Egyptian Red Sea Coastal and Marine Resources Management Project
Preliminary Risk Assessment Report

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Introduction

Within the Red Sea Region of Egypt there is a range of potential risks that can affect environmental quality and resource sustainability for both short and longer term scenarios of expanded tourism development. For this region a critical focus should be placed on maintaining the quality of marine resources so that tourists will want to continue visiting the region, and that these resources will continually provide for future generations. Consequently, it is important to understand the environmental risks associated with increased tourism development and the potential ramifications that such expansion can have on the quality of both environmental and human health.

Ecological risk assessment is a process that identifies stresses in the environment, characterizes them and analyses their potential effects on environmental quality. The process also identifies levels of uncertainty based upon the current knowledge of a given stress, and the information and actions necessary to reduce that level of uncertainty. The information base for the issues along the Red Sea coast varies widely, and therefore needs a standardized framework if such issues are to be understood and effectively managed.

A Risk Assessment Framework

Ecological risk assessment operates within a framework that identifies either individual or specific sets of environmental threats and analyzes available information. These are often contaminants (such as specific chemicals), but any threat to environmental quality, such as litter along the shoreline or excessive sediment, can be classified as a potential "stressor". The term "stressor" refers to any physical, chemical, or biological entity that can induce an adverse effect. Stressors can be natural or human-induced; either classification has the potential to be better understood and managed based on dissecting the cause and effect.

The framework for assessing ecological risk involves several steps. Throughout the process, data acquisition, verification and monitoring are consistently required. Thus, the process involves setting goals and objectives by environmental managers at the outset, and then using information bases and data collection in evaluating the goals and objectives, and assessing and managing ecological risk.

For this preliminary report, the framework for assessing ecological risk is presented below generically, and then these concepts are applied to Hurghada, Egypt in a case study context. The case study will require further development as additional information about the area is collected and refined. Furthermore, the basic assumptions adopted for problem formulation presented for this preliminary draft may be modified by the core team.

Step 1: Problem Formulation

An important first step in risk assessment, known as problem formulation, involves discussions with environmental managers, in-country experts, and review of data and sources, to identify the major issues that will be considered critical. The management goals and objectives at this stage are essential, for they establish the standards in defining the mission of the assessment. At the problem formulation stage potential stressors are identified and inventoried. In the Red Sea's case, stressors may range from point source pollution, oil spills, specific chemicals, threats of natural events (such as floods associated with wadis) and possibly even levels of tourism or overfishing. Ecological components impacted by the identified stressors (such as keystone indicator species on a coral reef or mangrove community) are also identified.

As part of problem formulation, constructing a conceptual model can be useful to understand the exposure pathways of contaminants along the Red Sea Coast. For the purposes of this report, Hurghada, Egypt (and areas to the south) will be used as the conceptual case study to develop an ecological risk assessment procedure for the Egyptian Red Sea Coastal and Marine Resources Project (see Figure 1).

The outcome of problem formulation is documentation of the rationale for, and decisions about the products developed during this step. Problem formulation not only sets the foundation for the analysis and characterization of the risk assessment, it can also provide recommendations about needs for further research, and identification of stressor-assessment endpoint[1] relationships that may not have been considered before. In some cases problem formulation may be sufficiently compelling to elicit some management action without going through the entire risk assessment process. An example might be identification of a solid waste facility with leaching chemicals located within the 200 meter coastal setback zone. Obviously, no assessment would be required to determine the necessary management action. Likewise, excessive solid waste and debris along the shoreline can be collected and properly disposed without the need of assessing its risk to intertidal and subtidal resources.

Analysis Plan

An analysis plan is the final phase of problem formulation. Here risk hypotheses in the conceptual model are evaluated to determine how they will be assessed using available and new data. The design of the assessment, data needs, measures, and methods for conducting the analysis are delineated. Data may come from many different sources. For example, if a new hotel construction is planned that may cause physical obstruction in or near a wadi, disturbance, potential pollutants, data on wildlife migration routes, physical topography, location of potential pipelines, or seismic activity are possible data that may

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[1] Refer to the definition of "endpoint" under Risk Analysis

be needed to evaluate hypotheses about risk to human safety and wadi integrity as a result of hotel construction. These are incorporated into an analysis plan which includes the most important pathways and relationships identified during problem formulation that will be pursued in the analysis phase. A plan may be constructed for each identified stressor or group of related stressors. Data availability will determine how well these pathways can be pursued. Where data are not available, recommendations for new data collection should be part of problem formulation. Obviously, this has implications for long term monitoring and evaluation throughout the Red Sea coastal zone.

Step 2: Risk Analysis

Step two is an analysis of ecological effects and exposure. The characterization of exposure to stressors and their effects should be based on ecological factors (community structure or chemical and physical pathways) and human values, and involves understanding the cause and effect relationships between various practices and resource use.

The *assessment endpoints* identified during risk assessment are those coastal resources of the Egyptian Red Sea region that may be affected from several main factors-- such as persistent, chronic impacts from resource use (land use and associated pollutants), physical use and carrying capacity of specific resources (such as coral reefs and effects associated by diving tourists, fisheries) and pollution events (such as oil or chemical spills). In short, an assessment endpoint is an explicit expression of a particular resource or environmental value that is to be protected.

Measurement endpoints are those parameters that are chosen to monitor the status of a given resource to determine levels of exposure and environmental quality. For example, in the case of coral reefs, measurement endpoints would include percent live coral cover--ratio of macro algal cover to hermatypic reef cover; percent diseased corals, species richness or diversity, or even tourist/use intensity. The possibility that multiple stressors may confound the interpretation of risk also needs to be considered, and will be addressed later in this report.

Characterization of exposure

Characterization of exposure involves specifically defining the specific pathways of a given stressor on an assessment endpoint, and collecting data on the contaminant levels in a given area. The characterization of ecological effects may include a suite of measures (based on available data). Toxicity tests, field surveys, residue levels and other current data can be collected and compared either to accepted thresholds or criteria, or to designated, non-impacted or reference sites.

<u>Step 3: Risk Management</u>

Once the framework is in place (problem formulation, stressors inventoried and their characterization of exposure and effects completed), and information sources and gaps are clearly identified, then two further steps can occur. First, in many cases levels of uncertainty of risk can be quantified based on information availability. Second, a risk management strategy can be developed to increase the information base through monitoring and evaluation. Management and action programs can be designed to minimize the risk of stressor exposure to resources.

Evaluation of Uncertainty

Levels of uncertainty in assessing environmental risk are directly related to the information base developed for a particular stressor. In some cases determination of uncertainty has been better developed, due in large part to detailed laboratory analyses for particular pollutants (i.e. pesticides and oil). For example, in the case of contaminants, predicted or measured ecological toxicity data can be used to calculate a concern concentration (CC) in assessing risk. The CC, based on the extent and type of data available, is calculated by dividing the toxicity data by an appropriate assessment factor (ASF). Typically a base set of data for evaluating the potential ecological effects of a chemical would include a 96-hr LC50 to a fish, a 48-hr EC50 to an invertebrate and a 96-hr IC50 to an alga. Tests which measure end points such as lethality are considered acute tests while tests which measure end points such as reproduction and growth over the full life-cycle of the test organism are considered chronic. If the base set of data were provided the CC would be equal to the toxicity measured with respect to the most sensitive organism. This approach provides conservative estimates until more specific data can minimize the level of uncertainty.

In field testing, a predicted environmental concentration (PEC) is calculated based on the highest predicted environmental release under "worst case conditions". The PEC depends on the processes and environmental controls that may be in place (such as the level of treatment within a sewage treatment plant). The PEC is estimated to be the amount of material which is not removed in the treatment process divided by the stream flow for that location or locations where minimal dilution might be expected in the receiving water.

In combination with the above mentioned concentrations (CC and PEC), the quotient method is frequently employed to evaluate the safety margin for a chemical in the environment. The quotient method refers to the ratio of the CC to the PEC. A ratio greater than 1 indicates that a safety margin exists and that no impact on the environment is expected. If a safety margin less than one is calculated, then several options are possible; additional data could be obtained to lower the uncertainty in the data, lower process releases or improved waste treatment could be used to lower the PEC. These steps would be part of the risk management process.

Complications in the risk assessment paradigm may exist when; trying to evaluate impacts of organisms which could reproduce in the environment, ecological effects which do not have a threshold concentration so that a clear no-effect concentration does not exist, potential for synergistic effects (for example, multiple stressors) or additive toxicity in the environment and ecological effects which do not have a specific organism against which a threshold could be benched marked (such as global warming). However, this is directly related to the comprehensive state of knowledge following the risk assessment, and the quality of the resulting monitoring programs established to improve the coastal resource information base.

Uncertainty in other contexts, such as wadis, sea level rise, and global warming, will require a more qualitative, assessment, at least initially. Uncertainty for other risk factors, such as tourist visitation on coral reef sites will use a combination of measurements and qualitative indicators.

Multiple Stressors

Previous research has focused on cause and effect relationships between individual stressors and the impacts they may have on individual organisms. However, recent research indicates that individual stressors are unlikely to be the sole causes of environmental impacts. Instead, a combination of stressors and factors (whether chemical, biological, or physical) are likely to confound any effects or risks associated with a specific identified stressor. The advent of computer modeling using nonlinear algorithms is enabling improved analyses of multiple environmental stressors, and examples in the coastal marine environment have been identified (i.e. temperature, nutrient concentrations and salinity demonstrating combined effects on water turbidity in South Florida, USA). An improved understanding of the role of multiple stressors in assessing risk underscores the importance of effective monitoring programs that systematically collect and quality-assure specific environmental metrics, such that multiple stressor analysis becomes possible.

Risk Management and Action Programs

Once a framework has been developed and the gaps of information determined, then a risk management action program can be designed to:

- re-prioritize those issues where little analysis is required, yet immediate management action is possible;
- design modifications to existing data collection necessary to complete gaps in a given database about a particular stressor or set of stressors;
- collect additional data that are required to reach an informed decision about a potential risk, and specifically where those data need to be collected.

This management and action plan can then serve as a feedback mechanism for continued risk analysis and evaluation.

Hurghada Case Study

The Hurghada area is chosen as a case study for developing a risk assessment framework, largely because it is the largest of the coastal communities within the project area, and has the potential to cover a broad range of relevant issues. The following framework provides examples of how information is identified, developed and reported; it is not intended to be comprehensive or exhaustive in its coverage at this stage of development. It should be noted that portions of the framework are incomplete pending further field investigation and the generation of additional, specific information, or a modification of basic assumptions by the core project team.

Problem Formulation

Based on a review of available data, and preliminary discussion with some of the in-country team and experts during the November, 1997 mission by the consulting team, an inventory of coastal resources and potential stressors were identified (Table 1). A conceptual model of the resources of interest, the stressors and their introduction into the environment help elucidate the pathways by which contaminants, activities or events can affect the coastal zone (Figure 1). The characterization of ecological effects for each assessment endpoint are presented under Risk Analysis and are based on currently available data, such as the baseline report, coastal surveys, and the scientific literature.

The Hurghada area has rapidly expanded along the Red Sea coast to the north and south. As a result of significant construction, nearshore ecological resources are potentially at risk. These resources include beaches, mangroves and associated wetlands, seagrass beds and coral reefs. Coral reefs are an especially important resource of concern to the Hurghada area, because of their value to the tourism industry on which much of the new coastal expansion has been based. Nearshore reefs have already sustained damage from unplanned hotel and tourist growth, through activities such as land filling, excessive sedimentation and over-fishing (Baseline Report, 1997).

The purpose of this risk assessment is to systematically inventory and examine all potential stressors, and develop an ongoing information base and plan to determine those resources that are at greatest risk (see Table 1), and develop monitoring and management programs aimed at reducing that risk (Figure 2).

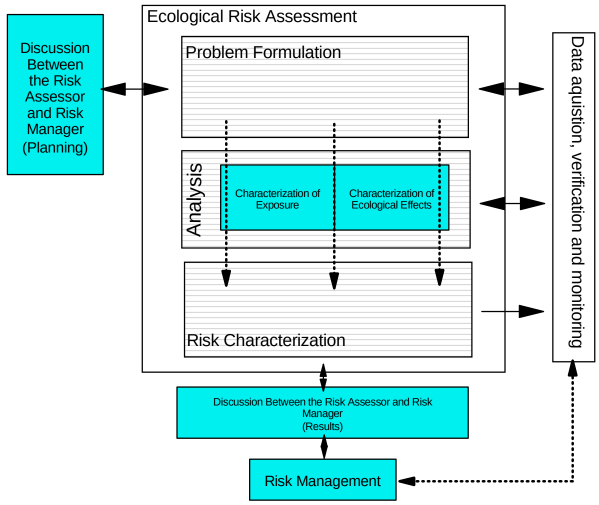

Figure 2. Risk Analysis planning framework.

Risk Analysis

Analysis includes the technical evaluation of data on the exposure to stressors, and their effects. This can involve either measuring or predicting the distribution of a given stressor over both space and time, and its interaction (or contact) with the resources (or assessment endpoints) initially identified during problem formulation (for example, the conceptual model presented in Figure 1). While predictive models can be useful in helping to assess risk, this example currently relies entirely on literature values from studies elsewhere, laboratory analysis for individual species either closely related or known to occur in the region, and available field data, if any. For Hurghada, several of the resources and stressors identified in Table 1 are individually examined below in the context of risk characterization. Other resources or stressors are presented in outline format only, and require additional information and further investigation to accurately characterize exposure and risk. Table 1 also identifies where data gaps are evident, and likely require either additional data or more detailed data collection and analyses.

Risk Characterization

Resource at Risk: Coral Reefs
Stressor(s): Sewage, excessive nutrients, sedimentation, diving tourists, anchor damage
Exposure pathway(s): Sewage outfalls adjacent to hotels, municipal plants, urban centers, individual treatment plants, groundwater seepage, .

Characterization of ecological effects:

The dynamics of coral mortality and algal growth resulting from sewage pollution have been studied on a fringing coral reef near Aqaba (Walker and Ormond, 1982). The reefs are affected by sewage discharge and by sediment deposition from an apatite ore loading facility. Although the relative importance of sewage pollution and apatite loss from ships was not determined, spatial affects of the sewage discharge were apparent. An increase in algal cover, a decrease in coral diversity, and an increase in small grazing mollusks were "obvious" from a 5m 'upstream' to approximately a 50 m 'downstream' location from the outfall. Walker and Ormond (1982) found that the death rate of coral tissue near the outfall was 4-5 times the death rate observed in a control area. *Stylophora piscillata*, a fast-growing opportunistic species (Loya 1976), was the only remaining abundant coral. Dead portions of colonies were covered with filamentous algae.

Although biomass of algae was elevated at the outfall site compared to the control area, algal overgrowth did not appear to be a direct cause of coral death. Mortality was possibly related to inhibition of calcification by high phosphate concentrations, stress caused by high sediment loads, or localized bacterial infection triggered by the sewage effluent. Because grazer populations were higher at the sewage area compared to the control site, Walker and Ormond (1982) attributed the excessive algal growth to nutrient enrichment rather than a relaxation of grazing pressure. The authors concluded that the effect of increased sediment loads near the outfall were greatly aggravated by the ability of the algal mats to trap sediment, resulting in further stress to adjacent coral tissues.

Sedimentation: Corals are physiologically and ecologically adapted to sediment as a constant variable within their environment. However, excessive sedimentation has been shown to have deleterious effects on corals. In Hurghada, over a given year only 2% of the days are considered calm from constant winds (Hefny 1997). While over 40 different dive sites with coral reefs have been identified in Hurghada, only about 5-7 are consistently used because of the the wind. Wind carries airborne sediment and causes the resuspension of sediment in nearshore, shallow waters, thus increasing the total suspended solid concentration within the water column. However, heavy sedimentation form construction sites, impervious surfaces (such as roadways) and flash flooding from heavy storms at the deltas of wadis pose a much greater risk to nearshore coral communities. Table 2 provides an indication of the range, risks, threshold concentrations, and impacts for sediments among various coral reefs through out the world.

Table 2. Range and risks associated with sedimentation on corals

Impact	Sedimentation Rate $mg/cm^2/day$	Reference
slight to moderate	6-20	Randall and Birkeland (1978)
decreased abundance/cover	3	Loya (1976)
altered growth forms	7-8	Lasker (1980)
decreased growth rates	~1	Dodge et al. (1974)
possible reduction in recruitment	1-15	Ott (1975)
possible reduction in nos. of spp.		

moderate to severe *greatly decreased abundance/cover* *greatly decreased growth rates* *predominance of altered forms* *reduced recruitment* *decreased nos. of spp.* *possible invasions of spp. (i.e. algae)*	20-50 15 14 37 (6-125) 10	Randall and Birkeland (1978) Loya (1976) Lasker (1980) Griffin (1974) Morelock et al. (1979)
severe to catastrophic *severe degradation of communities* *most spp. excluded* *many to most colonies die* *recruitment severely reduced* *regeneration slowed or stopped* *invasion of open substrates by opportunistic spp.* *coral cover severely reduced*	>50	Randall and Birkeland (1978)

Source: USEPA, 1983

Heavy metals: Heavy metals may also be a stressor for coral reefs; however, aside from quantified ranges (Table 3), little specific information exists as to any lethal concentrations. Clearly, more research is needed to determine whether heavy metals pose a threat to corals.

Table 3. Range of heavy metal concentrations recorded in corals reefs from previous research.

Component	**Fe**	**Zn**	**Cu**	Pb	Ni
Water Column (mg/L)	1.0-5.93	0.02-1.5	0.01-1.8	0.18	-
Sediment (μg/g)	237-11,445	7.6-40	2.2-1.7	18-45	74-122.6
coral skeleton (μg/g)	ND-560	0.08-25	0.24-18	0.04-39	ND-126
coral tissue (μg/g)	ND	ND-126	7.5-18	4.8-31	-

Source: Peters et al. (1997)

Diving Tourists: As an economic cornerstone to Hurghada, diving among the Red Sea's high quality coral reefs and seagrass beds is an expectation for many of its tourists. In Hurghada the number of dive operators has been estimated between 80 - 112. There are 40 estimated dive sites, but only 5 or 6 can be dived most days given weather conditions. The most popular areas in Hurghada are: Giftun Island, Abu Ramada, Careless Reef, Sha'ab Umm Qamar, Sha'ab Abu Nuhas, *Thislegorm* (wreck) and the Brothers Islands (Baseline Report, 1997). Large numbers of tourists diving on a limited number of sites have the potential to impact corals and their associated species. Handling and breaking corals, collecting souveniers, over fishing and anchor damage from pleasure craft all have the potential to significantly impact this resource.

Potential measurement endpoints to determine impacts to coral reefs:

- Percent coral cover (with temporal comparisons)
- Phosphorus tissue concentration (in algae)
- Nitrogen concentration in algal tissue
- Nitrogen:Phosphorus ratio
- Percent algal cover
- Chlorophyll a (for remote sensing)
- Disease Frequency
- Water quality measurements for background concentrations of SRP, DIN, Total Suspended Solids, other parameters
- Percent coral breakage from tourists, anchors
- Parameter comparison to control sites

Resource at Risk: Beaches

Stressor(s): Solid waste, oil, debris, land filling

Exposure pathway(s): improper disposal of solid waste and litter; oil spills or bilge pumping; improper disposal of hazardous chemicals.

Characterization of ecological effects: Solid waste, oil and land filling has the potential to interfere with coastal processes. The stressors can physically smother land features, flora and fauna, and are potential sources of chronic leaching into nearshore waters. Certain debris can also pose human health risks.

Potential measurement endpoints to determine impacts to beaches:

- Percent coverage or presence of solid waste, letter or debris (and an observed trends in this statistic over time)
- Level of use of a given beach by people

Resource at Risk: Mangroves and associated wetlands

Stressor(s): Heavy metals, oil, sedimentation (from flash flooding), pesticides, hypersalinity

Exposure pathway(s): Solid Waste (and litter); sediment deposition from storm events; increased salinity from limited tidal inundation and evapostranspiration; oil spills or bilge pumping; improper disposal of hazardous chemicals.

Characterization of ecological effects: Mangroves often serve multiple functions along coastal zones, but clearly are transitional buffers (or ecotones) between the land and sea interface. Mangroves provide habitat for both fish and invertebrates (especially juveniles) and wildlife, and provide a filtration function for land-based sediment and pollutants at ambient concentrations, and shoreline stabilization functions along coastal shores. These functions may be impaired if exposure pathways are modified such that one or more of the stressors identified above impacts mangroves and associated wetlands in significant or chronic concentrations.

Heavy metals: Table 4 provides some indication of the species and range of heavy metal concentrations that have been measured at various impacted mangrove sites around the world.

Table 4. Ranges of heavy metal concentrations recorded in mangrove communities from previous research worldwide.

Component	**Fe**	**Zn**	**Cu**	**Mn**	**Cd**	**Pb**
Sediments (µg/g dry weight)	100-33,492	0.28-379	0.3-75	1.23-640	0.1-2.39	1-650
Suspended Material (µg/L)	195-2,808	18-595	62-76	466-788	2.85-3.2	21-139
***Rhizophora* spp.** (µg/g dry weight)	0.16-166	0.03-32	0.12-11	0.42-497	0.04-0.24	0.43-27
Invertebrates (µg/g dry weight)	124-886	30-1,800	2.6-20	4.8-31	0.4-10	0.9-5.06

Source: Peters et al. (1997)

However, these ranges for these heavy metals provide no information regarding any lethal contamination values for mangroves. Such information will be required through detailed literature searches or field and laboratory research within the region.

Oil: Mangroves and associated wetlands are highly sensitive to spilled oil. Given the generally small grain size of sediment within these communities (thus high surface areas), the low wave action and tidal amplitude make mangroves vulnerable to smothering by oil. Given its high biological oxygen demand, oil can effectively halt mangrove community production if in large quantities, due to translocation of the oil-related chemicals into plant tissues. However, no threshold concentrations or lethal doses have been standardized for mangroves, and vary from site to site. Communities with heavy or chronic exposure to oil or other pollutants are generally at greater risk to any additional perturbation.

Pesticides: Mangroves are also highly sensitive to pesticides or other organophosphate or chemical contaminates. Most data on the effects of pesticides on mangroves have been collected in postwar evaluations following herbicide or defoliate applications.

Measurement endpoints:

- For mangroves and associated wetlands, inventories of the geographic location of those communities of concern should be identified and mapped at sufficiently large scales.
- Productivity (in $gC/m^2/yr$)
- Contaminant concentration within plant tissue, sediment
- Percent oil coverage

Resource at Risk: Wadis

Stressor(s): Flash flooding; excessive sedimentation

Exposure pathway(s): Runoff and associated sediments

Characterization of ecological effects:
Based on the report by Hefny (1997), zones of increased potential risk are those subjected to direct flow of water from flood events. The level of risk increases where the geological structure, relief topography (i.e. percent slope) and sediment morphology is conducive to initiating large floods with high water velocity. Basic criteria were established to rank those wadis with greatest potential (Table 5; see table 4.1 in Hefny, 1997 or table 4-21 in the baseline report). While it is clear that Hurghada is bordered on the north and south by wadis (see Map #4 of the baseline report), detailed inventory and ranking of those features near Hurghada is not presently available for this report.

Risk Level	**Risk Factor**			
	Water Depth (cm)	Water Velocity (m/s)	Max. Diameter (cm)	Sed. Volume (1000 m^3)
High	> 50	> 2.0	> 12.5	> 100
Medium	25 - 50	1.2 - 2.0	8.0 - 12.0	50 - 100
Low	< 25	< 1.2	< 8.0	< 50

Table 5. Taken from Hefny (1997). Criteria established for risk classification of wadis. These criteria require assignment to the various wadi features within the region to geographically reference those sites with the highest risk potential. For ecological risk, 50 and 100 year flood events have the greatest potential to impact nearshore environmental resources, such as mangrove wetlands, seagrass beds, and coral reefs fringing immediately adjacent to the shoreline.

Multiple stressors in combination with the issue of 50 or 100 year floods could lead to decisive mortality if the other stressors are chronic. While it is obvious that from a risk minimization perspective, human settlement should occur away from wadis, they should also not be viewed as areas suitable for secondary human activities (for example, adjacent industrial development or public works, such as solid waste or land fill facilities). Given the flood potential of these areas, the transport of contaminants to the Red Sea is likely if land use practices locate sources adjacent to these features without proper controls. Should chronic stressors be present from other sources, (i.e. heavy metals or pesticides) pulse events, such as flash flooding, have a higher potential to reach a precipice or threshold for community stability (such as smothering seagrass beds or corals, and subsequent mortality by sediment). Land use in and around wadis should be regulated to minimize risk of contaminant transport during floods. Mineral extraction activities in wadis may increase substrate instability, thus leading to larger sediment deposition during storm events.

Resource at Risk: Seagrass Beds
Stressor(s): Sedimentation, Pesticides, Increased salinity (RO discharge), sedimentation, heavy metals

Exposure pathway(s): Proximity to pollutant sources, or deltas.

Characterization of ecological effects: To be developed

Potential measurement endpoints:

- Inventories of the geographic location of those communities of concern should be identified and mapped at sufficiently large scales.
- Productivity (in $gC/m^2/yr$)
- Contaminant concentration within plant tissue, sediment
- Standard physical-chemical parameters within the water column

Resource at Risk: Water Quality

Stressor(s): Sediment, pesticides, oil, industrial effluent, sewage, agricultural runoff, nonpoint source pollutants from urban and impervious surfaces.

Exposure pathway(s):

- Sewage outfalls (abundance and distribution along the Hurghada coast)
- Industrial Point Sources
- oil refineries
- Dry-dock facilities (paint)
- Tin Washing areas
- Pesticides
- Phosphate mining
- RO discharge (Increased salinity)
- Sedimentation
- Heavy Metals

- Solid Waste (and litter)

<u>Characterization of ecological effects</u>: To be developed

<u>Potential measurement endpoints</u>: To be developed

Levels of Uncertainty

Based on the above examples the levels of uncertainty are generally difficult to quantify given the limtied available data. However, in the case of corals and sediment as a stressor, one tool used to calculate uncertainty, can be demonstrated as an example. The Quotient Method, presented in the introduction, can define a level of uncertainty based upon the ratio of a concern concentration (CC) to the predicted environmental concentration (PEC). Based upon sediment threshold data presented in Table 2, severe impacts from sediment were based upon >50 $mg/cm^2/day$. Thus, as an example 50 $mg/cm^2/day$ could be argued as the CC. Should subtidal sediment traps placed along several of Hurghada's construction zones indicate a rate of 60 $mg/cm^2/day$, then this quotient ratio would fall below 1.0, indicating that the safety margin for this stressor has been exceeded. Therefore coorective measures would be needed to reduce the PEC the risk to nearshore corals.

Risk Management and Interim Recommendations

Given the present status of these examples of exposure and ecological effects analyses above (i.e. the gaps in specific information), it is currently difficult to summarize the likelihood that adverse ecological effects are occurring to some of the resources (or assessment endpoints), until the specific locations, exposure pathways and concentrations (if applicable) are comprehensively identified. However, it is clear that given the existing development and land use within the Hurghada area, exposure and risk to nearshore resources has been highest in construction zones.

Clearly, the reduction of exposure and risk to such resources in and immediately adjacent to these areas and the management options available are somewhat obvious: remove immediate accute and chronic threats, institute rehabilitation or restoration programs, and monitor change compared to unimpacted reference sites. However, the more significant challenge lies in identifiying the stressors and their exposure to the highest valued resources, and anticipating those environmental impacts that may be induced through the interaction of multiple stressors. The monitoring programs and the measurement parameters necessary to foresee those potential risks and impacts will be developed as a result of this process. Therefore, based on these current examples, a risk management plan for Hurghada should initially contain the following components:

1) those obvious management actions that can readily reduce exposure, risk and negative impacts to nearshore coastal and marine resources as presented in the conceptual model (Fig. 1; for example, reduce litter, inventory sewage outfalls or other on-site sewage disposal facilities) in those areas where land use is most intensive;

2) inventory those areas in Hurghada where more specific information can elucidate the exposure and characterization of effects (i.e. industrial and commercial facilities);

3) identification and coordination of all existing monitoring programs within the Hurghada area, so that level of effort in data collection is as efficient as possible. Such an inventory will identify and help prioritize what additional monitoring programs require implementation to address the resources of highest concern.

Clearly, there are other aspects of ecological or environmental risk that can be examined and discussed here; however, this preliminary report defines the basic framework that applies to all identification, analysis and management of risk, and provides a practical tool for coastal management.

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Table 1. Inventory of risk assessment endpoints, stressors, measurement endpoints and their information status as related to Hurghada, Egypt.

Resource or Stressor	**Assessment Endpoint (Management Expression)**	**Source/ Location**	**Measurement Endpoint(s)**	**Data Available?**	**Existing Monitoring Program?**
RESOURCES					
Wadis	Ensure that wadis do not become a significant point source of sediment or pollutant loading to coastal resources. Ensure that land use activities adjacent to wadis are not subject to flood hazards, substrate instability or injurious to human health.	North and south of Hurghada	Water Depth (cm); Water Velocity (m/s); Max. Diameter (cm); Sediment Volume (1000 m^3). Identification of high risk zones.	Yes; Hefny, 1997; none on sediment chemical composition	unknown, but recommended in Hefney report.
Beaches	Ensure that Hurghada beaches are clean, 100% free of litter and debris, and safe for human use. Ensure that sensitive nesting sites for wildlife, especially sea turtles, are adequately protected.	specific inventory required with geographic reference for each beach identified. Determination of level of debris, and identification of priority sites	percent litter cover, level of usage; sea turtle nesting site	unknown	unknown for Hurghada, but shoreline debris noted during coastal assessment and sampling by Dr. A.E. Rifaat, et al., Oct./Nov. 1997
Mangroves and associated wetlands	Ensure that mangrove and associated wetlands are buffered from pollutants and sediment loading, so that they may continue to provide effective filtration, energy storage, nursery and wildlife habitat functions and support other critical marine ecosystems.	specific inventory required with geographic reference for each significant mangrove/wetland area identified.	species composition and dominance; spatial area; productivity (gC/m^2/yr); pH; salinity; concentrations of heavy metals; population dynamics of associated fish, invertebrates and wildlife	unknown	unknown for Hurghada, but mangrove communities identified during coastal assessment and sampling by Dr. A.E. Rifaat, et al., Oct./Nov. 1997
Seagrasses	Ensure that seagrass communities continue to provide sediment retention functions, nutrient cycling and critical nursery habitat	specific inventory required with geographic reference for significant seagrass beds.	Phosphorus tissue concentration, Nitrogen concentration, O_2, concentration, salinity, relative percent gross	unknown for Hurghada; some data available from research elsewhere.	unknown

Resource or Stressor	Assessment Endpoint (Management Expression)	Source/ Location	Measurement Endpoint(s)	Data Available?	Existing Monitoring Program?
	functions to support fisheries and coral reef ecosystems.		epiphytic cover, disease frequency in fish or invertebrates, water quality: measurements for background concentrations of SRP, DIN, TSS. Sedimentation, Species inventory and relative abundance of adults and juveniles of selected species.		
Coral Reefs	Ensure that coral reefs are protected and sustained for use by the tourist industry and fisheries while their integrity as the highest quality reefs in the world is not diminished.	specific inventory required with geographic reference for each significant coral reef. Baseline report identified over 40 sites near Hurghada, but only 5-7 routinely visited by divers given average weather/wind conditions.	Phosphorus tissue concentration or enzymatic assay (in algae), Nitrogen concentration in algal tissue, Percent algal cover, Chlorophyll a (for remote sensing), Disease frequency in corals, fish or invertebrates, water quality, measurements for background concentrations of SRP (>0.01 μ M), DIN (>0.1 μ M) threshold concentrations, TSS; N:P ratio; ratio of algal cover to hermatypic scleractinian corals. Species inventory and relative abundance of adults and juveniles of selected species. Number of diving tourists, percent damage to corals from visitation.	unknown for Hurghada; data available from research elsewhere, as well as some laboratory studies	unknown for Hurghada specifically; some data may be available from recent coastal survey by Dr. A.E. Rifaat, et al., Oct./Nov. 1997
Fisheries	Ensure that fisheries provide sustainable yields for future generations while maintaining species diversity.	number and source location of fishers: artisanal versus transient. Number of Fishermen in Hurghada	location of spawning areas and population dynamics of commercially important species; volume of catch, and temporal analysis;	Breika, M.I.M. 1997. Present status of the fisheries in the southern part of the	unknown

Resource or Stressor	Assessment Endpoint (Management Expression)	Source/ Location	Measurement Endpoint(s)	Data Available?	Existing Monitoring Program?
		area: 2,022 (or 11% of total)	technical efficiency currently used	Egyptian Red Sea coast; from Hurghada to Shalateen. GEF Egyptian Red Sea Coastal & Marine Resource Management Project	
STRESSORS					
Sewage	Manage sewage to the extent that it becomes an effective resource as opposed to a pollutant	sewage outfalls, hotel septic tanks/drainfields or cesspits, boats, in transit or in marinas, industrial facilities, residences	concentrations of N, P fecal coliform bacteria in the water column, Phosphorus tissue concentration (in algae), Nitrogen concentration in algal tissue, Percent algal cover, Chlorophyll a (for remote sensing), Disease Frequency in corals, fish or algae, water quality, measurements for background concentrations of SRP, DIN, TSS.	unknown in Hurghada; data available from research elsewhere.	Yes, along at some stations along coast as part of background data collection, but not specifically targeted to outfalls in Hurghada
Miscellaneous Chemicals	Manage chemical discharge so that its introduction into the environment does not result in pollutant concentrations that adversely affect coastal resources or human health.	roadways, hotels, urban runoff, boats, marinas, industrial facilities, bound to sediment, ground seepage	chemical concentrations in sediment, surface or groundwater, and biota	unknown in Hurghada; some data available from research elsewhere, as well as some laboratory studies	status unknown for Hurghada, but coastal assessment and water quality sampling conducted by Dr. A.E. Rifaat, et al., Oct./Nov. 1997
Sediment	Manage sediment so that it does not threaten coastal or marine habitats.	Dunes, wadis, atmosphere, impervious surfaces	Max. sediment diameter (cm); sediment volume (1000 m^3); total suspended solids within the water column; sediment accumulation within fixed, permanent intertidal and	unknown for Hurghada;data available from research elsewhere, as well as some laboratory studies	status unknown for Hurghada, but coastal assessment and water quality sampling conducted by Dr. A.E. Rifaat, et al.,

Resource or Stressor	**Assessment Endpoint (Management Expression)**	**Source/ Location**	**Measurement Endpoint(s)**	**Data Available?**	**Existing Monitoring Program?**
			subtidal study sites; or deployment of sediment traps		Oct./Nov. 1997
Petroleum hydrocarbons	Effectively minimize petroleum hydrocarbons as a pollutant within the coastal zone.	bilges, oil spills, industrial facilities, roads, marinas	specific location of oil spills, marinas and boat yards. total petroleum hydrocarbons in sediment and water column	unknown in Hurghada; data available from research elsewhere, as well as laboratory studies	status unknown for Hurghada, but coastal assessment and water quality sampling conducted by Dr. A.E. Rifaat, et al., Oct./Nov. 1997
Nutrients	Manage nutrients so that they do not result in biological change to seagrass or coral reefs communities	from phosphate mines, sewage outfalls or treatment systems, fertilizers, agricultural runoff	chlorophyll a concentrations in nearshore waters, total dissolved inorganic nitrogen, total Kjedhal Nitrogen, soluble reactive phosphorus, total phosphorus, Phosphorus tissue concentration (in algae), Nitrogen concentration in algal tissue, Percent algal cover, Chlorophyll a (for remote sensing), Water quality, measurements for background concentrations of SRP, DIN, TSS. Threshold concentrations of 0.01 μ M SRP and >0.1 μ M DIN.	unknown	status unknown for Hurghada, but coastal assessment and water quality sampling conducted by Dr. A.E. Rifaat, et al., Oct./Nov. 1997
Heavy Metals	Effectively manage heavy metals so that they are not pollutant threats to coastal resources or fisheries	inventory of industrial or commercial sites and marinas, and non-point sources from adjacent roadways	measured ambient concentration compared to laboratory LC50 data for individual species	unknown	status unknown for Hurghada, but coastal assessment and water quality sampling conducted by Dr. A.E. Rifaat, et al., Oct./Nov. 1997
Solid Waste	Effectively manage solid	location of solid waste	volume of solid wastes	unknown	unknown

Resource or Stressor	Assessment Endpoint (Management Expression)	Source/ Location	Measurement Endpoint(s)	Data Available?	Existing Monitoring Program?
	wastes through proper facilities and disposal procedures. Eliminate solid wastes completely from Hurghada beaches and shorelines	facilities and current processes	collected and processed compared to solid wastes generated per facility		
Pesticides	Effectively manage pesticides so that they do not pose risk of exposure to coastal or marine habitats or resources.	inventory of areas with pesticide use and commercial operations	measured ambient concentration compared to laboratory LC50 data for individual species	unknown	unknown
EVENTS	Effectively minimize impacts to existing developments and coastal resources from flash flooding events	inventory of the areas with highest potential based on historical data	To be determined	unknown	unknown
Flash flooding					
Sea level rise	Develop predictive capacity through modeling to determine the most sensitive locations in Hurghada to changes in sea level rise within the 200 meter setback zone, and to specific sites (such as coral reefs areas) where changes may potentially impact community structure or tourism activity.	N/A	changes in mean high water levels at permanent study site over time; comparison of data to other stations within the Red Sea Region.	unknown	unknown
Global Warming	To be determined	N/A	Accurate mean surface and sea surface temperatures analyzed over time.	Local data unknown. Satellite data for sea surface temperature.	unknown