-28.7°N and 34.5°634.7°E. The af tershock distribution shows a clear NNE-SSW trend (Abdel Fattah *et al.,* 1997). The last large earthquake (MW ¼ 7.1) occurred on 22 November 1995, off the town of Nuweiba at the central part of the Gulf of Aqaba (Shamir, 1996; Baer *et al*., 1999). The Nuweiba earthquake caused significant damage along the Gulf of Aqaba from Eilat and Aqaba in the north to Nuweiba and Dahab in the south (Al-Tarazi, 2000). Various rockfalls, liquefactions and slip features were also reported along the coast; The 1995 Nuweiba earthquake induced a wave that washed over the shores of the Gulf of Aqaba. (Wust *et al.,* 1997; Klinger *et al.,* 1999). Evidence of this earthquake can be seen underwater on the reefs, mainly on the big massive colonies (Tilot, pers. obs.). Tsunami and seiche waves often accompany large earthquakes. Evidence shows that reefs along this stretch of the Gulf of Aqaba coastline are episodically destroyed and rejuvenated. Nuweiba is very close (South-eastern part of the underwater wadi fan) to the epicenter of seismic activities in the rift area (Abdel Fattah *et al.,* 1997). This is also a **risk factor for the planned power plant project**.

In summers 2002, 2003 and 2005 sporadic **coral bleaching** (corals lose their zooxanthellae and/or pigments) events were recorded for the first time for some coral species, e.g. *Montipora lobulata*, in the northern part of the Gulf of Aqaba (Rosenberg and Loya, 2004) and linked to global climate change and increasing ocean temperatures (in particular surface waters). Coral bleaching is a major concern among scientists and resource managers. In 1998, more than 90% of shallow corals were killed on most Indian Ocean reefs. The northern Red sea was unaffected until recently. Even with their marked temperature acclimatization, most corals in the Arabian Gulf were killed with peak SSTs (Sea Surface Tempertaure). Recently Eritrea's corals are affected by a massive bleaching event and do not recover as easily as usual after a couple of months each summer (Tilot *et al.,* 2008b; Tilot, pers. obs.). Until today, the northern Red Sea has remained relatively unaffected, however global warming, resulting in an increase in the frequency and intensity of world-wide coral bleaching events sets the ground for additional severe threats to the reefs which would be surimposed to their vulnerable situation.

Coral diseases (among which White Band Disease, Tissue bleaching, Shut-Down-Reaction, in reference to Antonius, 1995) are not presently recorded in Nuweiba but some occur in more northern sites of the gulf of Aqaba, close to the border with Israel, where corals suffer from a combination of impacts (oil and heavy metals pollution, solid and liquid waste discharge, coastal development, influx of nutrient from fish farms, increased sedimentation, over-exploitation of marine species, eutrophication). These impacts challenge the resilience of coral reef communities (Rosenberg and Loya, 2004). Very little is known about the ecology and pathology of coral diseases in Red Sea reefs in general. Presently in the northern part of the Gulf of Aqaba, in Eilat, an unidentified disease affects a hard coral colony *Goniastrea sp*. (Antonius and Riegl, 1997; Rosenberg and Loya, 2004).

The 1998, the coral cover in some areas of the egyptian red sea has declined by more than 30% due, not to global bleaching, but to coastal development, **corallivorous starfish** *Acanthaster planci,* or **Crown Of Thorns (COTS), outbreaks**, illegal anchoring, scuba diving, snorkeling and reef walking. Coral cover at 2 sites in the Gulf of Aqaba decreased from 37% to 13% between 1997 and 2002, most probably due to COTS outbreaks (PERSGA/GEF, 2004). The COTS *Acanthaster planci* outbreaks occurred in 1994, 1998 and 2001 along the gulf of Aqaba (Salem, 1999). The first COTs outbreak in 1994 was relatively minor, whereas the 1998 outbreak was extensive and probably continued through 1999 and 2001 although major control programs were implemented (PERSGA, 2008).

During the underwater surveys done recently by the author in Nuweiba, only one *Acanthaster planci* has been seen, which proves that the reefs are healthy and in good equilibrium.

Corallivorous gastropod *Drupella cornis* invasions, occurring sporadically in some areas such as in Ras Um Sidd (Sharm el Sheikh) in 1998, are often correlated to a prevalence of diseases (Schuhmacher, 1992). Generally they attack the most abundant reef-building species, *Acropora hemprichi*. Presently, these snails have not been sited in great numbers in Nuweiba.

The **bathymetry** in the Gulf of Aqaba at Nuweiba site is shallower corresponding to a sill due the bottom topography of the Gulf of Aqaba at this site and to the input in sediment over centuries of the wadi (see Figure in Annex). This factor is **not in favor** of the installation of **inlet and outlet pipes** that should preferably be set at great depth to impact the less marine communities.

Archeological studies in the Nuweiba area display the existence of artefacts (pillars in Nuweiba and the corresponding site in Saudi Arabia, wheels of pharaoh's chariots discovered by Ron Wyatt in 1978, see Appendix) that would lead to that the hypothesis that Moses crossed the Red Sea at Nuweiba to go to the Arabian peninsula (present Saudi Arabia) where waters are shallower. This **remarkable discovery is an asset for Nuweiba of national and regional importance.**

<u>Description of the planned site in Nuweiba for the power plant inlets and outlets</u>

Since the description of the site in the EIA is far from complete, data on the locations planned for the pipes vary as well as the information on the velocities of the flow at intake and outlet.

Therefore in order to collect sound background information, a comprehensive survey of the bay has been achieved by the author with mapping of the habitats and associated communities and current patterns. Major features appear:

The characteristics and the state of health of the coral reef and seagrass communities indicate a good health, a good capacity and a **high resilience, concepts that are presently valued in the protection of an ecosystem integrity and the conservation/management of the biodiversity *** (Tilot, 2009; West and Salm, 2003).

Traditional **measures of biodiversity** or species richness (or Whittaker's (1975) □ diversity, i.e. a count of the total number of species in a sampled area) and evenness (or equitability, i.e. the proportional abundance of each species) are average compared to other sites in the Gulf of Aqaba. But as these measures of biodiversity tend to be inter-related at spatial and temporal scales and often effects of disturbances stay undetected until a very advanced stage of environmental degradation. Different measures**of biodiversity ensure more comprehensive characterization of biodiversity such as complementarity (average measure which weights the extent of evolutionary characters, species richness and/or restricted range, habitats from an area to other areas (Margules and Pressey, 2000)) and □□diversity*** (estimate of spatial turnover of species along a gradient, e.g. changes of species composition from site to site (Gray, 2000)). These most probably would be **high**, according to preliminary assessments, indicating that the communities are very resistant and adapt to stressful environments with natural changes that are seasonal and periodic.

Paradoxically, a particular area can be both a '**hotspot'** and 'coldspot' of biodiversity depending on the diversity measure(s) selected as Price (2002), Price and Izsak (2005) debated on the Persian Gulf versus Chagos islands. As a consequence, some areas of the red sea could be average when characterised merely by species richness, yet they would emerge hotspots if the choice of metrics is expanded to include endemism, taxonomic distinctness and □ diversity. Thus, Nuweiba could be prioritized as a hot spot and **could serve as gene bank facing the decline of coral communities in the region and in the world**.

But **it is important to stress again that if impacts**, such as planned in the **power-plant** project, are **continuous,** and **above a certain threshold**, they **would destroy these communities even if these are highly resilient and endowed with such ecologically adaptive characteristics.**

The presence of endangered species of the IUCN - World Conservation Union has been recorded in the area, the internationally important and **endangered species** of the IUCN - World Conservation Union, mainly green turtles *Chelonia mydas* and hawksbill turtles *Eretmochelys imbricata*

A **scientific and touristic scoop comes with the presence on the Nuweiba site of a mimic octopus** *Thaumoctopus mimicus* (Norman and Hochberg, 2005) which has never been recorded in the Red Sea. This octopus has been discovered in 1998 off the coast of Sulawesi in Indonesia on the bottom of a muddy river and has the extraordinary ability to imitate different animals: sea snakes, lionfish, flatfish to avoid predators. This ability of camouflage is remarkable, changing colors and patterns in order to mimic the corresponding predators of its encounters (Norman et al., 2001).

There is also the confirmation of the discovery of a new species of clam, *Tridacna costata*, differing from *Tridacna squamosa* and *Tridacna maxima*. *Tridacna costata* is less than 1% of all clams and is already threatened with extinction according to IUCN Red List. In addition, J.E.N. Veron has identified, in the Gulf Aqaba, 28 hard coral species new to the red sea (Tilot, 2003).

Most living hard coral percentages are located the furthest eastward and on the northeastern sides of the coral blocks, which could be explained by the general current pattern, coming from north to south combined to the impact of the occasional flood coming from south.

Fast growth of "new" corals (approx 4-5 years, according to the last reported Wadi flood), partially 20-30% live coral cover on reef slope up to 100% on coral blocks, in deeper depth,

The growth of hard corals on the artificial reefs laid out in 2007 by Scuba college is relatively fast (around 5 cm per year, which is quite impressive).

Extensive seagrass meadows, with 4 different species, *Halophila stipulacea, H. ovalis, Halodule uninervis* and *Syringodium isoetifolium*.

Large fish communities, healthy indicators species, undisturbed behaviours are observed.

High diversity and abundance is displayed mainly when depth increases.

Beach rock exists, over the whole length parallel to the coastline. On overhangs are fixed many ascidians *Didemnum, Dendronephthya, Plumaniidae* black coral, antipatharian (black corals)..

The desalination outlet that is observed is illegal (unless authorized by EEAA/NCS) as it crosses the setback and discharges in shallow waters warmer waters (>1℃) warm brine and treatment chemicals (chlorine and anti-scalants). The impact is obvious, the area in proximity is azoic. In general such discharges may cause bleaching and mortality of corals and diseases to the fish stocks. Although this is only a localized phenomenon, it may intensify with time.

*The concept of Ecosystem's health refers to its current state or condition at a point in time. The ecosystem's capacity makes reference to its potential for continued self-development, regeneration and evolution under normal circumstances (Kay and Regier, 1999). The concept of ecosystem resilience is the capacity of complex systems with multiple stable states to absorb disturbance, reorganize, and adapt to change by eventually shifting into alternate states (Folke *et al.,* 2004). It is central in the context of how coral reef ecosystems relate to disturbance in an increasingly human-dominated environment. Instead of focusing on the recovery of certain species and populations within disturbed sites of individual reefs, spatial resilience refers to the dynamic capacity of a reef matrix to reorganize and maintain ecosystem function following disturbance. Managing for resilience in dynamic seascapes not only enhances the likelihood of conserving coral reefs, it also provides insurance to society by sustaining essential ecosystem services.

The temporal and spatial scales of disturbances will determine the faculty of ecosystems to regenerate or change to an extent that the original pristine state will never be recovered (Berkes *et al.,* 2003) and the consequences for management are crucial as it is easier to sustain a resilient ecosystem than repair it once shifted. During the post impact phase, changes in species composition occur often favoring short-lived species that can quickly colonize after disturbances (Hughes *et al*., 2003). These alternate states can be maintained by density-dependent mortality (e.g. owing to altered predator-prey ratios) or by density thresholds required for reproductive success (Cury and Shannon, 2004). As emerging multidisciplinary approaches stress the importance of assessing and actively managing resilience, it is likely to be important to have extensive buffer zones, for added robustness and 'insurance'.

**Over the past decade, a suite of more intuitive/comprehensive average measures reflecting complementarity, relatedness (diversity), similarity (taxonomic distinctness) and other 'average' measures, have been developed (Warwick and Clarke, 2001) to measure biodiversity over both small and large spatial scales.

Detailed assessment of different possible impacts on the marine environment:

The expected changes in the marine environment are not properly and precisely described in the EIA document. The first column indicates the parameters needed for a proper evaluation. The second column includes the information found in the EIA document, in particular in paragraph 103, 111 and 113. The third column specifies EIB's comments with scientific evidence.

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Parameters	**Description in EIA by PGESCo**	**Comments by EIB**
Biological survey of the area	Wrong assessment of coral and seagrass communities, absence of detailed survey and mapping of the site	Essential for the EIA, a complete survey has to be achieved at the different potential sites.
Water temperature (annual variation)	General data provided. Site data only in July 2008	Need winter evaluation and maximum expected at site for evaluation of normal conditions for species
Outlet water temperature	Paragraph 103 indicates an increase of 9 degrees between inlet and outlet	Max value acceptable is 3℃ over the max natural value (Sheppard *et al.,* 1992). If more, most of the species will die.
Salinity (annual variation)	General data provided. Site data only in July 2008	Summer and winter data needed
Outlet salinity	No information	Necessary for evaluating the impact on species
Waves and swell	No information in particular maximum during winter storms	Necessary for the calculation of the stability of the underwater structure and fixation system. Impact on surrounding environment cannot be appreciated

Current at site (annual variation)	Only in summer, July 2008 and winter data is essential. Only at mid-depth need for surface and bottom with a maximum of 60cm/s on 18 July 2008	Needed all year and specially winter. If speed is 60cm/s in summer, winter can be double and infrastructure will have to stand this impact. Also necessary for calculation of minimum value in summer for modelling. Important to calculate the plume and the extended impact that can usually reach at least 1 km. Model to be prepared according to state of the art (Numerical model system Mike)
Flow at intake	No information, could be of 15m³ per second	To be provided for evaluation of impact on sediment, species and on safety of nautical activities
Current at outlet sea bottom (annual variation)	Only in summer, July 2008, and at mid depth with a maximum of 60cm/s on 18 July 2008 and numerous data around 20cm/s	Important to calculate the plume and the extended impact that can usually reach at least 1 km. Model to be prepared according to state of the art (Numerical model system Mike)
Flow at outlet	No information, could be of 15m³ per second	Needed for calculation, with normal operation and by pass in emergency. Important for evaluation of impact on sediment and species in the vicinity (turbidity)
Chemicals in outlet	The presence of chlorine is indicated without value to reduce the fouling	All data have to be precisely defined as they are necessary to evaluate the impact on fauna and flora. Numerous species are exclude by chlorine presence until more than 1km from the outlet (Nour El Din, 2004),
Ph of the outlet	Paragraph 103 is expected between 6 and 9	Acidification Ph6 can have an important impact on marine species and in particular on carbonate shells or skeleton.
Turbidity of outlet waters	No information	Turbidity could be linked to the quality of the outlet or to the disturbance of the sea bottom by the outlet
Noise and vibrations	Information on noise and vibration but not on the propagation in marine environment	Noise and vibrations at sea can have impact on marine mammals and other species and can be an issue on the fixation of larvae
Fixation of intake in the marine environment	No information	Necessary to evaluate the impact during construction and the operation. Need to calculate the stability according to existing currents and waves at the site

Fixation of the outlet in the marine environment	No information	Necessary to evaluate the impact during construction and the operation. Need to calculate the stability according to existing currents and waves at the site

The different elements presented in the Table are discussed hereafter:

Impact of water temperature increase

The EIA indicates a discharge of cooling water with an **increase of 9 C°.** An increase of temperature of more than 3 C° can be lethal for most of the org anisms when they are at their upper limit of acceptability (Sheppard *et a*l., 1992). For pelagic species, the immediate reaction is to move away. For the benthic species, such a temperature will mean temporarily (in summer) or permanent death and disappearance of the area.

For coral reefs, **bleaching and death** occurs with a **rise of temperature trespassing a threshold of around 34℃** over the maximum acceptable during the year (in summer) and for a **continuous period of time** trespassing the seasonal periodicity. Indeed, if the impact were only seasonal, as in the marine plateau of 100km in Eritrea where most of the 250 islands are located, the marine organisms, in particular coral reef communities prove to be highly resilient by adapting to the stress and recuperating after 2-3 months (Tilot *et al.,* 2008b).

The **impact of the inlet and outlet flows** of the planned pipes in shallow waters over several ℃ and a **continuous period of time** would **be lethal to most living organisms** in the bay and over a distance from the impact up to 1 km or more according to the flow and the directions of the currents as the extension of the thermal plume can be modified.

Shallow reef flats which are subject to periodic exposure at low tide and water temperatures varying between 16℃ and 40℃ are **more vulnerable to additional environmental stress** (Sheppard *et al.,* 1992). Even low levels of turbulence may cause heavy sand –scour in shallow water, reducing the growth of corals and other benthic organisms on which many fish depend. Algae are most productive in shallow waters due to higher levels of illumination and herbivorous species (surgeonfishes and parrotfishes) are most abundant in these shallows. Plankton is also most abundant in shallow water (<10m) and planktivorous fishes tend to be located in upcurrent areas to exploit the resource prior to depletion by others (Hamner *et al.,* 1988). Piscivores, the largest proportion of the biomass of fishes, are related to prey distribution, e.g., groupers are more abundant on the fore-reef where there is a peak in abundance of fish, especially planktivores. Most of reef fishes respond to predators by seeking refuge within the reef framework. Foraging migrations constitute an important link between ecosystems (Meyer and Schultz, 1985), such as for the outer-slope and lagoon zones, e.g., grunts and snappers which feed over sandy areas or seagrass beds by night and rest over large coral heads by days (Ogden and Quinn, 1984). Corals grow much faster where schools are stationed as there is fertilization (transfert of nitrogen and phosphorus) by faeces (Meyer *et al.,* 1983).

Impact of change in the salinity

As the water salinity can change during the cooling process, an **impact** could be expected at the discharge **as species are reluctant to increase or decrease in salinity**. The result will be a death of the existing communities to be replaced by more adapted species. A complete study is necessary.

Impact of modification of water circulation, high currents (inlet and outlet)

The knowledge of the water circulation in the area, in normal conditions and in the presence of extreme events (tide, currents, swell) is essential to evaluate the area impacted by the change in temperature of the water at the outlet and its diffusion. Such an evaluation is usually provided through a complete analysis of the site during summer and winter conditions and the modeling of hydraulic aspects of the circulation of cooling water in the marine environment from the outlet to the surrounding area. This could be done using an uni, bi or tri dimensional model of the type Mike normally a standard for outlets of cooling water discharges. As indicated in different documents (Nour El Din, 2004; Zahid Ahmed et al., 2001), the impact can reach important distances according to the flow of water at the outlet and has a temporary or permanent impact according to the local conditions up to a distance of 1500m

The change in water circulation will cause a **major impact** on benthic communities, in particular in **settlement pattern of numerous marine benthic organisms with planktonic stages** in their life cycle. It would also induce vertical mixing and thus rise the primary productivity which consequently would change planktonic community structures and diversity. Finally, it would increase the loading of fine sediments in the water column and therefore increase turbidity. These processes would seriously damage marine sensitive habitats such as coral reef communities and associated habitats. The impact would be more severe close to the pumping sites.

Impact of the change of water quality

The EIA indicates the addition of chlorine for reducing the fouling by organisms at the outlet pipe and the occasional presence of other pollutants. There is no indication on the treatment of the intake pipe but it will be subject to the same risk of fouling. As for the temperature, the presence of chlorine can be lethal for numerous organisms and a reason for others to move from the area. As indicated in Nour el Din (2004), the impact of chlorine on benthic communities can be effective up to at least one kilometer from the outlet according to the local conditions.

When both temperature and the presence of chlorine are increased, the cumulated effects can concern an area of at least 1km radius and as the inlet and outlet are separated of 500m only. In addition, there is a risk for the power plant that in summer, when water circulation is much slower in this part of the part, the water discharged with an increase of 9℃ would be pumped again into the station.

Impact of turbidity and sediment transport

Turbidity (increase the sedimentation rate and the loading of fine sediments in the water column) could be of great importance as it would seriously **damage the living processes** of marine sensitive **ecosystems** such as coral reefs and associated habitats. Also **sedimentation rate** has **major influences on coral community composition** which in turn influences fish assemblages through deterministic habitat effects (Sale, 1980). Almost all reef fishes have a pelagic larval dispersal phase, feeding on plankton for days to weeks before settling onto the reef (Roberts, 1991). This **pelagic phase** is **decisive** stage in the **life history** as larvae have small energy reserves and are extremely vulnerable to predators. Suspended inorganic particulate matter may reduce feeding efficiency of some species since larvae respond to food particles only over short distances and thereby increase mortality (Sheppard *et al.* 1992).

Impact of noise and vibration

In reference to the EIA report for the combined cycle power plant at Jertoved, Croatia, the existing power plant generates high levels of noise and vibration when in operation. The vicinity of the power plant is categorized by the regulatory authorities as Zone 2, for which the maximum permissible noise levels are 55 dB(A) during the day and 45 dB(A) during the night at the residences. Noise levels generated by the existing power plant operation range from 52 dB(A) in the centre of the Jertovec village to 60 dB(A) some 50 meters from the power plant fence. These values exceed the limits allowed by the regulations both in the day and at night time.

Concerning the planned site at Nuweiba, **noise and vibrations** would probably **disturb the fauna in the coastal and marine environment** and migrating birds. Marine wise, it could affect in particular marine mammals, such as dolphins, sea-turtles and pelagic fish as well as the life cycle of coral reefs and seagrass communities (e.g.spawning, nurseries).

Impact of the construction and the presence of infrastructures son the sea

There is no information on the type of pipes, there size and their length, the way they are buried or laid at the surface of the sea bottom, on their **impact** on the currents and the **circulation of the water** in the area, on their impact on the **navigation**, nautical sports and the **traditional fishing activities** by the Bedouins. Neither is there any information on the impact of marine life on these structures (fooling can be very important in hot water). Most probably they would not have the purpose of artificial reefs, as put forward in the EIA, as the conditions of discharged water would be lethal to most organisms. All these elements have to be provided as they will have a strong impact on the marine environment, underwater landscape and the economic activities taking place in the area.

Impact of the loss of the economic value of living marine resources and the deterioration of natural coastal habitats

The economical value of **living marine resources** and coastal habitats of the Egyptian coast of the Gulf of Aqaba, especially coral reefs, seagrass beds communities and beaches, is the **backbone of tourism development in South Sinai** and an important contribution to the national income. As former quoted e.g., an individual shark at the valuable diving site, in the offshore islands, exceeds $300,000, which represents more than 30 thousands time more than killed to sell on the market.

Synergetic effects of combined impacts

There can be synergetic effects of combined impacts on the environment. The increase of temperature added to the presence of chlorine, to a low Ph, and during the summer months, can create locally the conditions for the **total destruction of marine life over important areas**, the departure of pelagic fishes and in the vicinity of the sources of impact, eutrophisation and the development of jelly fishes, algal bloom, diseases and outbreaks of corallivorous species. These **processes could be toxic to marine organisms and human beings**.

In a softer scenario, the shift in the trophic composition of the ichthyofauna formerly planktivores on the shallow slope of disturbed reefs in the northern Gulf of Aqaba which could be due to the independence of planktivores from the benthic substrate in terms of food availability.

Also, changes in the fish communities in the northern Gulf of Aqaba due to industrial activities combined with other impacts (coastal constructions, sedimentation, nutrient input, algal growth, coral destruction, heavy metal load) can cause: a reduction in fish abundance, a decrease in total abundance of invertebrates and fish feeders, a change in trophic composition with an increase in total abundance of herbivorous and detritivorous fishes.

Conclusion

According to the lack of accurate data provided by the EIA concerning the impact on the marine environment at the planned site, **the location of the powerplant cannot be accepted until sufficient detailed information on the baseline data and assessed impacts based on scientific evidence are provided**. As the site for pumping and discharging is located in the marine area under the responsibility of EEAA Nature Conservation Sector as part of the National Park of Egypt dedicated to conservation and supporting tourism and local populations, the precautionary principle should be applied and a detailed EIA provided otherwise the project should be relocated at a less sensitive area.

Recommendations:

- to investigate more appropriate technologies that are fully respectful of the marine and coastal environment as there is a zero discharge policy covered by law 102.

- As the description of the different sites during the selection process has not been comprehensively achieved, one would recommend to investigate the marine environment in these areas.

- Background information leads to consider sites, in the Gulf of Aqaba, where depths are greater, coastline abrupt, rocky substrates, coral reefs and seagrass quasi inexistent or quite impacted by industrial activities and coastal development. These factors would be more suitable to the conditions required for the installation of outlet and inlet pipes at greater depths with minimum impact on the marine environment.

- The desalination outlet presently located in the planned location of intake and outlet pipes is illegal as it crosses the setback and discharges in shallow waters, warmer hypersaline waters (>1℃) with brine. The impact is obvious, the area in proximity is azoic. The technics applied presently for desalination plants in Southern Sinai recommend to pump seawater at 150m in the ground at proximity of the coast and to inject the discharged water with brine at greater depths, at 200-300m. This outlet should be relocated. A study is recommended to verify if Nuweiba could follow the same procedure if the geomorphology of the site would be favorable.

- to conduct regular cost-effective assessments/monitoring* strategies of the coastal and marine environment that would establish with a sufficient degree of accuracy and precision the abundances of corals and reef fish on key reef sites in South Sinai, and assess whether these amounts were likely to present a significant change from historical values (Price, 2004; Price *et al.,*1998; Tilot, 2003; 2007b; Tilot *et al.,* 2001; 2008a).

*Proposed strategy of monitoring of the coastal and marine environment:

a. Digital **video-photography assessments of corals** and other benthic habitats will be conducted on primary and secondary transects, and the imagery analyzed (using the AIMS 5-dot method[1)]). The use of video-photography which can with the latest digital equipment (in underwater housing) be used to record larger areas more quickly and more accurately than former photo quadrat methods. Two meters wide video-transects with the camera pointed directly down perpendicular to the reef will be filmed along transect lines and subsequently analysed using the AIMS 5-point method[1]. In addition a standard protocol in which the camera will be held at about 5 m and orientated at an angle to the reef will be used to record the general landscape along the 200m long transects used for counts of fish and large invertebrates. Video-photography will be supplemented by the use of the most current protocol for rapid assessment of coral reef systems[1,2,3,4]in order to facilitate comparison with other studies.

b. **Fish and large invertebrates**: fish in 4 different related groups of families (butterfly-fish & angel-fish; snappers & emperors, groupers, trigger-fish & puffer-fish) which are of key ecological or commercial importance will be counted by underwater visual census (UVC) along 10 m wide, 200 m long band transects at 4 different depths, 1 (mid-lagoon), 3, 10 & 17 m; very large invertebrates including sea urchins, the coral eating crown-of-thorns starfish (*Acanthaster planci*) and giant clams (*Tridacna sp.*) will be recorded along the same transects.

c. **Oceanographic and climatic conditions** will be measured during the surveys and whenever possible, additional data will be collected.

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Appendix 1

Observations (families and genus of most common species at all 3 dive spots within the planned locations in the bay)

Seagrass

Extensive seagrass meadows, with 4 different species, *Halophila stipulacea, H. ovalis, Halodule uninervis,* and *Syringodium isoetifolium*.

Fish

Muraenidae (*Gymnothorax sp., G. monochrous, G. nudivomer; Siderea sp., Siderea grisea*)

Ophichthidae (*Callechelys sp., C. marmoratus*)

Synodonthidae (*Synodus sp., S. variegatus; Saurida sp., S. nebulosa*)

Atherinidae (*Atherinomorus sp., A. lacunosus*)

Belonidae (*Tylosurus sp., T. choram*), in schools

Anthennaridae (*Antennarius sp., A. nummifer, A. commersoni*)

Holocentridae (*Sargocentron sp., S. spiniferum; Myripristis sp., M. murdjan)*

Fistulariidae (*Fistularia sp., F. commersonii*)

Sygnathidae (*Corythoichthys sp., C. schultzi, C. flaviofaciatus; Trachyrhamphus sp., T. bicoarctatus*)

Scorpaenidae (*Pterois sp., P. volitans, P. radiata ; Dendrochirus sp., D. brachypterus, Scorpaenopsis sp., S. barbata, Synanceia sp., S. verrucosa*)

Serranidae, Epinephelinae (*Aethaloperca sp., A. rogaa; Cephalopholis sp., C. argus; Epinephelus sp., E. variola, E. chlorostigma*)

Serranidae, Anthiinae (*Pseudanthias sp., P. squamipinnis*)

Pseudochromidae (*Pseudochromis sp., P. fridmani, P. springeri, P. flavivertex, P. olivaceus*)

Priacanthidae (*Priacanthus sp., P. hamrur*)

Apogonidae (*Apogon sp., A. pselion, A. fragilis; A fraenatus; Archamia sp., A. fucata; Cheilodipterus sp., C. arabicus, C. lineatus*)

Haemulidae (*Plectorhinchus sp., P. gaterinus, P. gibbosus; Diagramma sp., D. pictum*)

Lutjanidae (*Lutjanus sp., L. fulviflamma, L. ehrenbergii*)

Caesionidae (*Caesio sp., C. suevica, C. striata, C. lunaris*)

Lethrinidae (*Lethrinus sp., L. nebulosus; Monotaxis sp., M. grandoculis*)

Sparidae (*Diplodus sp., D. noct ; Acanthopagrus sp., A. bifasciatus*)

Nemipteridae (*Scolopsis sp., S. ghanam, S. bimaculatus*)

Pempheridae (*Parapriacanthus sp., P. ransonneti, P. vanicolensis*)

Mullidae (*Mulloides sp., M. vanicolensis; Parupeneus sp., P. forsskali*)

Pomacanthidae (*Pygoplithes sp., P. diacanthus; Pomacanthus sp., P. maculosus*)

Chaetodontidae (*Chaetodon sp., C. fasciatus ; Heniochus sp., H. diphreutes*)

Pomacentridae (*Amphiprion sp., A. sebae; Chromis sp., C. dimidiata; C. pelloura; C. viridis;C. marginatus; Dascyllus sp., D. aruanus; Abudefduf sp., A. vaigensis; Amblyglyphidodon sp., A. flavilatus; Chrysiptera sp., C. unimaculata; Pomacentrus sp., P. sulfurous*)

Labridae (*Bodianus anthoides; Xyrichtys sp., X. pavo, pentadactylus; Paracheilinus sp., P.octotaenia ; Cheilinus sp., C. lunulatus, C. digrammus, C. mentalis; Gomphosus sp., G. caeruleus; Labroides sp., L. dimidiatus; Labroides sp., L. quadrilineatus*)

Scaridae (mostly juveniles) (*Chlorurus sp., C. ; Hipposcarus sp., H. harid ; Scarus sp., S. ghobban, S. gibbus, S. niger*)

Mugilidae (*Crenimugil crenilabis*)

Sphyraenidae (*Sphyraena flavicauda*)

Carangidae (*Carangoides ferdau*)

Pinguipedidae (*Parapercis hexophthalma*)

Blennidae (*Ecsenius gravieri; Meiacanthus nigrolineatus ; Plagiotremus tapeinosoma ; Cirripectes castaneus*)

Tripterygiidae (*Helcogramma steinitzi*)

Gobiidae (Amblyeleotris sungami ; Cryptocentrus caeruleopunctatus ; Ctenogobiops feroculus ; Valenciennea puellaris ; Amblygobius hectori)

Acanthuridae (*Acanthurus nigrofuscus; Zebrasoma xanthurum, Naso unicornis*)

Bothidae (*Bothus pantherinus*)

Soleidae (*Pardachirus marmoratus*)

Balistidae (*Pseudobalistes fuscus, Rhinecanthus assasi, Sufflamen albicaudatus*)

Monocathidae (*Stephanolepsis diaspros, Paraluteres prionurus*)

Ostraciidae (*Ostracion cubicus, Tetrasomus gibbosus*)

Tetraodontidae (*Arothron hispidus, A. stellatus; Torquigenes sp.; Canthigaster valentini*)

Diodontidae (*Cyclichthys orbicularis*)

Invertebrates

Mollusca

Muricidae (*Murex ramosus*)

Cassidae (*Cassis cornuta*)

Patellidae (Patella)

Vermetidae (Dendropoma)

Conidae (Conus)

Chromodorididae (Chromodoris)

Phyllidiidae (Phyllidia)

Tridacnidae (Tridacna)

Pteriidae (Pteria, Pincatada)

Crustacea

Hippolytidae (lysmata)

Stenopodidae (Stenopus)

Diogenidae

Trapeziidae

Ocypodidae

Cirripedia (Tetraclita and Tetrachthalmus)

Polychaeta

Serpulidae (Spirobranchus)

Sabellidae (Sabellastarte indica and Indian sabella)

Echinoderms

Crinoidea (Oligometra)

Holothuroidea (Holothuria edulis, H. astra)

Echinoidea (Heterocentrotus, Echinometra, Echinotrix, Diadema)

Tunicates

Ascidiidae (Styelidae, Polycarpa, Eusynstyela, Didemnum)

Porifera

Negombata, Aaptus, Suberites, Pione, Stylissa, Hemimycele, Mycele, Ciella, Siphonochelina, Callyspongia

Cnidaria

Hydrozoa : Millepora dichotoma, Platyphylla

Plumulariidae

Scyphozoa

Cassiopeia andromeda

Nausithoe

Anthozoa

Tubipora musica

Rhytisma fuluum

Sarcophyton

Dendronephtya

Lithophyton

Xenia

Antipathes (under overhang of beachrock, usually just show up below 30m)

Cirripathes

Cerianthus

Palythoa

Entacmea

Heteractis

Stichodactyla

Cryptodendron

Pocillopora

Seriatopora

Stylophora

Astreopora

Montipora

Acropora

Goniopora

Porites

Cocsinaraea

Gardinoseris

Pachyseris

Pavona

Galaxea

Fungia

Mycedium

Favia

Goniastrea

Platygyra

Lobophyllia

Plerogyra

Tubastrea

Turbinaria

Description of underwater surveys on the site of planned inlet and outlet pipes

HOUSE REEF SOUTH (dive 1, 17/10/2009)

Ocypode saratan on beach, intertidal

Diving visibility 6-10m

first quarter

sandy, fine mud, slope

seagrass 0-10m (photos 001-007)

artificial reefs (jeep, 2 metallic structures disc shape on top of each other) (photos 008-022)

008-022 artificial reefs, first reef

023-024 sand, seaurchin, seagrass

025-032 second reef, jeep

033-041 seagrass with soft corals on ropes

042-044 desalination outlet with brine

045-048 artificial structure with soft corals and mollusks

049 sand where desalination plant outlet with brine, worms in sand

050-051 sand and some seagrass

052 shallow dead reef with soft coral, shrimps and fish

074 sandbar

Particular species (in order of appearance)

Stephanolepsis diaspros (seagrass) and Trachyrampus bicoarctatus

school of juvenile fish Heniochus (seagrass), school of juvenile Parupeneus

small coral block :

hard corals: Stylophora pistillata, Tubipora musica

soft corals: Sarcophyton

Dendrochirus brachypterus

The Platform artificial reefs:

Rhytisma fulvum

Hard corals: Platygyra sp., Favia, Acropora

Soft corals : Litophyton, Siphonochalina siphonella, Polycarpa

Holothuria edalis

Canthigaster margaritata or Paraluteres arquat

Torquigenes flavimaculatus (plenty around 5 cm)

Canthigaster coronate

Second quarter :

Patchy reef, sandy areas in between (30% live coral) 10-20m

075-083 shallow dead reef with dominance of soft corals

Particular species (in order of appearance)

Sabellas tarbe indica

Corythoichthys cf. schultoi

Pteria aegyptiaca

Pinna margaritifer

Myscale fistulifera, Nausithoe punatata (or Pteria)

Esscenius graviei

Lutjanus

Sarcophyton big and mauve

Juvenils Bodiarus anthioides

Tetraomus gibbosus (sandy area)

Small school of Sphyraena flavicauda

Amblyeleotris sungami/stenitoi

Acanthopagrus bifasciatus

Pseudochromis flavivertex

Paracheilinus octotaenia

Variola louti

A lot of soft corals Sarcophyton

Some hard corals Acropora

Ciscinaraea

Skeleton of sea turtle

Fish Cheilinus lunulatus

Third quarter :

Patchy reef, sandy in between (15-7m), most coral growth (about 60% living cover)

084-093 deeper reefs with higher percentage of live hard corals and great abundance of fish

094-100 Seagrass on sand and reef patches with pearl oysters, higher percentage of live hard coral communities

101 old fish trap

102-181 reefs with higher percentage of live hard coral communities and great abundance of soft corals, schools of fish, big fungia (dating from before the mass death of the reefs probably by siltation when flash floods), high percentage of soft corals

182-193 overhang and caves

194-195 wreck with metallic structure

Mycedium, Galaxea, Pachyseris, Negombala or lotrochata, Pione (Clione) cf. verstifica

Sargocentron

Antennarius

Cirripathes arguina or spiralis

Lobophyllia

Gonopiora, Stylissa cartei, Lutjanus bengalensis, Cryptocentrus cryptocentrus, lusamate ambioenesis

Synanceaia verrucosa

Acthaloperca rogae

Eusynstyela misatiensis, Phyllida varicose, Chromodoris quadricolor, Cryptodendron adhaesiva

Fourth quarter:

sandy slope, seagrass (7m-0)

196 sand

197-203 seagrass dune parallel to coast and slope

204-205 rare seagrass

206-212 small reef patches and beachrock

213-216 seagrass with bunches of coral

Juv. Ostracion,

Redfex forskoehlii

Callechelys marmorata (4 ind), Hermit crabs (Diogenisae)

Lunistor (Muster?)pavo

HOUSE REEF NORTH (dive 2, 17 10 2009)

visibility 10-15m

First quarter:

Sandy entrance, some seagrass and small coral patches (0-4m)

001-003 Seagrass

004-014 beachrock, small patches of reefs on sand, overhang, dead reef

015-017 slope, seagrass, steep slope, sand

Cyclianthys spilostylus

Arothron hispidus

Pocillopora (with Drupella)

Later bigger reef patches and reef slope (1-8m)

018-054 dead reef with some coral colonies and soft coral

Heterocentrotus mammilatus (10% live coral)

Xenia umbellate

Paraprianthus ransonneti

Parupeneus cyclostomus (juv.   and more adults)

Suberites clavata (visible at about 20cm)

Acanthaster planci (at 7m under cave, diameter 20-25cm)

Coris aygula (juv.)

Diagramma pictum (about 30cm)

Epinephelus tauvina

Arothron diadematus

Tubastrea micantha

Gymniothorax griseus

Palythoa tuberculosa

Callyspongia

Polychaeta ‘spagetti worm”

Second quarter:

shallow reef pillars/islands with sandy areas in between (like labyrinth) (1-6m)

(90-100% live coral cover) very diverse corals

063-188 reefs with sand patches, often including sragrass

Chaetodon autsriacus

Juv. Clorurus sordidus

School of Sphyraena flavicauda

Big Porites colonies (6m depth), P. lutea, nodifera, Fungiidae,

Acanthurus nigrofuscus

Millepora platyphylla

Monotaxis grandoculis

Gomphosus caeruleus (females and males)

Third quarter

Same as second quarter, additionally some seagrass patches

Big group of sarcophytons

Zebrasoma xanthorum

Hipposcarus harid

Holothuria astra

Entacmea quadricolor

Pocillopora

Stylophora

Astreopora

Acropora

Goniopora (big colonies)

Gardinoseris or Goniostraea

Platygyra

Favia, Plerogyra, Lobophyllia, Mycedium, Porites

Fourth Quarter

Mainly sandy slope and seagrass, some coral patches

189 sediment with mounds, blocks of dead reefs with soft corals

206-216 seagrass with holothurians and typical organisms

Cerianthus, Holothuria athra, Echinothrix diadema, juv. Conus textile

CHANNELLED WADI, PLANNED OUTLET (FIRST SCENARIO, PGESCO)

(dive 3, 18 10 2009)

001-002 seagrass

003 location according to the coast of the beginning of the dive

004-020 Edge, overhang of beach rock sidewalk

021-043 seagrass with relatively high amount of solid waste

044-050 bits of dead reef colonized by soft corals

051 seagrass with mounds

052-057 dead reef with some healthy live hard coral colonies and soft corals

058 dead reef

059-078 some live coral patches interspersed with sand patches

068 nets

079 fish Cargangoides ferdau

080-097 higher abundance of fish and soft corals and recolonizing hard corals

098-099 Seagrass with mollusks including big Cassis cornuta

100-114 reef patches of dead corals and higher abundance of soft corals and recolonizing hard corals

115-116 patches of dead corals

117-121 more hard coral recolonization

122-139 more regrowth of hard corals on reefs

140 close up of soft corals

143-145 old nets and seagrass

Underwater films

Start at House reef south artificial reefs matches Dive 1 photos 008-022 artificial reefs, first reef

023-024 sand, seaurchins, seagrass matches Dive 1 photos 023-024 sand, seaurchin, seagrass

025-032 second reef, jeep reefs matches Dive 1 photos 025-032 second reef, jeep

033-041 seagrass with soft corals on ropes matches Dive 1 photos 033-041 seagrass with soft corals on ropes

1:33 seagrass communities matches Dive 1 photos 033-041 seagrass with soft corals on ropes

1:53 sandy slope on the planned position of the intake pipes, close to desalination outlet with brine matches Dive 1 photos 049 sand where desalination outlet with brine

2:21 seagrass with some coral communities and dead reefs (Acropora), relatively high abundance of fish communities matches Dive 1 photos 050-051 sand and some seagrass

2:55-4:50 reef between planned intake and outlet pipe (first scenario told to Mike) on sandy bottom, abundance of soft corals, further down slope with seagrass, underwater dune parallel to beach matches Dive 1 photos 052 shallow dead reef with soft coral, shrimps and fish

8:50 3rd dive channelled wadi area of the planned outlet pipe (first scenario told to Mike) sand and seagrass .

10:10 solid waste in seagrass (flushed by wadi when flash floods) matches Dive 3 photos 021-043 seagrass with relatively high amount of solid waste

11:22 reef south of planned outlet (dixit Mike, former location indicated by the company) dead reef with soft corals and rarely small hard coral colonies matches Dive 3 photos 100-114 reef patches of dead corals and higher abundance of soft corals and recolonizing hard corals.

12:10 small crustacean in sand

13: 30 bigger coral patches, mainly dead, with nets matches dive 3 photos 115-116 patches of dead corals

14:40 relatively higher abundance and diversity of hard corals, abundance of soft corals matches Dive 3 photos 117-139 more hard coral recolonization

15:36 schools of diverse fish communities, Anthias..

16:17 sandy bottom, seagrass and big shell Cassis matches Dive 3 photos 098-099 Seagrass with mollusks including big Cassis cornuta

16:25 sandy bottom and coral patches, abundance of soft corals and big Fungia and other mushroom corals, large colonies of soft coral, matches Dive 3 photos 102-181 reefs with higher percentage of live hard coral communities and great abundance of soft corals, schools of fish, big fungia (dating from before the mass death of the reefs probably by siltation when flash floods), high percentage of soft corals

17:22 large colony of massive hard coral

17:29 reef with higher densities of soft corals and large colonies of hard corals Porites and branched corals, Turbinaria,

18 30 schools of barracudas

18:30 Millepora acropra, Fungidae porites

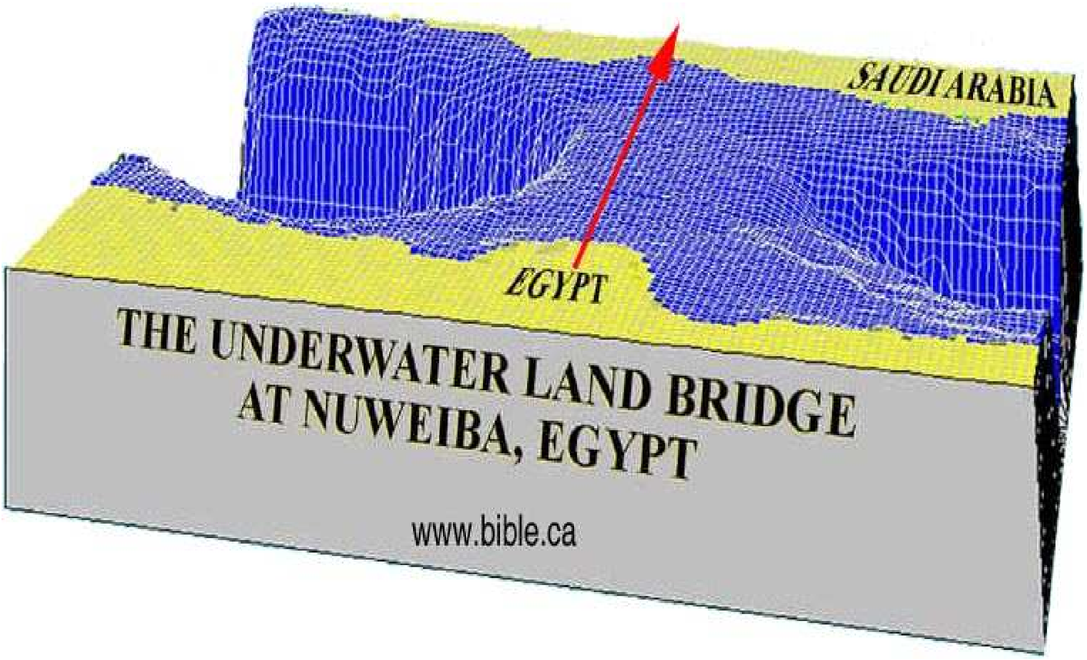
18:48-18:56 net matches Dive 3 photo 068 nets

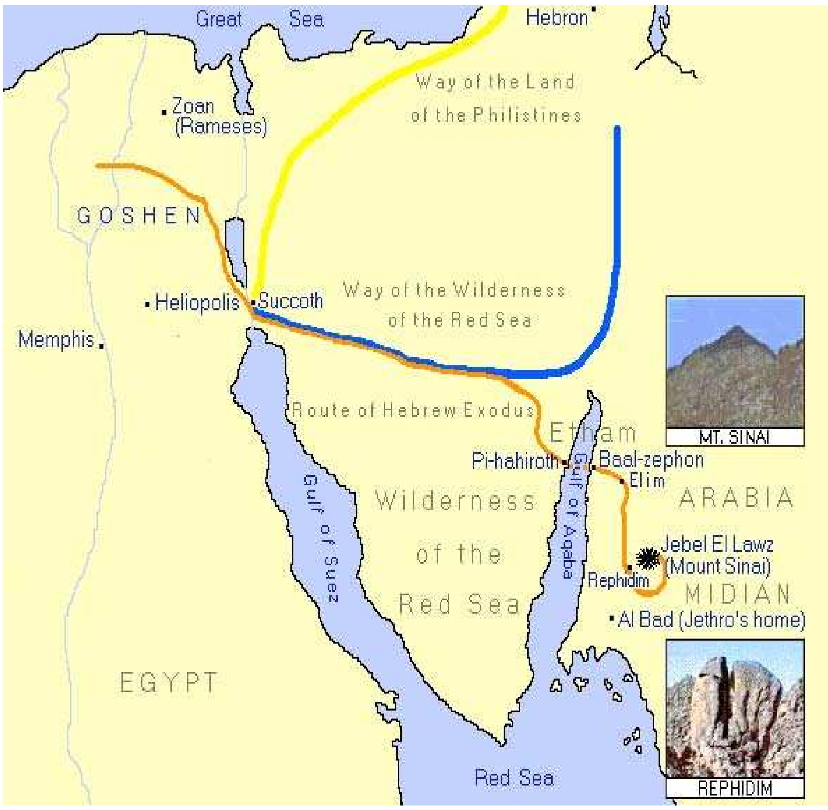
18:56 seagrass area and sand matches Dive 3 photos 206-216 seagrass with holothurians and typical organisms

19:06 beachrock close to planned outlet, it forms a sidewalk parallel to coastline with specific fauna on edge and overhangs and cryptic fauna in darker places matches Dive 3 photos 004-014 beachrock, small patches of reefs on sand, overhang, dead reef

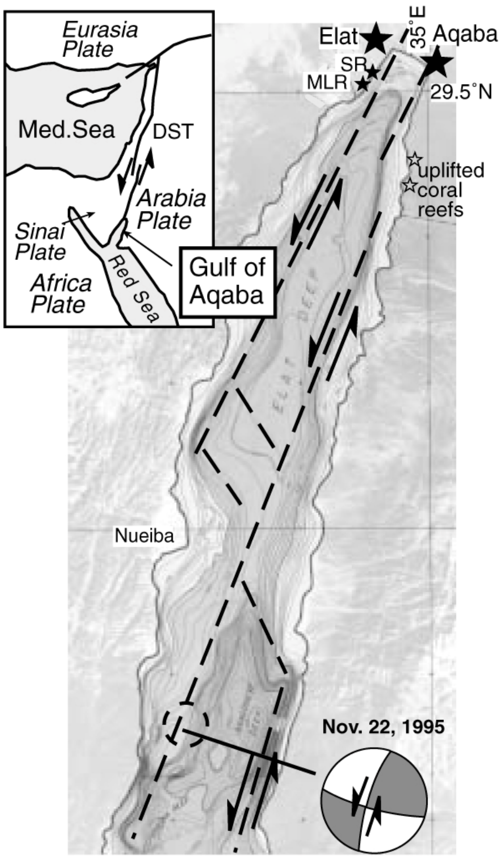
Appendix 2

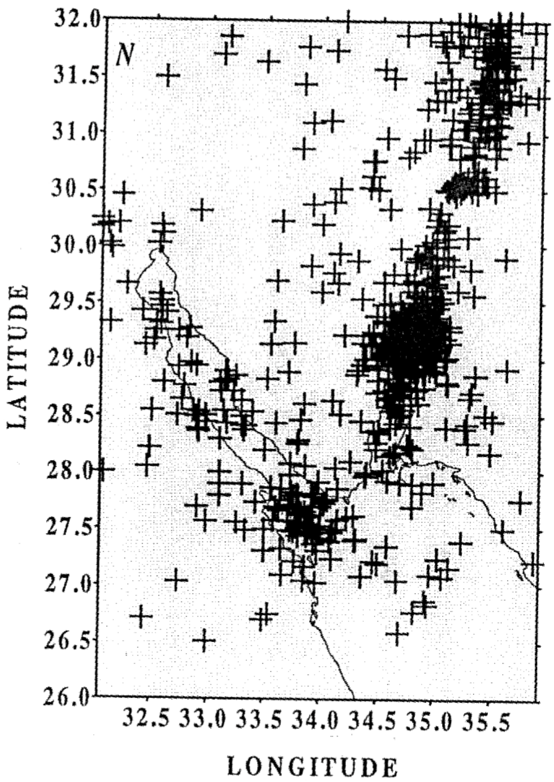
Sonar depth measurements reveal an underwater landbridge between Egypt and Saudi Arabia





Bathymetric chart of the Gulf of Aqaba Epicentral distribution of the Gulf of Aqaba showing the location and solution of the for the period March 1903-December 1993 sinistral 1995 earthquake east of the town of Nuweiba,





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