Available online at www.sciencedirect.com
ScienceDirect
Procedia Environmental Sciences 4 (2011) 251–259
Procedia Environmental Sciences

Urban Environmental Pollution 2010

The impact of global climatic changes on the aquatic environment

Alaa E. Eissa [a], Manal M. Zaki [b*]

[a] *Department of Fish Diseases and Management, Faculty of Veterinary Medicine, Cairo University, Giza 11221,Egypt*
[b] *Departments of Veterinary Hygiene and Management, Faculty of Veterinary Medicine, Cairo University, Giza 1122, Egypt*

Received date September 30, 2010; revised date January 30, 2011; accepted date January 30, 2011

Abstract

Global climatic change, as defined by the U.S. Global Change Research Act of 1990 (GCRA), "means changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life". Climatic changes are the most drastic variables interacting with all live aspects of the world's development equation. Global warming, melting glaciers, sea level rise with increased coastal erosions, increased rate of lake evaporation, green house effects, increased ocean acidity, increased rates of biological invasions and deteriorated biodiversity are the interacting variables. There is a very clear fact that climatic change is not a country made product, however, it is a trans-continental issue. The abrupt surge in the catastrophic consequences of climatic changes was primarily derived from the hydrologic changes in global water that gradually moved forward toward the land. This fact puts the aquatic species on the top list of the most impacted creatures. As an ideal example for the regional impacts of global climatic changes, the coastal zones of the Levantine Mediterranean Sea at the basins of countries like Egypt, Israel and Lebanon are on an ongoing process of continuous coastal land erosions with subsequent fisheries recession due to critical damage of the breeding habitats of the native fishes at such pristine areas of the world. Further, the historical opening of Suez Canal in 1869 was a triggering force behind the development of many ecological changes in the Levantine Mediterranean as well as the Egyptian territories from the Red Sea basin. Such climatic changes have favoured the move of some invasive species like Rabbit fish and Erythrean mytilid mussel from the Red Sea to the Mediterranean Sea with their consequent huge negative impacts on the native biodiversity of the southeast Mediterranean. Other detrimental factors that will ultimately lead to great impact on the aquatic biodiversity are the inland aquaculture, eutrophication; aquatic habitat destruction and fragmentation. Thus, without a real creative international initiative to save the world's ecosystem from the colossal destructive effects of climatic changes, there will be possible endangering effects on all living creatures on planet earth.

Keywords: Global warming, climatic changes, biodiversity, aquatic animals, Egypt, invasive species, Levantine

* Corresponding author's email: drmanalmoustafa2008@yahoo.com

doi:10.1016/j.proenv.2011.03.030

1. Introduction

Diversifying categories of the world renowned scientist have been deeply implemented in researching the uprising global threat of the climatic changes on the existence of all living creatures on the planet earth. Climatic changes have been known for a while for their deleterious impact on the biology, fecundity, growth and biodiversity of aquatic, terrestrial and aerial animals [1]. Throughout the last two decades , scientist were working hard on establishing criteria for defining the core meaning of the word " global warming" forgetting the fact that the environment is not only a thermal but also constitutes a large scale of other integrating factors such as gaseous emissions , chemical effluents, and deforestation [2].

Terrestrial environment has been most affected by land conversion, often to agricultural use [3] which represents the most devastating model of global climatic change on earth's component. Overexploitation of fishing resources, pollution, and climate change are examples of major drive of change in marine ecosystems [3, 4]. Primary motives of change for freshwater ecosystems include modifications and use of watersheds; human contamination of water resources; altered hydrology; and invasive species [3, 5]. Many assessments have recognized climate change as a major motive of change that will play an increasingly important role in the coming decades [6]. Climate change can occur over evolutionary and ecological time scales as a result of natural and anthropogenic causes [1].

As an essential life component of those creatures that were deeply impacted with the fact of rapidly developing worldwide climatic changes, aquatic animals moved up to the top of the most suffering creatures list [7].The more the industries infiltrating the water bodies in a certain state the more the impact on such aquatic species.

Thus, the urgent need for investigating other hidden causes that influentially leads to the disaster of global climatic change demands in depth search in all available structural components of the environment. In this review, most of the integrating causes of the global climatic changes and their impacts on the regional and transcontinental aquatic environments were deeply discussed. Ultimately, our final goal is to alarm the international community to the devastating effects of global climatic changes on the survival, growth and prosperity of the aquatic animals in their environment with subsequent impact on the world's human development.

2. Discussion

2.1 Sea level rise

Thermal expansion of ocean water and accelerated melting of glaciers, sea level is likely to rise by about half a meter by 2100 [8]. Sea defences in many coastal regions will need to be improved, even though at considerable cost. However, such adaptation is not possible for countries with large river deltas such as Bangladesh, Southern China and Egypt and for many islands in the Pacific and Indian Oceans [9].

A considerable number of aquatic species will be threatened with the continuous increase in sea level to a degree that some of them will be listed under the category of threatened or extinct species by the end of this century [10]. Among the species that are vulnerable to such drastic effects, migratory fishes (mullet and eels), other aquatic species (turtles), coral reefs (red sea corals), some aquatic crustaceans and large number of aquatic birds (flamingo, aquatic warbler, pelicans and swan goose) [11]. The threats are mainly due to destruction of spawning areas and nesting grounds for the above mentioned species [10, 11].

2.2 Increased rate of evaporation of water resources

The gradual rise in earth's temperature initiates subsequent episodes of water evaporation. This critical problem is due to the unregulated human interference in the god gifted nature. At present, as much as 6 % of Earth's river runoff is evaporated as a consequence of human manipulations [12]. In vast areas around the globe, heavy rainfall may become heavier while semi-dry areas may receive less rainfall. There will be more common and more intense floods or droughts, especially in sub-tropical areas, which are liable to such events [13]. Floods and droughts already cause more mortalities, catastrophes and economic collapse than any other type of disasters. Any increase in their occurrence or magnitude could be the most destructive impacts of global climate change.

Lake Manzallah and Lake Qarun are Egyptian models for those water bodies that have been intensely suffering from gradual evaporation with consequent increase in salinity and decrease in surface area of both lakes [14]. However, some internal closed lakes and rivers in Africa were more vulnerable to evaporation and surface area decline than those of opened or semi-opened nature [15]. These dynamic changes in the hydrologic cycle of water triggered a reliable number of aquatic species to migrate to alternative water bodies in case of opened and semi-opened types while enforced others to live in the danger of being endangered, threatened, or even extinct species.

2.3 Effect of manmade dams

Major rivers worldwide have faced dramatic changes in flow, reducing their natural ability to adapt to and absorb disturbances. Given predicted changes in global climate and water needs, this may create severe problems, including loss of native biodiversity and risks to ecosystems and humans from increased flooding or water scarcities [16]. Most of the ecological studies that have linked the climate change with the growing changes in river basins have emphasized that the area in need of management action to mitigate the impacts of climate change is much greater for basins impacted by dams than for basins with free-flowing rivers [17].

Humans have constructed dams for a variety of reasons: water storage, flood prevention, electricity generation, irrigation, navigation, and recreation [18, 19]. However, there is a significant drawback of dams which is the negative impact on local ecosystems. The dams may interfere with the fishes routing systems by suppressing many olfactory instincts, which are responsible for the incredible homing system of fish [20]. Some species may also be exposed to predators that they would not normally meet in a fast-moving river, and may be in danger of predation especially if they are young and weak [19]. Dams also, interfere with the natural processes for food allocation, habitat, and mates. Another problem caused by dams is genetic segregation: fish can no longer move freely though different habitats and may become genetically segregated from other fish populations throughout the river [21].

In Egypt, the great brown flood that came pouring out of the desert had a fertilizing effect on waters of the southeastern Mediterranean similar to that which it had on land. During the past decades, the Levantine Basin has been subjected to the effects of two important events, the opening of the Suez Canal in 1869 and the construction of the Aswan High Dam in 1964. Since 1965 when the High Dam became fully operational, the Nile flow to the Mediterranean has greatly diminished [22, 23, 24, 25]

Although the construction of the High Dam has been an unquestionably tremendous boon to Egyptian agriculture and has benefited industry by providing cheap electric power [18], it has also had influential negative effects on the transport of fertile clay and sediments. These sediments are now trapped behind the dam, a situation which has led to severe erosion along the Egyptian coast [26, 27, 28]. The dam also had great impact on the fertility of the coastal waters. The fertilizing effect of the inflow of the nutrient-rich water during the flood season once resulted in exceptionally dense blooms of phytoplankton off the Nile Delta. This "Nile bloom" provided nourishment to sardines and other pelagic fishes. It also constituted a large source of silt material, which forms a vital source of food for commercially valuable organisms such as shrimp [25, 29]. The effect of High Dam on the development of marine fisheries was catastrophic. The sardine fishery primarily composed of *Sardinella aurita*, which is heavily dependent on the magnificent amount of phytoplankton during the flood season [18, 30]. Thus, the total catch of sardine was declined from 18,000 tons in 1962 to 600 tons of sardine in 1969. The shrimp fishery also severely affected as the catch decreased from 8,300 tons in 1963 to 1,128 tons in 1969 [30].

Although it has been more than forty years since the construction of the High Dam, it seems that there has not been enough time for the ecosystem of the Levantine Basin to reach a new level of ecological equilibrium [18]. The results of the recent investigations, however, reveal the direction in which the pelagic ecosystem is adjusting. The recent recovery of total fish landings, particularly the sardine catch, is an important indicator among many, but the mismatch between low primary productivity and relatively high levels of fish production in the region still presents a puzzle to scientists [31].

2.4. Effect on food abundance

Several studies on food availability and abundance indicated that the global food reserve is in a state of continuous decline. The distribution of food production will dramatically change from certain geographical area to another around the world mainly because of the uprising shortage of water availability. The developing countries will be the most impacted nations with the problem of global water shortage due to the rapid increase of human population and inadequate agricultural production.

The largest uncertainty in forecasting the effects of climate change on ecosystems is in understanding how it will affect the nature of interactions among species. Climate change may have unexpected consequences because different species show unique responses to changes in environmental temperatures. Research indicated that trophic linkages between phytoplankton and zooplankton (nutritional backbone for majority of lower aquatic trophic stages) can be disrupted by the increase in water temperature of a certain water body. Now, there is a well established fact that diatom blooms and other aquatic biota are drastically affected by the global warming induced mismatch in water temperature [25]. This in turn will have severe consequences for resource flow to upper trophic levels [32].

There is evidence that climate warming is a diminishing factor for the productivity in Lakes. The regional warming patterns since the beginning of the twentieth century, leads to rise in surface-water temperature which disrupts the stability of the water column [33]. Further, the regional decrease in wind velocity has contributed to reduced mixing; decreasing deep-water nutrient upwelling and entrainment into surface waters. There are some conclusive evidences that the impact of regional effects of global climate change on aquatic ecosystem functions and services can be larger than that of local anthropogenic activity or overfishing [33].

A recent increase in the frequency, degree and duration of harmful algal blooms in coastal areas suggests that anthropogenic activity has impacted the lower as well as the higher organisms in the marine food chains [34].

2.5. Effect on marine and estuarine environments

Climate change may result in sea level rise; water temperature increase; and deviations from present patterns of precipitation, wind, and water circulation [35, 36]. Estuaries may experience loss of breeding areas, disturbance of marine waters and associated organisms, changes in circulation models that affect maintenance of some native species, increased hypoxia and storm magnitude [36, 37]. Estuarine and coastal systems could experience pole-ward retreat of cold-tolerant species and range expansion of warm-tolerant species [35,38].

2.6. Thermal effects

The average air temperature near the Earth's surface over the past century shows a lot of variability due to influences such as volcanic eruptions, variations in the heat from the sun and other natural phenomenal changes involving earth, seas, and air [39]. One major cause behind the ascending rise of world's temperature is the increased emissions of carbon dioxide gas. If carbon dioxide concentration increases during the 21st century to more than double of its pre-industrial value then estimates show that global average temperature will rise by about 2.5ºC. When compared with the temperature changes we commonly experience a rise of 2.5ºC does not seem very large. However, we should remember that, it is a rise in the average yearly temperature panel over the whole globe. Between the middle of an ice age and the warm periods in between ice ages, the world's average temperature changed by only about 5 ºC. Thus, a 2.5ºC rise represents about half an 'ice-age' in terms of climate change. For this to occur in less than a century, as reported, is considered a very rapid change.

An important consequence of global warming is the sex ratios change among animals. For example, many reptiles are reliant on temperature sex determination [40], as are some birds [41] and fish [42]. Temperatures of 29.2°C produce a 1:1 sex ratio in sea turtle populations; including the green turtle, hawksbill turtle, leatherback turtle, loggerhead turtle and the olive ridley turtle. Higher temperatures will lead to the feminization of populations [43], which will affect breeding success and ultimately will result in extinction of certain species.

Temperature fluctuations during early fish development are another detrimental factor that may induce different prototypes of deformities including skeletal deformities [44]. Primitive construction and remote location of fish hatcheries might expose the early developmental stages of fish to the sharp fluctuations in temperature and inappropriate hatching enclosure hydrodynamics. Such adverse climatic changes might disrupt vital developmental processes during early morphogenesis and might give rise to different types of deformities [44].

2.7. Gaseous Emission

The Earth absorbs the heat energy of sunshine mainly at the surface. To maintain a steady temperature, a balancing amount of energy is then radiated upwards from the surface at longer, infrared, wavelengths [45]. Some of the gases in the atmosphere which are present naturally, particularly water vapour, carbon dioxide and methane, absorb some of this infrared radiation so acting as 'blankets' over the surface [45]. CO_2 is the primary molecule influencing the pH of oceans [46]. Since the 1800's, oceans have absorbed 1/3 of anthropogenic CO_2 emissions (Sabine et al. 2004) and the average oceanic pH has dropped by 0.10 units, equivalent to a 30% decrease. If unmitigated, oceanic pH is likely to decrease by a further 0.4 units [46] by 2100. Increases in atmospheric CO_2 are currently more rapid than at any point in the last 650,000 years [47].

A reduction in pH will have impacts on the entire oceanic system, with high latitude cold water oceans affected earlier and more severely than warm water oceans. Concentrations of atmospheric CO_2 and other radioactively active trace gases have risen since the Industrial Revolution [7]. Such atmospheric modifications can alter the global climate and hydrologic cycle, in turn affecting water resources [7]. Fossil fuel combustion now adds 5.5 - 20.5 billion metric tons of CO_2 to the atmosphere annually, mostly in economically developed regions of the temperate zone [48]. The fact that increased CO_2 affects species differentially means that it is likely to drive substantial changes in the species composition and dynamics of all terrestrial and aquatic ecosystems [49].

Farming, livestock husbandry, and the combustion of fossil fuels cause excess sulfur dioxide, ammonia, and nitrogen oxides to be released to the surrounding environment, where they are transformed into nitric acid and sulfuric acid. Despite the fact that, much of these acids are dumped on land, some of them can be lodged in the air all the way to the coasts of oceans and seas. When nitrogen and sulfur compounds from the atmosphere are mixed into coastal waters, the change in water chemistry is as much as 10 to 50 percent of the total changes caused by acidification from carbon dioxide [13]. Such new chemical mix changes the chemistry of seawater, with the increase in acidic compounds lowering the pH of the water while reducing the capacity of the upper ocean to store carbon. Further, the uprising increase in nitrogenous deposition into natural water systems can increase the dominance of non-native species [52]. Although some of these fertilization studies used relatively large (>10 g m^{-2} year $^{-1}$) amounts of nitrogen in their fertilization treatments, other studies have shown that, where nitrogen is a limiting nutrient, even small nitrogen additions can benefit invasive species [13].

2.8. Invasive species global supremacy

The introduction of species into new areas is a natural phenomenon that has occurred throughout evolutionary history [50]. In modern times, however, the natural movement of species has been augmented by humans operating in a globalized world. In the Great Lakes, Suez Canal, Suez Gulf, Akkaba Gulf and Mediterranean Sea for example, intense vessel traffic from international trade is the major vector for introduction of non-native aquatic species [51]. Further, the surge in nitrogen and nitrogenous compounds precipitations into natural water systems is known to elevate the supremacy of invasive aquatic species [52]. Ecological chemistry studies have determined that nitrogen is a limiting nutrient for the growth and prosperity of invasive species [13].

A small Erythrean mytilid mussel, *Brachidontes pharaonis*, is one of the earliest invasive bivalves to enter the Mediterranean, already present in 1876 near the northern access of the Suez Canal [53]. Common in the Levant Sea, where it stays in thick bunches on intertidal rocks, and sediments, it has extends as far west as Sicily, probably in ship dumping, where it is found in marine, high temperature environments [54,55].

Non-native species (also described as alien or exotic) that are intentionally or unintentionally released into new environments can become invasive species, causing environmental, economic, and/or human health harm (US Executive Order 13112 establishing the National Invasive Species Council) [56]. In the past 3 decades, the continuous global surge in temperatures has positively favored the establishment, growth and supremacy of non native (invasive species) in its new environment. An ideal end product for such environmental impact of global climatic changes is the freshwater red swamp crayfish (*Procambrus clarkii*), an invasive species that was unintentionally released into the Egyptian natural aquatic environment [57,58]. Such invasive species have drastically dominated the vast majority of Nile River tributaries in Egypt with the induction of extreme environmental, economic, and/or human health harm [57]. The degree of spread, environmental and economical damage is obviously related to the degree of local Egyptian and continental River Nile water chemistry changes (increased nitrogen deposition, eutrophication, increased acidification (carbonate, sulfate, and nitrates), and dissolved oxygen decline with continuous rise of water temperatures.

In fact, only a small percentage of non-native species become invasive and cause ecological and/or economic damage [59,60]. However, for those species that do become invasive, their impacts can be devastating. Available data indicate that invasive species can threaten the very existence of native species in the invaded environments [61]. Invasive species are a major cause of extinctions worldwide (25 percent of fish extinctions, 42 percent of reptile extinctions and 22 percent of bird extinctions) [62]. In the U.S. alone, damage and losses from invasive species are estimated at a value of approximately $120 billion annually [60,63]. Also, despite advances in understanding what makes environments suitable for invasion and determining characteristics of species capable of invasion, it is still difficult to predict which species will become invasive [64].

Aquatic invasive species (AIS) can cause a wide range of ecological impacts including loss of native biodiversity, altered habitats, changes in water chemistry, altered biogeochemical processes, hydrological modifications, and altered food webs [65]. Wetlands, including estuaries, are some of the most invaded habitats in the world [66]. Some of the most notorious U.S. invaders are aquatic species such as the Great Lakes sea lamprey (*Petromyzon marinus*), zebra mussel (*Dreissena polymorpha*), Asian carp, *Caulerpa* (marine green alga), and the green crab (*Carcinus maenas*). Locally, an indefinite number of invasive aliens have been reported within the basins of the Levantine areas of Red and Mediterranean Seas including Egyptian northern estuaries, Suez Canal, River Nile and its tributaries [57,58].

Invasive species can be major ecosystem stressors, and their interaction with other global change stressors is not fully understood. The global-change components can affect species distributions and resource dynamics in terrestrial and aquatic ecosystems, and consequently can interact with biological invasions [3]. These impacts include competitive effects, in which an invading species reduces resources available to other species, and ecosystem effects, whereby AIS alters fundamental properties of the ecosystem. Both types of effects can threaten native biodiversity, and some ecosystem effects feed back to elements of global change [65]. Kolar and Lodge [51] identify global change and other anthropogenic stressors that increase the number or the impact of freshwater invasive species. These stressors are: globalization of commerce (including shipping, bait trade, aquarium and pond trade, and aquaculture); waterway engineering (including canals and dams); land use changes (including siltation, eutrophication, and water withdrawal); climate and atmospheric changes; and intentional stocking. Further, a slightly different set of global change and anthropogenic stressors affecting invasions in the oceans, including: overfishing; chemical pollution and eutrophication; habitat destruction and fragmentation; biological invasions (facilitating other invasions); and climate change were reported by Carlton [67].

3. Conclusion and Challenges

Climate change is predicted to have a wide range of impacts on aquatic animal populations and those who depend on them. Driving of so many aquatic species to be under the category of endangered, threatened or extinct species was mainly motivated by the devastating impact of global climatic changes. Sea level rise with the subsequent coastal erosions is one major influential factor in the damage of breeding habitats of so many migratory aquatic species including fishes, shellfishes and birds. Increased ocean acidification is a detrimental factor for the predicted decline of large number of shellfishes due to the intense decalcifying effect of increased carbonic acid effects on calcium deposition in shell carrying animals. Another critical impact of global warming is the growing change in sex ratios among marine mammals, fishes, amphibians and aquatic birds. This critical process might lead the aforementioned species to be endangered, threatened and/or extinct. Increased eutrophication in tropical and subtropical areas is a coping image of global warming effect on the regional aquatic environments which could be damaging to the native species while favoring biological invasions in certain aquatic region.

Incorporation of analytical principles with the results of the number of researches that have discussed how biological invaders respond to global change leads to a conclusion that most of the critical components of global change are likely to increase the prevalence of biological invaders.

Environmental impacts on the production of aquatic food (aquatic wild and captive animals) are diverse, complex and interactive. Scientific community still knows relatively little about how various biotic systems react to changes in environmental and ecological spheres. In respect to the possibility that climatic and other environmental changes could adversely affect world edible aquatic animals production, there is a clear need to apply the precautionary principles such as taking presumptive action to minimize the future course of devastating environmentally- damaging global climatic changes.

Coastal regions facing climate change for example are subject to multiple burdens associated with globalization of aquatic animal production / trade, and in the poor or under-developed countries, lack of public infrastructure, high disease load as well as other factors limiting the ability to adapt. A final proposal to protect fishing sector and communities in coastal areas having the minimum ability to survive the devastating effects of climatic changes is to identify the most vulnerable aquatic species and communities; investigate possible governmental aided adaptation; consider limitations on private adaptations; and look for desirable adaptations which contribute to long term declines in vulnerabilities, rather than short-term management strategies which may enhance vulnerability. Thereby, there is an urgent need for policy integration throughout government sectors, as coastal planning, river basin management, agriculture, fisheries and health where climate change risks reacts.

Acknowledgment

The authors are grateful to Drs. Rabie Fayed and Mohamed Moustafa, the professors at the Faculty of Veterinary Medicine, Cairo University for their valuable inputs and comments during planning and writing of this review.

References

1. K. Cochrane, C. De Young and D. Soto. Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. Fisheries Technical Paper, 530. FAO, Rome, 2009, 216pp.

2. Food and Agriculture Organization of the United Nations, Building Adaptive Capacity to Climate Change: Policies to Sustain Livelihoods and Fisheries. New Directions in Fisheries, A Series of Policy Briefs on Development Issues (FAO, Rome), 2006.
3. G.C. Nelson, Chapter 3: drivers of ecosystem change: summary chapter. In: Hassan, R; Scholes, R; Ash, N, eds. Ecosystems and human well-being: current state and trends, volume 1. Washington, D.C.: Island Press; Publisher, 2005, pp.73-76.
4. T.P. Hughes, D.R. Bellwood and C. Folke, New paradigms for supporting resilience in marine ecosystems. Trends in Ecology and Evolution. 20 (2005) 380.
5. P.M. Vitousek, Beyond global warming: ecology and global change. Ecology 75 (1994) 1861.
6. IPCC, Climate Change.The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon et al., Eds., 2007, Cambridge Univ. Press, Cambridge, UK, and New York.
7. L.H. Chang, C.T. Hunsaker and J.D. Draves, Recent research on effects of climate change on water resources. Journal of American Water Resources Association. 28 (1992) 273.
8. A.E. Carlson, A.N. Legrande, D. W. Oppo, R. E. Came, G. A. Schmidt, F. S. Anslow, J. M. Licciardi and E. A. Obbink, Rapid early Holocene deglaciation of the Laurentide ice sheet. Nature Geoscience. 1 (2008) 620.
9. D.J. Marcogliese, Implications of climate change for parasitism of animals in the aquatic environment. Canadian Journal of Zoology. 79 (2001) 1331.
10. H. Galbraith, R. Jones, P. Park, J. Clough, S. Herrod-Julius, B. Harrington and G. Page, Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds. 25 (2002)173.
11. S.E. Newson, S. Mendes, H.Q.P. Crick, N.K. Dulvy, J.D.R. Houghton, G.C. Hays, A.M. Hutson, C.D. Macleod, G.J. Pierce and R.A. Robinson, Indicators of the impact of climate change on migratory species. Endangered Species Research. 7 (2009) 101.
12. K.M. Strzepek, and J.B. Smith, As Climate changes: International Impacts and Implications. Cambridge University Press, Cambridge, England, 1995, 3-13 pp.
13. P.M. Vitousek, H.A. Mooney, J. Lubchenco and J.M. Melillo, Human domination of earth's ecosystems. Science. 277 (1997) 494.
14. INECO, Towards the development of a strategy for water pollution prevention and control in the Bahr Basandeila region. Coordination Action Project supported by the European Commission through the 6th Framework Programme, 2009, (Contract No: INCO-CT-2006-517673).
15. J.F. Talling, Environmental regulation in African shallow lakes and wetlands. Revue d'Hydrobiologie tropicale 25 (1992) 87.
16. P.T.J. Johnson, J.D. Olden and M.J.V. Zanden, Dam invaders: impoundments facilitate biological invasions into freshwaters. Front Ecol Environ. 6 (2008) 357.
17. M.A. Palmer, C.A. Reidy Liermann and C. Nilsson, Climate change and the world's river basins: anticipating management options. Front Ecol Environ. 6 (2008) 81.
18. J.M. McCall, Primary production and marine fisheries associated with the Nile outflow. Earth & Environment. 3 (2008)179.
19. E. Francisco, Tales of the Undammed. Science News. 15 (2004) 235.
20. R.M.. Baxter, Environmental Effects of Dams and Impoundments. Annual Review of Ecology and Systematics. 8 (1977) 255.
21. D.M. Rosenberg, P. Mcculy and C. M. Pringle, Global-Scale Environmental Effects of Hydrological Alterations: Introduction. Bioscience. 50 (2000) 746.
22. Y. Halim, S.K. Guergues and H.H. Saleh, Hydrographic conditions and plankton in the South East Mediterranean during the last normal Nile flood (1964). International Review of ges Hydrobiology. 52 (1967) 401.
23. G.H. Thomas and W.F. Wadie, Trends of fish catch and factors responsible for its fluctuations in the Egyptian Mediterranean sea waters. Bulletin of the High Institute of Public Health, XIX. 4 (1989) 883.
24. Y. Halim, , S.A. Morcos, S. Rizkalla and M.K.h. El-Sayed, The impact of the Nile and the Suez on the living marine resources of the Egyptian Mediterranean waters (1958-1986) I'/n: Effects of Riverine Inputs on Coastal Ecosystems and Fisheries resources. FAO Fisheries Technical Paper. 349 (1995)19.
25. S. El-Sayed and G.L. van Dijken, The southeastern Mediterranean ecosystem revisited: Thirty years after the construction of the Aswan High Dam, 2007, from http://www- ocean.tamu.edu/Quarterdeck/QD3.1/Elsayed/elsayed.html.
26. A.M. Fanos, The Impact of Human Activities on the Erosion and Accretion of the Nile Delta Coast. Journal of

Coastal Research. 11 (1995) 821.
27. S. Daniel, Nile delta: extreme case of sediment entrapment on a delta plain and consequent coastal land loss. Marine Geology. 129 (1996)189.
28. O. E. Frihy, K.M. Dewidar and M. M. El Banna, Natural and human impact on the Northeastern Nile Delta Coast of Egypt. Journal of Coastal Research. 14 (1998) 1109.
29. N.M. Dowidar, Phytoplankton biomass and primary productivity of the south-eastern Mediterranean. Deep-Sea Resources. 31(1984) 983.
30. FAO (Food and Agricultural Organization), Effects of Agricultural Development on Vector- Borne Diseases. ACL/MISC/12/87. Rome: FAO, 1987.
31. N. Scott, The Artificial Nile – The Aswan High Dam destroyed a fishery, but human activities may have revived it. American Science. 92 (2004)158.
32. M. Winder, and D. E. Schindler, Climate Change Uncouples Trophic Interactions In An Aquatic Ecosystem. Ecology. 85 (2004) 2100.
33. C.M. O'Reilly, S.R. Alin, P. Plisnier, A. S. Cohen and B.A. McKee, Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa. Nature. 424 (2003) 766.
34. G. M. Hallegraeff, A review of harmful algal blooms and their apparent global increase. Phycologia. 32 (1993)79.
35. D. Scavia, J.C. Field, D.F. Boesch, R.W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, M. Harwell, R.W. Howarth, C.Mason, D. J. Reed, T.Royer, A.H. Salinger and J.G. Titus, Climate change impacts on U.S. Coastal and Marine Ecosystems. Estuaries. 25 (2002) 149.
36. J.M. Roessig, , C.M.Woodley, J.J. Cech and L.J. Hansen, Effects of global climate change on marine and estuarine fishes and fisheries. Reviews in Fish Biology and Fisheries. 14 (2004) 251.
37. F.G. Nordlie, Physicochemical environments and tolerances of cyprinodontoid fishes found in estuaries and salt marshes of eastern North America. Reviews in Fish Biology and Fisheries. 16 (2006) 51.
38. V.S. Kennedy, Anticipated Effects of Climate Change on Estuarine and Coastal Fisheries. Fisheries. 15 (1990) 16.
39. J. T. Houghton, L. G.Meira Filho, B. A. Callander, N. Harris, A. Kattenberg and K. Maskell, Climate Change 1995. The Science of Climate Change, 1996, Cambridge University Press, Cambridge,
40. F.J. Janzen, Climate change and temperature-dependent sex determination in reptiles. Proceedings of the National Academy of Science. 91 (1994) 7487.
41. A. Göth and D.T. Booth, Temperature-dependent sex ratio in a bird. Biological Letters. 1 (2005) 31.
42. N. Ospina-Álvarez and F.Piferrer, Temperature-Dependent Sex Determination in Fish Revisited: Prevalence, a Single Sex Ratio Response Pattern, and Possible Effects of Climate Change. PLoS ONE. 3(2008) 2837. doi:10.1371/journal.pone.0002837
43. L.A. Hawkes, A.C. Broderick, M.H. Godfrey and B.J. Godley, Investigating the potential impacts of climate change on a marine turtle population. Global Change Biology. 13 (2007) 923.
44. A.E. Eissa, M.Moustafa, I.N. El-Husseiny, S. Saeid, O. Saleh and T.Borhan, Identification of some skeletal deformities in some freshwater teleost raised Egyptian aquaculture. Chemosphere. 77 (2009) 419.
45. R. DeFries, F. Achard, S. Brown, M. Herold, D. Murdiyarso and B. Schlamadinger.. Earth observations for estimating greenhouse gas emissions from deforestation in developing countries. Environmental Science and Policy. 10 (2007) 38
46. K. Caldeira, and M.E.Wickett, Anthropogenic carbon and ocean pH. Nature. 425 (2003) 365.
47. U. Siegenthaler, T.F. Stocker, E.Monnin, D.Lüthi, J. Schwander, B. Stauffer, D. Raynaud, J.M. Barnola, H. Fischer,V. Masson-Delmotte and J. Jouzel, Stable carbon cycle-climate relationship during the Late Pleistocene. Science. 310 (2005)1313.
48. R.J. Andres, G. Marland, I. Fung and E. Matthews, One degree by one degree distribution of carbon dioxide emissions from fossil fuel consumption and cement manufacture, 1950-1990. Global Biogeochemical Cycles. 10 (1996) 419.
49. G.W. Koch and H.A. Mooney, Carbon Dioxide and Terrestrial Ecosystems (Academic Press, San Diego, CA, 1996).C. Korner and F. A. Barzar, Carbon Dioxide, Populations, and Communalities'. Academic Press, 1996, San Diego, CA,
50. W. Tinner and A.F. Lotter, Central European vegetation response to abrupt climate change at 8.2 ka. Geology. 29 (2001) 551.
51. C.S. Kolar and D.M. Lodge, Freshwater non-indigenous species: interactions with other global changes. In:

Mooney, HA; Hobbs, RJ, eds. Invasive Species in a Changing World. Washington, DC: Island Press, 2000, pp 3-30.
52. M.J.W. Burke and J.P. Grime, An experimental study of plant community invisibility. Ecology. 77 (1996) 776.
53. B.S. Galil, Loss or gain? Invasive aliens and biodiversity in the Mediterranean Sea. Marine Pollution Bulletin. 55 (2007) 314.
54. G. Rilov, Y. Benayahu and A. Gasith, Prolonged lag in population outbreak of an invasive mussel: a shifting-habitat model. Biological Invasions. 6 (2004) 347.
55. M. Pirro de, G.Sara`, A. Mazzola and G.Chelazzi, Metabolic response of a new Lessepsian Brachidontes pharaonis (Bivalvia, Mytilidae) in the Mediterranean: effect of water temperature and salinity. In: Casagrandi R. Melia` P (Eds.) Ecologia. Atti del XIII Congresso della Societa` Italiana di Ecologia, 2004, Retrieved at January, 28th 2010, from http://www.xiiicongresso.societaitalianaecologia.org.
56. F.J. Rahel and J.D. Olden, Assessing the effect of climate change on aquatic invasive species. Conservation Biology. 22 (2008) 521.
57. M.R. Fishar, Red swamp crayfish (*Procambarus clarkii*) in River Nile, Egypt case study. Biodiversity Monitoring and Assessment Project (BioMap) Nature Conservation Sector Egyptian Environmental Affairs Agency, Ministry of State for Environmental Affairs, 2006, pp32.
58. G. Wizen, B.S. Galil, A.l. Shlagman and A. Gasith, First record of red swamp crayfish, *Procambarus clarkii* (Girard, 1852) (Crustacea: Decapoda: Cambaridae) in Israel – too late to eradicate? Aquatic Invasions. 3 (2008)181.
59. OTA (U.S. Congress, Office of Technology Assessment), Harmful non-indigenous species in the United States. OTA-F-565, 1993, pp. 57.
60. R.P. Keller, D.M. Lodge and D.C. Finnoff, Risk assessment for invasive species produces net bioeconomic benefits. Proc. Natl. Acad. Sci. USA. 104 (2007) 203.
61. D. F. Sax and S. D. Gaines, Species diversity: from global decreases to local increases. Trends in Ecology & Evolution. 18 (2003) 561.
62. G.W. Cox, Alien species in North America and Hawaii: impacts on natural ecosystems. Island Press, 1999,Washington, D.C.
63. D. Pimentel, R. Zuniga and D. Morrison, Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics. 52 (2005) 273.
64. D.M. Richardson and P. Pysek, Plant invasions: merging the concepts of species invasiveness and community invasibility. Progress in Physical Geography. 30 (2006) 409.
65. J.S. Dukes and H.A. Mooney, Disruption of ecosystem processes in western North America by invasive species. Revista Chilena de Historia Natural. 77 (2004) 411.
66. J.B. Zedler and S. Kercher, Causes and consequences of invasive plants in wetlands: opportunities, and outcomes. Critical Reviews in Plant Sciences. 23 (2004)431.
67. J.T. Carlton, Scale and ecological consequences of biological invasions in the world's oceans, 1999, Pages 195-212 in O.T. Sandlund, P..J. Schei, and A. Viken, editors. Invasive species and biodiversity management. Kluwer Academic Publisher, Dordrecht, the Netherlands.