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Impact of Climate Change on Aquatic Biodiversity of Egypt
(A Concise Review)

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ABSTRACT
In 1992, Egypt signed the Biodiversity Convention and ratified it in 1994. Article 6 of this Convention required the parties to formulate national strategies setting a framework for the conservation of biodiversity.
Climate change is already having noticeable impacts on biodiversity. Projected future changes are likely to result in changes in the distribution of species and ecosystems, and overall biodiversity loss. Individual species respond differently, according to their climate tolerances and their ability to disperse into a new location, alter their phonology (e.g. breeding date) or adapt to shifting food sources. This means that it is difficult to predict how communities will change or how current interactions between species will be affected.

INTRODUCTION

Climate change is now considered as one of the greatest challenges not only to the national and regional governments but also to the global community. The international scientific community has proven that global warming of the climatic system is unequivocal. As a result of global climatic disorder the sufferings of humankind have already increased remarkably especially in Least Developed Countries.

As for **biodiversity**, climate change will probably affect marine species through ocean acidification, or ecosystem stratification, or increasing oceanic dead zones. Adaptation actions are undertaken either to avoid, or take advantage of, actual and projected climate change impacts either by decreasing a system‘s vulnerability or increasing its resilience. This may entail reprioritizing current efforts as well as identifying new goals and objectives to reduce overall ecosystem vulnerability to climate change.

In 1992, Egypt signed the Biodiversity Convention and ratified it in 1994. Article 6 of this Convention required the parties to formulate national strategies setting framework for the conservation of biodiversity

Climate change is likely to significantly complicate the achievement of environmental management objectives that presently command public attention and significant commitment of resources (Boesch *et al*., 2010). The recently released third assessment report of IPCC estimates global mean warming this century of up to 5.8 ºC in the extreme. This report makes it clear that climate-change effect on the distributions, life histories, and even survival of species. (Hanna *et al*., 2002; IPCC, 2002).

Also, Ecosystems are already showing negative impacts under current levels of climate change … which are modest compared to future projected changes…. In addition to warming temperatures, more frequent extreme weather events and changing patterns of rainfall and drought can be expected to have significant impacts on biodiversity. Some species may benefit from climate change (including, from a human perspective, an increase in diseases and pests) but the rapid nature of the change suggests that most species will not find it as beneficial as most will not be able to adapt.

What changes might we expect in the future?

Computer models predict an average global temperature increase of 1.4 to 5.8 ºC by the year 2100. Predicted impacts associated with such a temperature increase include:

- a further rise in global mean sea level of 9 to 88 cm,
- more precipitation in temperate regions and Southeast Asia, associated with a higher probability of floods,
- less precipitation in Central Asia, the Mediterranean region, Africa, parts of Australia and New Zealand, associated with a greater probability of droughts more frequent and powerful extreme climatic events, such as heat waves, storms, and hurricanes,
- An expanded range of some dangerous "vector-borne diseases", such as malaria.
- Further warming of the Arctic and Antarctic, leading to more sea-ice disappearance (Iturralde, 2007; UNEP, 2007).

Climate change is already having noticeable impacts on biodiversity. Projected future changes are likely to result in changes in the distribution of species and ecosystems, and overall biodiversity loss. Individual species respond differently, according to their climate tolerances and their ability to disperse into a new location, alter their phonology (e.g. breeding date) or adapt to shifting food sources. This means that it is difficult to predict how communities will change or how current interactions between species will be affected.

Many studies have attempted to project the rate and extent of species or ecosystem responses to climate change. Terrestrial species are typically expected to move towards higher latitudes or higher altitudes, tracking shifts in temperature. Marine ecosystems will be affected not only by an increase in sea temperature and changes in ocean circulation, but also by ocean acidification, which increases the vulnerability of fragile ecosystems such as coral reefs.

1. Impact of climate change on global marine ecosystems:

1.1. Marine Ecosystems

It is often forgotten that the world's oceans are one of the largest food reserves on the planet. According to estimates of the Food and Agriculture Organization (FAO), globally some 200 million people depend on fishing and aquaculture. Expected increases in water temperature and storm frequency destroy natural habitat, threaten marine biodiversity and endanger the viability of fishing as a sustainable human livelihood

Knowledge about the impact of climate change on the world's oceans is still poor and the complexity of the marine ecosystem calls for intensified research. Climate change will probably affect ocean circulation and mixing patterns. Circulation and mixing control nutrient availability to the oceans' microscopic plants (phytoplankton) and their access to solar radiation required for photosynthesis.

Climate change will probably affect marine species through ocean acidification, or ecosystem stratification, or increasing oceanic dead zones.

1.2.Ocean Acidification:

Global climate change, in terms of modifying the biology of the oceans, is the impact of anthropogenic CO_2 on the pH of the oceans, which will affect the process of calcification for some marine organisms. When CO_2 reacts with water it produces a weak acid called carbonic acid, changing the sea water chemistry.

1.3.Increasing ocean stratification:

As climate change warms the oceans (even just an increase of about 0.2 ºC per decade, on average), the warmer water (which is lighter) tends to stay on top of what is then a layer of colder water. This affects tiny drifting marine organisms known as phytoplankton. Though small, "Phytoplankton is a critical part of our planetary life support system. Ocean stratification has been widely observed in the past decade and is occurring in more and larger areas of the world's oceans. Researchers have found a direct correlation between rising sea surface temperatures and the decline in phytoplankton growth around the world.

1.4.Increasing oceanic dead zones:

The past half-century has seen an explosive growth in aquatic dead zones, areas too low in dissolved oxygen to support life. Fertilizer and sewage run-off cause huge growth of plankton. However, these then quickly die and are consumed by bacteria that deplete waters of oxygen. Such dead zones were rare 40 years ago but now number several hundred.

2. Aquatic Biodiversity changes as related to climate changes in Egypt

Egypt is one of the vulnerable countries to climate change. Low laying land in the Nile delta region is considered to be especially at risk from the effects of any sea level rise resulting from global warming (El Raie et al., 1995). The impact of global warming up on Egypt is manifested in a variety of influences which includes, water resources, agriculture, food resources, coastal zones, as well as biodiversity of marine, freshwater and terrestrial ecosystems.

2.1.Effect of climate change on Marine Ecosystem:

2.1.1. Coral reefs

Despite the fact that coral reefs cover less than 1 percent of the earth's surface, coral reef structures are home to more than 25 percent of marine organisms, including reef fishes, sponges, jellyfish, worms, shrimps, lobsters, crabs, bivalve, gastropods, starfish, sea urchins, sea cucumbers, marine turtles, marine snakes, marine mammals and marine birds. Moreover, coral reefs deliver an estimated economic value of $375 billion from tourism / year worldwide, fisheries and shore line protection.

The extent and severity of mass coral bleaching events have increased worldwide over the last decade. Prior to 1998, mass coral bleaching had been recorded in most of the main coral reef regions, but many reef systems had not experienced the effects of severe bleaching. Since 1998, coral bleaching has become a common phenomenon around the world. Every region has now experienced severe bleaching, with many areas suffering significant bleaching-induced mortality (Hanafy & Ismail, 2012)

Corals in many tropical regions are experiencing substantial mortality from increasing water temperatures and increasing storm intensity, on top of a host of other ongoing challenges from development and tourism, increases in ocean acidity, unsustainable fishing, and pollution. Additionally, decreasing pH leads to a decreased aragonite saturation state, one of the main physico-chemical determinants of coral calcification. There is now extensive evidence of a link between coral bleaching – a whitening of corals as a result of the expulsion of symbiotic zooxanthellae and sea surface temperature anomalies Bleaching usually occurs when temperatures exceed a 'threshold' of about 0.8-1°C above mean summer maximum levels for at least 4 weeks (IPCC, 2002).

Dead Reef Bleached Reef Healthy Reef

Fig.1.Bleached Reef in the Red Sea, Egypt (Hanafy & Ismail, 2012)

In Egypt, Hanafy and Ismail (2012) conducted a detailed survey in August and October 2012, in comparison to the baseline survey conducted in 2011, in order to quantify the level of impact of increasing temperature on bleaching event of the Egyptian reefs of the Red Sea. For this purpose, 136 sites were checked by sighting the presence or absence of bleached coral colonies along the coast of the two Gulfs of Suez and Aqaba, and the Red Sea. Moreover, a total of 16 sites were surveyed quantitatively. The surveyed reefs were located on the Egyptian coast of the Red Sea, starting from Neweibaa in the northern part of the Gulf of Aqaba ending with Shalatien on the Egyptian southern border. Sites were selected carefully to cover the geographical range of the bleaching event and to cover both exposed and sheltered reefs as well as inshore and offshore reefs.

They found that the increase of water temperature affected certain reef building coral genera including; *Montipora*, *Porites*, *Acropora*, *Stylophora and Pocilliopora* and some non-reef building corals including, *Millipora* and some of the soft corals and sea anemone. The mass bleaching event was restricted mainly to the first 6 meters of depth, and then reduced sharply in depths between 6 meters to 10 meters. Although sheltered areas were found to be more impacted by coral bleaching, the mass bleaching event affected both sheltered and exposed sites. The mass bleaching event also affected inshore and offshore sites.

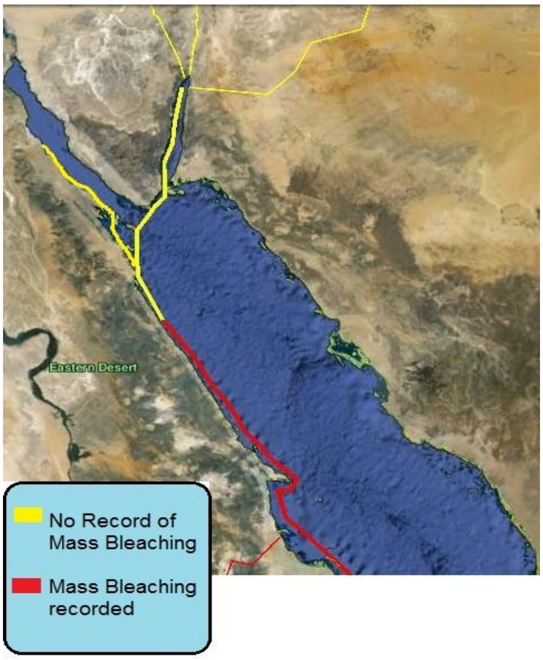

Figure 2: Extent of the Mass Bleaching Event on the Egyptian Red Sea Coast (Hanafy & Ismail, 2012)

Reefs are also home of a large variety of organisms, including fishes, sponges, Cnidarians (which includes some types of corals and jellyfish), worms, crustaceans (including shrimp, spiny lobsters and crabs), *molluscs (including cephalopods)*, *echinoderms (including starfish*, *sea* urchins and sea cucumbers), sea squirts, sea turtles and sea snakes. Aside from humans, mammals are rare on coral reefs, with visiting cetaceans such as dolphins being the main group. A few of these varied species feed directly on corals, while others graze on algae on the reef and participate in complex food webs. Consequences of climate change on coral reef habitats will definitely impact all these organisms.

2.1.2. Marine turtles

Five species of marine turtles have been observed in the Egyptian Mediterranean and Red Seas; the green turtle (*Chelonia mydas*), the hawksbill (*Eretmochelys imbricata*), the loggerhead (*Caretta caretta*), the olive-ridley turtle (*Lepidochelys olivacea*) and the leatherback turtle (*Dermochelys coriacea*) (Frazier and Salas, 1984).

Three species are found in the Mediterranean; the loggerhead (*Caretta caretta*) and green turtles (*Chelonia mydas*) nest in the Mediterranean coast, and the giant leatherback (*Dermochelys coriacea*) is an occasional visitor. However, only the green and hawksbill turtles are considered common and have been observed nesting and feeding along the Egyptian Mediterranean and Red Sea coasts (Frazier and Salas, 1984). At present time, these two species are enlisted in the IUCN Red List either as critically endangered, hawksbill turtles (IUCN 2011), or endangered, green turtles (IUCN 2011). Furthermore, they are enlisted in Appendix I of the Convention on International trade of Endangered Species (CITES), which forbids their trade in signatory countries (CITES 2011).

Nesting sites along the Egyptian Mediterranean and Red sea coasts are submitted to an increasing pressure coming from unsustainable coastal development and habitat degradation due to erosion and rising of sea level due to climate changes. These are well identified threats to nesting sites of turtles (Hanafy & Sallam, 2003; PERSGA/GEF; 2004; Mortimer and Donnelly, 2008); and no information is available at present on their future impact on nesting populations, and further detailed studies are needed.

Another major threat to sea turtles is the increasing of temperature that can cause a reduction to their populations. Since temperatures in the sands define the sex of the turtle while developing in the egg, many feared rising temperatures would only produce one sex, but more research remains to be done in order to understand how climate change might affect sea turtle gender distribution.

2.1.3. Sharks

The fact that the reef walls rise so abruptly at such vertical angles from the deep is the reason why you can see large numbers of sharks at very close distances from the shore in Egypt. Almost anywhere else in the world you would need to go for a good two hours in a boat to see what you can see Ras Muhammed with your feet almost dry on Terra Firma!

Since the Red Sea is really just an extension of the Indian Ocean, most of the shark species found in that tropical ocean occurs here too. There are about 400 species of sharks living in the seas today; of them 44 are recorded in the Red Sea. About 18 of reef and pelagic sharks species were recorded in the waters of Ras Muhammed, these are; Angel, Blacktip, Blacktip Reef, Blue, Great Hammerhead, Great White, Grey Reef, Lemon, Leopard, Nurse, Oceanic Whitetip, Sand Tiger, Scalloped Hammerhead, Silvertip, Tiger, Whale Shark, Whitetip Reef and Zebra. The **Blacktip Reef Shark** is found at Ras Muhammed close to the reef walls but also very close to shore and even in the mangrove swamps when the tide is up. As a reef species, it feeds on reef as well as pelagic fish as well as shrimps and squid. These reef sharks are threatened to disappear with bleaching of coral reefs.

The **Oceanic Whitetip Shark** (*Carcharinus longimanus*) is found all over the world except in the poles, but prefers water temperature higher than 20 degrees Celsius. This is the reason why there are so many of these sharks at the Northern end of the Red Sea.

Many scientists reported that changes of behavior of sharks in Egyptian Red Sea during the last decade might had a relationship with climate changes; temperature, water circulation, pH of water…..etc, as changing in physical parameters of water can impact on electric impulses they receive.

2.1.4. Dolphins

Dolphins are marine mammals, warm-blooded, found mostly in the shallower areas of the Red Sea. Most species of dolphins are enlisted in the IUCN Red List either as critically endangered or endangered (IUCN 2011). They use echolocation to find prey or avoid predation, so changes in physical characters of water will impact them.

2.1.5. Dugong

The Dugong or the sea cow (*Dugong dugon*) is a quite large mammal reaching lengths of up to 4 meters. This marine mammal is found along the coasts of the Red Sea, East Africa and across most of southern Asian coasts. In Egypt they are found in the southern Red Sea shores, but in summer it can be seen as far north as Ras Muhammed, as this species is very sensitive to temperature changes. The Dugong is in extreme danger of being extinct as it has been hunted in the past for its meat and leather.

2.1.6. Fisheries

Climate change is affecting the aquatic habitats and the fishing resources already. A comprehensive amount of studies documenting this has been published for a variety of marine organisms like tunas, cod, sardine, anchovy, krill, phyto- and zooplankton. Warm water species spread to the North and local extinctions has happen at the edges of the current range for salmon, sturgeon, etc.

Prediction of the consequences of climate change on marine population is complex and both positive and negative effects can be expected dependent on species, geographical area and distribution. Thus for many salmonids increased winter temperature will increase growth but also increase the risk for infectious diseases. An increase in summer high temperatures will result in high mortality. The influence on primary production will vary geographically but most model projections predict a moderate global increase of less than 10% (Brander, 2006).

However, major changes in algae species composition can be expected and this might affect growth in higher trophic levels particularly in sea waters. Also, the slow down of oceanic currents (Curry and Mauritzen, 2005) will reduce the vital upwelling of nutrients and thus ultimately lower the primary production in some areas. The expected major changes in ocean currents are also likely to influence the distribution and migration of fish larvae.

2.1.6.1.Fishes of Red Sea

Coral reefs support an extraordinary biodiversity; although they are located in nutrient-poor tropical waters. They are the home of a variety of tropical or reef fish, such as the colorful parrotfish, angelfish, damselfish and butterflyfish. Over 4,000 species of fish inhabit coral reefs. These species will be dramatically affected also in case of disappearance of coral reef habitats.

In Egypt, there are over 1,000 species of fish found in Red Sea area (Siliotti, 2002). Statistically, there are more fish found in the Northern Red Sea per square meter than anywhere else in the world; ranging from the minuscule to the 6 meter long. They all congregate at Ras Muhammed to benefit from the nutrient waters brought by the currents throughout the year. The Ras Muhammed region, although a spectacle all year round, is particularly crowded by its gilled inhabitants during the summer months. Ecologically, fishes of the Red Sea are divided to reef and pelagic ones.

2.1.6.2.Reef Fishes

Reef fishes are those colorful ones that you see in those Prussian-blue waters off of Ras Muhammed. There is a huge variety that makes the array of colors almost inconceivable. The reason why these fishes are so colored is because, it is as much a survival method as it is a mate attracting ploy. At times of danger, there is a strong need to blend in with the wide range of color provided by the soft and hard coral species.

2.1.6.3.Pelagic Fishes

These are open-sea fish, usually larger and are attracted to the nutrients of Suez Gulf and to the walls and reefs of Ras Muhammed by the food in the form of thousands of smaller reef fish that are, in turn, attracted to the area by the nutrient-rich deeper waters as well as shelter provided to them by the reef. The reef wall at Ras Muhammed rise sharply from the depth also contributes greatly to their presence in such abundance. Pelagic fishes are usually travelling in big schools. They spend a big portion of their time in the relatively cool waters of the open sea, but during feeding period they are back to the reefs, where you can see them! Examples of pelagic fishes are sharks, tuna, groupers, and barracuda.

On the other hand, at Ras Muhammed a total of 261 fish species representing 89 genera in 46 families, and that southern reef housed a greater diversity of fish species than northern reefs. Exposed reefs contained higher diversity of fishes than sheltered reefs, which was attributed to the lower incidence of divers and fishermen in these areas. The most abundant family is the Pomacentridae (damselfishes), represented by 16 to 26 species across all sites, followed by the Labridae (wrasses), represented by 20 species. The most common damselfish is *Chromis dimidiata*, and the most common wrasse is *Labricus quadrilineatus*. The least abundant family is the Scaridae (parrotfishes), represented by only nine species, of which *Hipposcarus harid* and *Scarus ferrugineus* are the most common. Among the Acanthuridae (surgeonfishes), *Naso literatus*, *Acanthurus negrifuscus* and *A. sohal* are the most common species. Chaetodintidae (butterflyfishes) diversity increased in the north, with *Chaetodon larvatus, C. auriga* and *C. fasciatus* among the most common.

2.2.Freshwater Ecosystems

The diversity of species in freshwater habitats is disproportionately high as compared to other ecosystems. Freshwater habitats cover less than 1% of the world’s surface, yet they provide a home for over 25% of all described vertebrates, more than 126,000 known animal species, and approximately 2,600 macrophyte plants.

There are an estimated 27,400 freshwater species of fish, molluscs, crabs, dragonflies and plants; these are the groups that IUCN and Conservation International decided to assess in their entirety as part of their Global Freshwater Biodiversity Assessment. Of these, only 6,000 species have been assessed so far at a global scale and included in the 2008 IUCN Red List, leaving over 21,000 species still to be assessed.

Climate-induced changes in air temperature, precipitation, and other stressors are already affecting the physical, chemical and biological characteristics of freshwater ecosystems. Many of these trends will be exacerbated in the future. Impacts on habitat (loss and transition) and species (range shifts, invasive species interactions, and phenology) are highlighted here.

River Nile and Wetlands

One of the world’s largest river deltas, the Nile Delta is home to hundreds of thousands of waterbirds in winter and hosts threatened and restricted-range small mammals and reptiles. The Nile Delta was once known for large papyrus (Cyperus papyrus) swamps, but papyrus is now largely absent from the delta. Five globally threatened species occur in the key biodiversity areas present in the corridor. People have lived in the Nile Delta region for thousands of years, and it has been intensively farmed for 5,000 years. Rising sea levels would destroy weak parts of the sand belt, which is essential for protecting the lagoons, wetlands and low-lying reclaimed agriculture lands. The impact would be very serious. A high percentage of Egypt's fish catches are made in the lagoons. Sea level rise would change the water quality and affect most freshwater fish.

The coastal part of the Nile Delta covers with a series of extensive freshwater and brackish wetlands. The expected increased temperature in our northern lakes and increased eutrophication allows algae to grow producing algal blooms (Hunter, 2003). Furthermore, the effect of global warming will be more obvious in the closed water bodies. Wetlands also have substantial exchange with atmospheric water in the form of precipitation and evaporation (Winter, 2000). The increased Evaporation rate could affect the salinity of the closed water bodies such as Qarun and Wady El-Rayan lakes.

Change in sea level as a result of climate change is one of the greatest threats to wetlands in flat coastal landscapes. Rising sea level could simply drown the wetlands. However, lowering of sea level could also affect these types of wetlands because it lowers the base level of streams and ground water flow systems, which would tend to dry out the wetlands. In some very broad, gently sloping coastal areas, it is conceivable that wetlands could shift seaward or landward if the changes in sea level were slow enough for the wetland plant communities and soils to develop (Winter, 2000).

Based on a search of the scientific and grey literature, the following implications of climate change for species, populations, and biological communities have been identified:

1. Shifts in species range and distribution
2. Altered phenology and development
3. Shifts in community composition, competition, and survival
4. Altered interaction with non-native and invasive species
5. Effect on fisheries
6. Effect on Aquaculture

2.2.1. Shifts in species range and distribution

Future climate warming will alter the extent of habitat available for cold-, cool-, and warm-water organisms depending upon region, and result in range expansions and contractions. Species at the southern extent of their geographical distribution will shift northward and face local extirpation at their southern limit, while expanding at the northern limit of their range. Further, physical constraints such as drainage patterns, waterfalls, and land-locked areas play a large role in determining the boundaries of a species range and the rate at which it may respond to changing conditions.

- **Observed Trends in Egypt**

i. The malacofauna (The molluscs of the Nile):

The most recent inventory of the malacofauna of the Egyptian part of Nile was done by Ibrahim et al. (1999). This study is valuable because it is the first time that the Nile has been sampled so intensively in all habitats. The malacofauna of the Lower Nile can be discerned from that of the other regions by the presence of Palaearctic taxa. Some of these, e.g., Lymnaea stagnalis, L. auricularia, Planorbis planorbis, are widespread in the Palaearctic region. During the Early Holocene they occurred further south but presently they are restricted to the freshwater part of the Nile Delta (Van Damme, 1984), from which they are rapidly disappearing due to climate change (Van Damme, 1984). Five Palaearctic species are endemic, either to the Lower Nile or to the Ethiopian Highland. According to Brown (1994) the endemic Palaearctic snails Theodoxus niloticus, Valvata nilotica and Gyraulus ehrenbergi are closely related to and perhaps co-specific with Levantine species. Also, two palaearctic unionids, Unio abyssinicus and Unio dembeae, have presently disappeared from the Lower Nile but were abundant during the Egyptian Nile. Palaearctic, boreal species that have been in retreat since the middle Holocene and that were holding out in the Nile Delta have been rapidly disappearing during the last three decades. Chambardia letourneuxi, the only endemic bivalve recorded from the Egyptian Nile, has not been collected since the beginning of the twentieth century and probably is extinct. Unio abyssinicus, a Palaearctic relict, only surviving in Lake Tana, must be considered as threatened since it is sensitive to climate change. The same may be the case for Ethiopian montane species such as Bulinus octoploidus and Pisidium ethiopicum.

2.2.2. Appearance of Harmful Algal Blooms

A direct consequence of global warming is thermal expansion of water is the photosynthesis and plankton growth. This is a basic process to the aquatic ecosystems, and in general both rates double when temperature increases by 10°C (Raven and Geider, 1988). The qualitative conclusion from their investigations on the effects of climate change in the aquatic ecosystem indicate that the risk of harmful dinoflagellate and raphidophyte blooms will increase rather decrease due to climate change.

- **Observed Trends in Egyptian freshwater ecosystems:**

i. Algal Blooming in Suez freshwater canal

In October 2003, a wintertime algal bloom appeared in the Suez freshwater canal; the drinking water supply for the Suez City. Unpleasant odor and color of the drinking water caused panic in the urban community. Microcystis aeruginosa, Oscillatoria foromosa and Oscillatoria princeps dominated the phytoplankton and were the cynobacterial bloom-forming species. A recent study from Egypt revealed that 25 per cent of 75 Anabaena and Nostoc strains isolated from soil, rice fields and water bodies contained microcystins Toxin.

ii. Algal Blooming in Lake Nasser

Irregularly, serious problems of unbalanced biological conditions arise in sluggish areas of Lake Nasser. Overgrowth of Cyanophyceae species causes floating crusts and scum's, where plants die quickly and disintegrate in the intense sunlight. This causes depletion of oxygen below the point required for fish and other aquatic animals.

Mohamed (1993) recorded the occurrence of water blooms in Lake Nasser eight times during six years (from 1987 to 1992) and pointed out that water blooms occurred only in very limited areas of the southern part of the Lake.

Cyanophyceae species were found in all samples of blooms. Microcystis aeruginosa was the dominant species in all the samples of water blooms (Mohamed, 1993). He pointed out that Oscillatoria spp. were observed in extreme values at Korosko, while Aphanocapsa sp. was present in high quantities at Abu Simbel. Recently, water blooms have been recorded in the central area of the Lake.

2.2.3. Shifts in community composition, competition and survival

Changes in baseline conditions of aquatic ecosystems could influence the outcomes of competition between species with differential temperature tolerances, as well as affect the necessary habitat requirements and survivability of sensitive species. Temperatures that commonly exceed physiological thresholds or lethal limits will presumably set relatively hard limits to species occurrence, although variation in life history and behavior (including phenotypic plasticity), such as the increasing exploitation of thermal refugee, may mitigate hard constraints. For example, fish and amphibian species will experience increased stream and lake temperatures that will affect their food supply and fitness (e.g. reproductive fitness and survival).

- **Observed Trends in Egypt**

The highest species richness in Afrotropical Africa is found in the Egyptian Nile where 39 species are present. In the 20th century, due to the disappearance of swampy habitats along the borders of the Egyptian Nile, many smaller gastropod species that live in debris and among aquatic vegetation became restricted to the slow flowing and stagnant canals of the Nile Delta where vegetation was still abundant and the bottom was muddy.

Compared to the Nilotic molluscan community recorded in 19th century, the present one shows only a slight decrease in species richness, due to the disappearance of a couple of Palaeartic species that were already relicts one hundred years ago. Their disappearance may have been caused by global climate change. It should be pointed out however, that the only endemic Afrotropical bivalve in Egypt, Chambardia letourneuxi, which was confined to the Delta has not been collected since the late 19th century and should be considered as Extinct.

4- Altered interaction with invasive and non-native species

Both invasive species and climate change are major ecosystems stressors. Climate change is expected to worsen the world’s invasive species problems (Dukes and Mooney 1999), because ecosystems are more vulnerable to invasion when they are disturbed (Hobbs 1991; Hobbs and Huenneke 1992). Disturbance events create opportunities for invasive pests to take the place of natives. For example, droughts probably assisted rabbits to displace rufous hare wallabies (Lundie- Jenkins *et al*. 1993).

For many native species to survive in the future, they may have to relocate by spreading south or perhaps into higher altitudes. But the speed at which species will be required to migrate could exceed those rates recorded in the past, when trees and other plants recolonised far northern latitudes after ice ages (Malcolm *et al*. 2002; Davis ; Shaw 2001).

- **Observations in Egypt**

The mosquitofish (Gambusia holbrooki) is among the most invasive fish in Egypt and abundant in most Mediterranean countries. It is unable to tolerate the colder winters of northern and central Europe. Understanding the effects of latitude on its life-history traits is essential to predict the potential for its invasion in different scenarios of climate change. The study of Huey *et al*. (2000) confirms the interest of latitudinal studies of invasive species (particularly given current scenarios of accelerated climate change). This knowledge is of enormous importance to understand the invasive potential of mosquitofish worldwide.

2.2.4. Impacts of climate change on freshwater fisheries

Freshwater fisheries ecology is profoundly affected by changes in precipitation and run-off which may occur due to climate change. Lake fisheries in southern Africa for example, will likely be heavily impacted by reduced lake levels and catches.

Increased temperature may lead to stronger, earlier and longer stratification of lakes and reservoirs and, with limited or no seasonal turnover, greater deoxygenation (i.e. Hypoxia) of bottom layers. River runoff is expected to increase at higher latitudes but decrease in parts of West Africa, southern Europe and southern Latin America. Overall, a global temperature increase of 1°C is associated with a four percent increase in river run-off. Changes in flood areas, timing and duration are also expected.

In general, temperature changes are likely to impact cold-water species negatively, warm-water species positively, and cool-water species positively in their northern ranges and negatively in their southern ranges. Also, there will likely be a general shift of cool- and warm-water species northward in northern hemisphere rivers. The abundance and species diversity of riverine fishes are predicted to be particularly sensitive to climatic disturbances, since lower dry season water levels may reduce the number of individuals able to spawn successfully. The timing of flood events is a critical physiological trigger that induces fish to migrate and spawn at the onset of the flood which enables their eggs and larvae to be transported to nursery areas on flood plains. Fishing yields are expected to drop as a result of the accumulated conditions related to temperature, rainfall and the behaviour of animal and plant species.

The future impacts of climate change on fisheries and aquaculture are still poorly understood. The key to minimizing negative impacts and maximizing opportunities will be understanding and promoting the wide range of creative adaptive measures and their interactions with existing policy, legal and management frameworks.

2.3.Role of Protected Areas in conserving biodiversity:

Leach *et al.* (2013) studied in Egypt the role of Protected Areas in conserving biodiversity from the future climate change and increasing of temperature. In this study they used two techniques in conservation science, first, to estimate the likely impacts on the distributions of mammals and butterflies in Egypt (MaxEnt), and second, to measure the effectiveness of Egypt's Protected Area network (Zonation). They predicted that future climate will have significant effects on species richness and the relative value for conservation of sites in Egypt: some areas will increase in species richness, whilst others will decrease significantly.

Currently, the sites of highest relative conservation value are found in the Nile Delta, southeastern and Sinai regions of Egypt and along the Mediterranean and Red Sea coastlines, with Protected Areas having a higher conservation value than unprotected areas. Under future climate scenarios the relative conservation value of Protected Areas are predicted initially to decline and then gradually increase by the 2080s. It is predicted that many areas, especially the Nile Delta and the southeast, will require extra protection in the future; areas that are currently not protected, but have high species richness and conservation value, may need to be protected to prevent loss of biodiversity.

2.4.SOCIOECONOMIC IMPACT OF CLIMATE CHANGE:

- Coral bleaching will certainly affect the tourism activity in Red Sea beaches and recreational villages, which are now big source of financial incomes for many of local people in these areas. Moreover, coral reef structures are home to more than 25 % of marine organisms, including reef fishes, sponges, jellyfish, worms, shrimps, lobsters, crabs, bivalve, gastropods, starfish, sea urchins, sea cucumbers, marine turtles, marine snakes, marine mammals and marine birds. Many of these species are main resources for fishermen and biodiversity tourism. An economic study concluded that coral reefs deliver an estimated economic value of $375 billion from tourism / year worldwide, fisheries and shore line protection.
- It is also concluded that there may be an increase in the number of cyanobacterial blooms because of a combination of increased nutrient concentrations and water temperature. This will certainly impact the fish production in many aquatic ecosystems in Egypt.
- Increased streamflow, warmer temperatures, calmer summer winds, and increased depth due to sea-level rise would affect the coastal lakes which contribute great national income. This is the case of the Delta wetlands of Egypt.

2.5. Vulnerability, Ongoing Studies and Systematic Observation:

2.5.1. River Nile

Many studies addressed the sensitivity of the **River Nile** waters to climate change. The sensitivity of different Nile basins to uniform changes in rainfall have been documented (Sayed,, 2004). It is clear that the Eastern Nile (Atbara and the Blue Nile) is extremely sensitive to the change in rainfall both positive and negative, where an increase of 10% in rainfall results in a 36% increase in water flow at Khartoum, and a decrease of 10% in rainfall results in flow reduction of 31%. The sensitivity of Nile water flows and consequently species diversity are also affected by the change in temperature, which causes corresponding changes in evaporation and evapotranspiration (Hulme *et al*., 1995). An increase of 4% in evapotranspiration would result in a reduction of Blue Nile and Lake Victoria flows by 8% and 11% respectively.

2.5.2. The coastal zones and inland lakes of Egypt

They are perceived as vulnerable to the impacts of climate change, not only because of the direct impact of sea level rise, but also because of the potential impacts of climate changes on their water resources, agricultural resources, tourism and human settlements. In particular, the low lying Nile Delta region, which constitutes the main agricultural land of Egypt and hosts over one-third of the national population and nearly half of all crops (World Resources Institute, 2007), industrial activities and commercial centers, is highly vulnerable to various impacts of climate change.

2.5.3. Salt water intrusion

Salt water intrusion and its potential impacts on wetlands and ground water quality in the coastal zone cannot be overlooked especially in low land areas along the Mediterranean coast of Egypt. This will in turn lead to disappearance of freshwater biota and deterioration of wetland diversity. This phenomenon is considered of utmost importance and warrant full investigation.

2.5.4. Environmental extreme events

The increase of intensity and frequency of environmental extreme events is also expected to affect the coastal zones of Egypt and extend over the whole country as well as across the Mediterranean. Saharan dust and heat waves are well known to seriously affect land agricultural productivity, materials lifetime and public health. Increased intensity and frequency of marine storms will necessarily increase risks of transportation accidents and health risks. A change of wind direction and coastal current pattern is also expected due to climate changes; that will seriously affect the marine fauna. Decreases of precipitation on the Red Sea coastal area, changes of the well known Nawwat pattern of extreme events at Alexandria, increased rates and frequencies of dust storms and prevailing temperature inversions are only a few examples of climate change observations in the coastal areas.

2.5.5. Mangrove and coral reefs:

The impact of climate change on mangrove trees and coral communities in the Red Sea will include coral bleaching due to increasing temperatures, loss of habitats as well as loss of biodiversity hence deterioration of fisheries and tourism.

2.5.6. Diversity

Reduction of plant and animal diversity in high temperature and very dry environment, as what happened in Elba and south Sinai mountains. Air temperature at

Elba Mountain increased about 3^0C since 1960s that led to disappearance of some sensitive plant species (such as Embet trees) down the mountains and moving some of them to the upper parts of the mountains, where low temperature and high humidity.

2.6. Ongoing Studies and Efforts Exerted

- In south Sinai protected areas a program is implemented for the management of existing communities of coral reefs and mangrove plants, and carrying out research for encouraging of ongoing artificial coral and mangrove cultivation and expanding coral and mangrove protectorates and strengthening management and protection.
- Natural Protection Sector in EEAA has proposed a plan for incorporation of predicted climate change impacts activities into the programs and action plans of biodiversity. Another plan was also proposed by EEAA for determination the most risk areas exposed to the effect of the climate change.
- The Egyptian National Assembly has recently approved new regulations to include Integrated Coastal Zone Management (ICZM) into developmental plans needed for better management of coastal resources including lakes and protection against impacts of climate change. This makes it necessary to have a strong institutional monitoring capability.

The following adaptation measures on the local scale are under considerations (El Shennawy, 2008):

- Creating wetlands in areas vulnerable to the impacts of sea level rise in low lying deltas. Lake Manzala and Lake Burullus are two examples of such areas eligible for such adaptation processes;
- Progressing with protecting and fixing natural sand dunes systems which constitute an important natural protection;
- Promoting the role of stakeholders' participation in evaluating the trade-offs between adaptation options.
- Incorporating the management of sea level rise risks into the development plans of Egypt's low elevation coastal zones in the Nile Delta.
- Developing an adaptation policy framework for the low elevation coastal zone areas; climate change risk reduction strategies; policies and relevant measures integrated into land use plan, and the identification of needs of laws and regulations related to coastal zone development to take careful account of climate risks.
- Identifying means of strengthening institutional and individual capacities to implement integrated coastal zone management plans.
- The National Plan for Land Use proposed also many programs for facing the climate change risks:
- Developing an adaptation policy framework for management of mountain habitats, as they are considered the strategic resource for biodiversity in Egypt.

- Reconsideration of the present and future protected areas network in Egypt to incorporate the expected impacts of climate change on biodiversity.
- Establishing research programs on plants inhabiting the arid environment, such as mountains and deserts.
- Man activities should be away of the coastal line by about one kilometer.

2.7. Systematic Observation

Systematic Observation Needs

For systematic observation, the following is needed:

Establishing of proper systematic observation systems, monitoring networks and institutional information systems on sea level rising to support decision making. The systems primary objectives would be the identification of vulnerable areas; monitoring biodiversity and species sensitive to climate changes inside and outside the protected areas; building of databases; development and implementation of measures for resource protection; and following up and enforcement of planning regulations. Also, establishment of institutional capacities for monitoring coastal and sea surface temperature variations in the Mediterranean and Red Seas, as well as lakes and wetlands, including more effective use of remote sensing and non- traditional observing strategies.

The institutionalization of systematic observations of sea surface temperature, coastal land use and sea level variations, ensuring the availability of results for to the scientific community and policy makers.

In Egypt, the Central Agency for Population, Mobilization and Statistics (CAPMAS) represents the official authority for national data collection and analysis for the country. Its website offers information and data concerning various environment and development indicators. In addition several other organizations are carrying out systematic observations for specific climate targets. The systems and programs available for systematic observation are the following:

2.7.1. Meteorological and Atmospheric Observation

The Egyptian Meteorological Authority (EMA) is the authority responsible for systematic observations and meteorological forecasting in Egypt since 1933. The country-wide monitoring network consists of 112 stations including surface and atmospheric stations, air pollution, global radiation and agro-meteorological stations.

2.7.2. Air Pollution Monitoring:

The Egyptian Environmental Affairs Agency (EEAA) has contracted the Environmental Hazards and Mitigation Center (EHMC) at Cairo University, and the Institute for Graduate Studies and Research (IGSR), Alexandria University for sampling, measuring and carrying out laboratory analyses for a number of air pollutants. The National Institute for Standardization (NIS) acts as the reference laboratory for standardization, quality assurance and control. A network of 47 stations is established over Cairo, Alexandria, main cities in the Delta and Upper Egypt.

2.7.3. Coastal Water Quality Monitoring Network:

The Institute of Graduate Studies and Research (IGSR), Alexandria University, is responsible for monitoring the Mediterranean coast of Egypt and the National Institute of Oceanography and Fisheries (NIOF) is responsible for monitoring the Red Sea coast. The monitoring institutions also participate in a laboratory quality assurance program supervised by an independent reference laboratory at the Faculty of Science, Ain Shams University.

EEAA has established a website where these data are published. The physical parameters monitored by this network verify and complement satellite measurements of Sea Surface Temperature (STT) so as to provide useful information on changes of SST at various localities of the coastal zone.

4- Framework for mitigation and adaptation actions for conserving Biodiversity:

In spite of recording many species and ecosystem vulnerability, but still there are no much knowledge on the impact of climate changes upon biodiversity in Egypt, especially in freshwater and arid terrestrial ecosystems, and there are many gaps in information about the sensitive species to increasing temperature. The future impacts of climate change on fisheries and aquaculture are still poorly understood. Although uncertainty and gaps in knowledge exist, sufficient scientific information is available to plan for and address climate change impacts now. Implementing strategic adaptation actions early may reduce severe impacts and prevent the need for more costly actions in the future.

2.8.General Approach to Mitigation Action

Egypt is fully aware that GHG emissions reduction, particularly by major producers, is the only measure that could ensure the mitigation of global warming and climate change. The mitigation measures are based on those described in national plans and country studies documents. Implementation of these national plans needs financial and technical support from the international donors.

Promotion of energy efficiency and utilization of renewable resources of energy not only contribute to the reduction of greenhouse gases but also are consistent with the long-term development goals of the Egyptian economy. Various policies and measures related to internalizing renewable energies, energy efficiency and reduction of GHG emissions, as advocated in the UNFCCC, have been developed in Egypt.

Technology transfer needs for mitigating the effects of climate change over the medium term include environmental friendly technologies for the protection of the Mediterranean coast in general, and low elevation coastal zones in the Nile Delta in particular. Technical and financial support is urgently needed to establish research programs with teams from existing universities and research institutes. In this respect, priority research areas within the different fields include:

- Developing new strains tolerant to heat, salinity and water stresses.
- Adaptation options based on genetic engineering applications.
- Evaporation and evapotranspiration reduction.

• Simple and cheap marine aquaculture techniques.
• Non-conventional water resources development.
• Advanced research in the area of improved water use efficiency and water demand management as no- regret solutions to cope with climate change.
• Vulnerability assessment of the coastal zone and exploration of options for adaptation in view of adopted scenarios of sea level rise
• Monitoring, modeling and assessment of impacts of salt water intrusion on coastal wetlands.
• Monitoring, modeling and assessment of potential impacts of climate changes on coral reef and impacts on tourism
• Socioeconomic considerations of immigration of vulnerable communities and employment considerations in safe areas

2.8.1. General Approach to Adaptation Action

Adaptation actions are undertaken either to avoid or take advantage of actual and projected climate change impacts either by decreasing a system‘s vulnerability or increasing its resilience. This may entail reprioritizing current efforts as well as identifying new goals and objectives to reduce overall ecosystem vulnerability to climate change.

2.8.2. -Adaptation actions:

Adaptation actions may occur in legal, regulatory, institutional, or decision-making processes, as well as in on-the-ground conservation activities. For example, actions that restore or protect wetlands, and riparian areas can help moderate or reduce stream temperatures, alleviate the flooding and scouring effects of extreme rainfall or rapid snowmelt, improve habitat quality, and enable species migrations.

Decision-makers may also modify or create laws, regulations, and policies to incorporate climate change impacts into infrastructure planning to protect ecosystems, promote green infrastructure and low impact development approaches to reduce extreme flows and improve water quality and habitat, and adapt Early Detection and Rapid Response protocols to identify, control, or eradicate new and existing invasive species before they reach severe levels. Although uncertainty and gaps in knowledge exist, sufficient scientific information is available to plan for and address climate change impacts now. Implementing strategic adaptation actions early may reduce severe impacts and prevent the need for more costly actions in the future.

The actions aim to:

(1) Remove other threats and reduce non-climate stressors that exacerbate climate change effects;

(2) Establish, increase, or adjust protected areas, habitat buffers, and corridors; and,

(3) Increase monitoring and facilitate management under uncertainty, including scenario-based planning and adaptive management.

The following is the number of actions that should be done:

- **Conduct/gather additional research, data, and products**

Gathering research, data, and products on actual and projected climate change impacts is critical to supporting adaptation action. Models and research products have predicted a range of plausible scenarios; as these tools are refined, many indicate that the extent and magnitude of climate impacts may be greater than previously thought. Incorporating the best available science, traditional ecological knowledge, and citizen science efforts may improve climate adaptation decisions.

- **Create/enhance technological resources**

Technology transfer needs for mitigating the effects of climate change over the medium term include environmental friendly technologies for the protection of the Mediterranean coast in general, and low elevation coastal zones in the Nile Delta in particular. Also, updated genetic engineering techniques are very important for producing tolerant species to high temperature, high salinity and dryness.
Technological resources can make adaptation action easier and more accessible. These resources include the tools that can support information exchange, modeling of vulnerability and risk, and decision-making. These resources can help planners, managers, scientists, and policy makers to identify priority species and areas for conservation, generate inundation and hazard maps, and ascertain organizations and communities that have successfully implemented adaptation strategies.

- **Conduct vulnerability assessments and studies**

Vulnerability assessments help practitioners evaluate potential effects of climatic changes on ecosystems, species, human communities, and other areas of concern. Vulnerability assessments and studies can identify impacts of concern, a range of scenarios that depend on the frequency and magnitude of changes, who and what is at risk from these impacts, and what can be done to reduce vulnerability and increase resilience. Specifically, climate change vulnerability assessments provide two essential components to adaptation planning:

i. Identifying *which* species or ecosystems are likely to be most strongly affected by projected changes; and Understanding *why* these resources are likely to be vulnerable, including the interaction between climate shifts and existing stressors.
ii. Determining *which* resources are most vulnerable enables managers to better set priorities for conservation action, while understanding *why* they are vulnerable provides a basis for developing appropriate management and conservation responses (emphasis in original). In other words, they can provide a factual underpinning for differentiating between species and systems likely to decline and likely to thrive, but do not in themselves dictate adaptation strategies and management responses. This emphasizes the fact that a vulnerability assessment is not an endpoint, but a source of information that can be incorporated into planning and decision-making.

- **Conduct scenario planning exercises**

Scenario planning involves the creation of a series of scenarios specifically for the planning process in question, as well as narratives to accompany those scenarios. It also involves the use of those scenarios for evaluating policy/management options. Scenario planning allows participants to identify actions that work well across multiple scenarios, to discover options for dealing with uncertainty, and can improve adaptive management.

- **Increase organizational capacity**

Sufficient organizational capacity is needed to support adaptation activities at all levels of government. This strategy includes improving the resources, tools, knowledge, and institutional support required to increase organizational capacity.

- **Create/host adaptation training and planning workshops**

While many researchers, conservation practitioners, and resource managers understand the reality of climate change, they are often still challenged by what actions to take. As a result, the conservation and resource management community needs assistance developing its thinking on dealing with climate change, finding the information or data it needs to make informed decisions, and finding people to interact with on this topic as individuals develop their own approaches.1304 Training and planning workshops can provide context, guidance, and practical examples of how adaptation is being addressed on-the-ground.

- **Provide training for people whose livelihoods are threatened by climate change**

This strategy directly addresses the potential economic consequences of global climate change. Increased water temperatures and ocean acidification will severely impact fisheries, aquaculture, and ecotourism and recreation based on natural resources.

- **Create new institutions (training staff, establishing committees)**

Creating committees and advisory bodies and having properly trained staff can institutionalize climate change considerations within an organization. Technical experts, scientists, and other staff can contribute important knowledge and recommendations to support governmental decision-making on climate adaptation.

- **Coordinate planning and management across institutional boundaries**

Many climate change impacts will affect multiple jurisdictions at once whether the effects are felt at local, regional, national, or international scales. Because climatic variability is not confined by political or social boundaries, cross-jurisdictional coordination of planning and management can improve adaptation efforts. Increased cooperation may include information sharing, improved communication, and establishing formal partnerships to share resources, funds, and knowledge.

- **Invest in/enhance emergency services planning and training**

Climate change is expected to increase risks to public health and safety throughout North America. Warmer temperatures and changes in precipitation patterns will likely increase incidences of wildfires and drought, pests and diseases, and intense heat waves. Integrating climate change concerns into emergency services planning and training, including police, fire and rescue, and emergency medical services, will be important to limit public health and safety risks.

- **Create stakeholder engagement processes**

As mentioned previously, gaining public buy-in for adaptation can be critical to ensuring the effectiveness of any strategy. Engaging stakeholders can occur in a variety of ways; for example, participating in meetings and workshops, one-on-one interactions, and websites, among others. Activities like interactive, participatory discussions, problem solving sessions, and role-playing exercises have been used to engage stakeholders in climate adaptation.

- **Increase/improve public awareness, education, and outreach efforts**

This action relates to improving the links between science, management, decision-making, and public awareness. These efforts may be in the form of presentations and workshops, print and internet media, steering and advisory committees, and traditional educational venues. More interactive approaches tend to be better at ensuring a two-way flow of information, recognizing that scientists must learn from managers, policy makers, and the public as well as vice-versa. Enabling managers and decision-makers to incorporate climate adaptation into practice requires that the appropriate science be available in useable forms when needed. The broader public also needs to be engaged in climate adaptation and be made aware of the potential ways that climate change may affect the economy, natural resources, livelihoods, health, and well-being. Gaining public buy-in may increase political and social capital to support climate adaptation action at local, regional, national, and international levels.

- **Evaluate existing monitoring programs for wildlife and key ecosystem components**

Monitoring systems provide information that managers can use to adjust or modify their activities through the process of adaptive management. This approach would evaluate the current state of the systems that collect, analyze, and interpret environmental information. It would determine how programs will need to be modified to provide management-relevant information on the effects of climate change and what new monitoring systems will need to be established in order to address gaps in knowledge of climate effects. The costs to adapt existing monitoring systems and develop new monitoring systems are likely to be high. In many cases this will probably require new legislation and regulations, and possibly new tools and approaches to monitoring. It will also require better integration and coordination across existing monitoring programs.

- **Improve coordinated management and monitoring of wetlands**

Three options for improving coordinated management and monitoring of wetlands are:

i. Promote climate-smart integrated resource management at the watershed level by offering financial and other incentives
ii. Use legislative reauthorizations to explore new ways to protect biodiversity and ecosystems in light of climate change and to integrate preservation and restoration1339
iii. Support research on the impacts of climate change (and the effectiveness of various management options) on wetlands

- **Incorporate predicted climate change impacts into species and land management**

Information about actual and potential climate change impacts can be of benefit to land and natural resource managers in making decisions and taking actions. Climate change is not addressed in many existing natural resource plan documents. This strategy would use existing natural resource planning mechanisms to inform decision-making on a broad spectrum of natural resource management topics. Many existing natural resource plans already contain provisions for updates and revisions, which could provide a mechanism for incorporating information about climate change effects and adaptation strategies.

The problems with this approach are mainly practical at present: there is a definite cost associated with revisiting and revising management plans; in practice, many resource management plans are updated infrequently. While detailed predictions of potential climate change effects have only been available for a small subset of species and areas, considerable progress is being made in down-scaling of climate information for use at more local levels. Below, three examples are provided for incorporating predicted climate change impacts into species and land management:

- **Incorporate climate change into wetland restoration planning:**

To incorporate climate change into wetland restoration planning, one option is to establish wetland reference sites to document the impacts of climate change and to determine the effectiveness of management and adjustment strategies. Another option is to develop protection and adjustment tools through the use of ―pilots. In all cases, monitoring success and failures and actively making the results of studies broadly available to the public and other practitioners is suggested.

- **Incorporate climate change considerations into aquatic invasive species management plans:**

The process could be initiated by conducting facilitated meetings and/or workshops to identify specific management strategies and research needs to inform management strategies. State (or other jurisdictions) councils also could work with one another to share information on climate-related data across regions. Coordination and information sharing among states (or other jurisdictions) will also facilitate the implementation of activities that are adapted to climate change effects. State and federal agencies (as well as other jurisdictions) also could collaborate in areas such as aquatic invasive species data collection, specifically where the spatial scale of the biological and environmental data needed by the federal government may be more efficiently collected by a state. In turn, the data provided to the federal government by states (or other jurisdictions) may be used in modeling scenarios that also would benefit state aquatic invasive species management efforts.

- **Incorporate climate change considerations into Ecosystem-Based Management:**

It is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors. Specifically, ecosystem-based management:

i. Emphasizes the protection of ecosystem structure, functioning, and key processes;
ii. Is place-based in focusing on a specific ecosystem and the range of activities affecting it;
iii. Explicitly accounts for the interconnectedness within systems, recognizing the importance of interactions between many target species or key services and other non-target species;
iv. Acknowledges interconnectedness among systems, such as between air, land and sea;
v. Integrates ecological, social, economic, and institutional perspectives, recognizing their strong interdependences.

- **Develop dynamic landscape conservation plans**

Dynamic landscape conservation plans include information on fixed and dynamic spatial elements, along with management guidelines for target species, genetic resources, and ecosystems within the planning areas. Fixed spatial elements include protected areas where the land use is fully natural. Dynamic spatial elements include all other areas within the landscape matrix, where land use may change over time. The plan includes a desired future condition for each element, based on predicted shifts in distribution of species and other ecosystem components, as well as any intermediate steps that may be necessary to transition between current and future condition. The management guidelines suggest mechanisms and tools for management (such as land acquisition, riparian plantings, or other wildlife-friendly farming practices) and specific government agencies responsible for implementation. The actual planning activities required to develop these plans are likely to be compatible with other local or regional-scale planning projects such as State Wildlife Action Plans or watershed management plans. However, planning efforts can be resource-intensive. Recommendations such as suggesting that certain spatial elements (i.e. areas of land or water) will need to be converted from human uses to natural management are likely to prove controversial.

- **Climate change adaptation in fisheries**

Adaptation strategies are location and context specific and, hence, difficult to model and predict. This section presents some existing and potential strategies for the sector that could reduce vulnerability and increase adaptive capacities towards climate changes and changes which may combine with them.

A wide range of adaptations is possible, either carried out in anticipation of future effects or in response to impacts once they have occurred. As shown below, some are implemented by public institutions, others by private individuals. In general, responses to direct impacts of extreme events on fisheries infrastructure and communities are likely to be more effective if they are anticipatory, as part of long-term integrated management planning. However, preparation should be commensurate with risk, as excessive protective measures could themselves have negative social and economic impacts. As climatic change increases environmental variation, fisheries managers who have not already done so will have to move beyond static understandings of managed stocks or populations. Inflexible management approaches may no longer apply. There is a need for implementation of adaptive holistic, integrated and participatory approaches to fisheries management, as required for an ecosystem approach

i. **Climate change mitigation measures in fisheries**

The primary mitigation route for the sector lies in its energy consumption, through fuel, raw material use and production. As with other food sectors, distribution, packaging and other supply chain components also will contribute to the sector's carbon footprint. Net mitigation contributions of fisheries, aquaculture and related supply chain features are small in overall terms but can be improved. In some cases, climate change mitigation would be complementary to and reinforce existing efforts to improve fisheries and aquaculture sustainability. However, when implementing such strategies, their possible negative impacts on food security and livelihoods would have to be better understood, justified where relevant, and minimized. There also may be valuable interactions for the sector with respect to environmental services such as maintaining the quality and function of coral reefs, coastal margins; inland watersheds, potential carbon sequestration and other nutrient management options, but these will need further research and development (R&D).

ii. Achievable mitigation measures in fisheries

Although a relatively small global contributor, capture fisheries have a responsibility to limit GHG emissions as much as possible. For example, eliminating inefficient fleet structures (e.g. excessive capacity, over-fishing), improving fisheries management, reducing post-harvest losses and increasing waste recycling will decrease the sectors' CO_2 emissions and improve the aquatic ecosystems' ability to respond (assimilative capacity and resilience) to external shocks.

Other technical solutions to reduce fuel use, subject to clear analysis of options and production returns, might include shifting towards static fishing technologies and to more efficient vessels and gears. In some cases, win-win conditions could be identified, where reduced fuel-use strategies would link with reducing fishing effort, improving returns to vessels, safeguarding stocks and improving their resilience to climate change. These will need to be seen in the context of global forces impacting fisheries, such as changing fuel prices and increasing internationalization of fish trade, especially through air freight. Increases in fuel prices will tend to decrease fuel use while increases in internationalization will tend to increase fisheries' contributions to CO2 emissions.

- **Potential adaptation measures in aquaculture**

In most cases and for most climate change-related impacts, improved management and better aquaculture practices would be the best and most immediate form of adaptation, providing a sound basis for production that could accommodate possible impacts. An ecosystem approach to aquaculture (EAA) management would be a most effective thematic adaptation measure. As with capture fisheries, responses range from public to private sector and can be reactive or anticipatory. The aquaculture of extractive species – using nutrients and carbon directly from the environment such as bivalves and macroalgae – may deserve further attention for its positive ecosystem characteristics and potential food security benefits. Integrating aquaculture with other practices, including agro-aquaculture, multitrophic aquaculture and culture-based fisheries, also offers the possibility of recycling nutrients and using energy and water much more efficiently. These could include fisheries and assist coastal communities in general. Short-cycle aquaculture may also be valuable, using new species or strains and new technologies or management practices to fit into seasonal opportunities. Aquaculture could be a useful adaptation option for other sectors, such as coastal agriculture under salinization threats, and could also have a role in biofuel production, through use of algal biomass or discards and by-products of fish processing.

i- Climate change mitigation measures in aquaculture

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ii- Achievable mitigation measures in aquaculture production systems

As with capture fisheries, aquaculture's total GHG contributions are relatively small, but it has equal obligations for reducing impacts. Policies to support climate change mitigation need to be developed that address resource access and use, production options and market-related measures such as certification, encourage transparent measures of mitigation standards with comparison to other food producing sectors and, where appropriate, ensure suitable social inclusion and protection. As with fisheries, a full LCA approach would be required. Key areas for focus would include fishmeal, fish oil and other feed inputs, and water and energy efficiency, especially for small scale producers. Genetic modification technologies could have particular efficiency impacts through widening the production scope of low-impact aquaculture species, or making agricultural crop materials or waste products usable for growing carnivorous aquatic species. However, this would require evaluation on wider social and political criteria. Technologies and management approaches should be accessible to small and rural farmers.

CONCLUSION

It is well recognized that all sectors of development in Egypt are highly vulnerable to impacts of climate change and that institutional structure for monitoring, integration and modeling is necessary for proper adaptation. So the studies are now being aimed to improve efficiency of resource use, protect vulnerable coasts and help the communities build up resilience to better manage their land, environment and crops

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