B5b ASSESSING CLIMATE CHANGE IMPACTS AND ADAPTATION ON MARINE ECOSYSTEMS

B5b.1 GOALS AND OBJECTIVES

B5b.1.1 THE PROBLEM

The projected global warming will affect the ocean's thermal budget, cause sea-level rise, modify ocean circulation and cause changes to marine ecosystems, ultimately with serious socio-economic consequences.

By the year 2050, a 30-50 cm sea-level rise can be expected and by the year 2100 a 1 m sea level rise, which will cause erosion of the coast line, increase the salinity of estuaries and increase the tidal range in river mouths and inlets.

Sea-level rise and water temperature increasing due to climatic changes are expected to have a pronounced impact on the offshore marine ecosystems on low-lying coast all over the world. The coastal area in Lebanon is expected to be affected by sea level rise (partly inundation of terraces and erosion, changes of coastal ecosystems and loss of land and productivity which will necessarily induce loss of urban areas and socioeconomic changes over the whole Lebanese coastal zone. Fishery resources will also be affected directly or indirectly due to declining and ultimate disappearance of coastal biotopes or ecosystems.

The framework Convention on climate change, which was signed by Lebanon, calls on parties to the convention to develop plans for responding to climate change.

No specific studies of the effects of climate change on any sector have been done for Lebanon, it is likely that increased in land desertification and intensification of agricultural systems will continue to increase population movement to coastal zones.

The strongest impact of the increased sea-surface temperature and particularly the sea-level rise will be felt in the offshore ecosystems.

The effects of climatic change on marine ecosystems could be for example:

- Change of the species composition
- Fluctuation in abundance of the pelagic fish stocks
- Change of the range of fish stocks.

B5b.1.2 GOALS OF ASSESSMENT

The goals of this work are:

- An assessment of the vulnerabilities of Lebanese marine ecosystems to the

impacts of climate change mainly to sea-level rise and water temperature increasing.
An evaluation of options to adapt of these potential impacts.

- Develop data and information that can be used at the national, regional and global level by decision makers or scientific community.
- This is also a part of an International assessment meeting government's obligations under article 3 of the UNFCC to reduce vulnerability to climate change.
- Species composition changes
- Community structure changes
- Assessment of the implications of accelerated sea level rise in order to anticipate the need for action. Identification of the types of problems that that Lebanon has to face
- How to adapt to these incremental future changes.
- Provide a base for a more global assessment of the vulnerability of coastal regions .

B5b.2 SCOPE

B5b.2.1 UNIT OF STUDY (EXPOSURE UNIT)

The Exposure unit is the Marine Ecosystems in coastal zones which we can divide in two parts:

-Benthic:- sandy coast
- rocky coast
-Pelagic: -plankton: primary production,…
- nekton: fisheries,...

By global warming, the former will be affected particularly by sea level rise and the later by water temperature increasing.

Figure B5b.1 shows the different sites of plankton research along the Lebanese coast.

B5b.2.2 THE STUDY AREA (CASE STUDY)

The study area is a natural region situated in the central part of Lebanese coast: **Jounieh bay**. It was chosen for many reasons:

- The existence of Fishery resources that are important to the country as a whole
- Very populated area (touristic complex, commercial...)
- Many marine studies were done in this area
- Two different habitats: sandy and rocky beaches.
- May be affected by impacts to more than one sector

Jounieh bay is located in the central part of Lebanese coast between 34° N et 35° 37' E et 33° 59' N et 35° 36' E (Fig. B5b.2)

Batroun Bay (Fig. B5b.3): Coordinates of the station are: 34 15 115N and 35 39 415E; it was chosen

- for the presence of terraces and being representative for other terraces in the country
- because part of this bay, near the National Center for Research is a natural reserve.

According to some preliminary study and personal observations, clay terraces from Batroun are actually in a privilege state, comparing to others, have a high level of biodiversity and are part of a natural reserve. Levantine terraces are a small area and are developed in soil clay or calcareous soil. It is a formation scarce in the Mediterranean Sea and found also in Crete, it is a horizontal line and a big part of rocky coastal area of Lebanon. It is constitute of two zones of different areas: external zone and internal zone which could be more than 10m width [2]. These terraces are not well studied like most of benthic aspects in the Lebanese coast.

Palm Island: declared as a natural reserve and it is an unpopulated area. Could be studied but a few researches were done in this region. Hydrological and phytoplanktonic populations were measured only in 1992 [3;4]It will be a good study area in the future for the global change without interference of human activities.

B5b.2.3 TIME FRAME AND SPATIAL FRAME

The time frame for impact studies is at different intervals 2020 and subsequently at 30 years intervals for the period 2050 to 2080.

Normal climatic period from 1940 to 1970.

B5b.2.4 DATA NEEDS

The availability of data on climatic and hydrographic parameters is not consistent and is a limitation in this study; hence, the collection of new data is an important element. The major data required for the exposure units are:

- Meteorological data: trend of annual atmospheric temperature and precipitation
- Hydrologic data: Water surface temperature, Salinity and Relative Rise in Sea level (RRSL)
- Topographic maps, preferably with at least-3m contour intervals;
- Bathymetric maps, particularly of the near shore areas (less than 10m of water)

Historical records indicative of previous sand of sea level will be important to study benthic ecosystem especially submerged marine terraces.

Some remarks should be done concerning available data:

1- Data available were collected during special projects in special places and times and it were stopped with the end of project. This is true for water temperature, salinity, planktonic populations which will be directly affected by atmospheric temperature increasing. No regular data available for a long period to help to put a trend line (Table 5B.1).

2- Data of fish product, which also can be affected by water temperature rise, is available only in FAO reports which were given by the Ministry of Agriculture (Fishing Bureau) and are approximately the same every year. Those are not exact because fishermen sell a large quantity of fish to the consumers, without any indication to the Ministry; also fish collected by amateurs and illegal methods are not mentioned there.

3- Data on benthic populations especially in the intertidal zones, which will be directly affected by sea level rise and will be a good indicator, are very scarce.

For all these reasons we did a choice for some parameters trying to estimate the effect of

climate change:

- Water temperature
- Phytoplanktonic populations
- Total product of fish and total product of Clupeidae.

These parameters were chosen because phytoplankton populations constitute the autotrophic primary producers in the pelagic food chains in marine waters and it is well known that their annual cycle is affected by many physical features that affect nutrient levels; these include fronts characterized by large horizontal gradients in variable such as **temperature** [1]. Concerning the third parameters, Clupeidae which are very sensitive to temperatures change and represented in our country by sardines *(Alosa fallax, Sardinella aurita, S. maderensis and Sprattus sprattus* [6] are planktivores and so directly affected by these populations. High positive and negative correlations are found between trends in temperature and catches of sardines and good sardine catches occurred when the global temperature was high (around 1940 and in the 1980s) and conversely poor sardine catches were experienced when the global temperature was low (in 1960s) [7]. Also, changes in the abundance of some species of fish are associated with long-term changes in the oceanic climate and Russel cycle in the western English Channel is an example [5].
Table B5b.2.1. shows the available data which were used in this report, its sources in literature and its sites. We should note that when we did the average of temperature in every month for many years, we realized that the differences between numbers is not very sensitive; while the numbers of phytoplankton populations varied considerably in the same month, because stations are inshore and many factors can affect the density other than seasonal variations such as local advection of nutrients, cloudiness, local currents related to climatic conditions, etc...

Table B5b.1 Available data, Data needs and sources for Marine ecosystems and sites

Study site	**Required data**	**Availability**	**Source**
Jounieh Bay	-climatic	National table, maps	Aerogare de Beyr
	-Bathymetric maps	Maps	Lebanese army
	-Hydrological data T°C	1979,80,87,88,96,97	NCMS,
	-Time series	Few	researchers
	-sea level	??	
	-beach profile data	few	NCRS
	-aerial photographs	few	NCRS
	-Biological data	none	
	-Total fishes caches	1972 - 1990	NCMS, FAO [18]
	- Clupeidea		FAO [18]
	-Phytoplanktonic Populations	1980, 1987 [19] ,1988,1997,1998	NCMS
Batroun Bay	-Climate	ditto	
	-Bathymetric maps	none	
	-Hydrological data T°C	1997, 1998	NCMS
	-Biological data Phyto. populations	1997,1998	NCMS

NCSM : National Center for Marine Sciences
NCRS:National Center for remote sensing

B5b.3 METHODS, MAJOR ASSUMPTIONS AND UNCERTAINTIES

B5b.3.1 APPROACHES FOR VULNERABILITY AND ADAPTATION ASSESSMENT

B5b.3.1.1 ANALOGUES

- To compare past events or periods or regions similar to possible present or future conditions. In the matter of marine ecosystem, a few qualitative studies were done in general in the world and particularly in the Mediterranean Sea, hence found analogues will be difficult.

B5b.3.1.2 FIELD SURVEY

Field observations are extremely useful for this study due to the lack of systematic and upgraded data in Lebanon. For this study, which is limited in time, it is not possible to collect data through experimentation;

B5b.3.1.3 EXPERT JUDGMENT

In this matter qualitative analyses of responses are required; Expert judgment is useful to identify uncertainties and research gaps.

*B5b.3.1.*4 MODELING

The relationships between climate, biophysical and/or socio-economic variables are formalized in models. We can apply a **biophysical (primary) impact models,** because such models express the relationships between environmental variables (e.g. T°C, precipitation, sea level) and the primary exposure unit (e.g. phytoplankton populations, coastal inundations)

In Lebanon, the **empirical model** would be more applicable than other types of models as the others are more constrained with requirements for comprehensive and analytical data.

A simple inundation model that predicts, in a spatial context, changes in the coastline due to changes in sea level.

B5b.3.2 METHODS EVALUATION

Estimates of the potential effect of climate change in marine ecosystems have been produced using simulated climatic conditions or scenarios developed by several distinct methods, including (1) scenarios obtained from atmospheric general circulation models (GCMs).

Table B5b.2 shows the different level of importance of climatic and hydrographic parameters in benthic and pelagic ecosystems.

Table 5B.2. Parameters affected marine ecosystems (Summary Matrix)

Ecosystem	Atm.T°C	Rainfall	Water T°C	Water Salinity	Sea level change
Benthic	*	*	**	**	***
Pelagic-planktonic	*	*	***	***	*
Pelagic Nektonic	*	*	***	***	*

Data needs: *** very high
** medium
* low

Table 5B.3. Relationships between meteorological and marine parameters

Climate variable	Impact	Projected variables values	Linkage to other interacting sectors	Historic physical data needs
Precipitation	Impact in salinity	GCM- predicted precipitation values used directly	-Land use in coastal area -Water resources	Total annual rainfall
Temperature	Water temperature	predicted from GCM	-Primary production and fisheries	Mean annual air temperatures for area of concern
Sea level	Benthic ecosystem	geodal elevation	-economic system (tourism, - inundation -change in species distribution	historic sea level rise
Temperature and sea level	Benthic & pelagic ecosystem	same as above	-economic level -biodiversity level	Physical descriptions(sea level, water T°c, Salinity) of fish

B5b.3.3 ASSUMPTIONS AND UNCERTAINTIES

B5b.3.3.1 ESTABLISHING THE BASELINE

Base line In Jounieh bay: Figure B5b.4 shows the base line of water temperature (average of available data between 1979 and 1998).

Figure B5b.5 shows the base line for phytoplankton populations for the same period. We expected that these populations will be directly affected by water temperature rise which in turn be affected by air temperature; also inundation and salinity decrease can also affect these populations.

Fish populations particularly clupoidae will be affected by these populations because they constitute their aliments for these reasons we did the base line of clupeidae (Fig.5B.7) and for total catch of fish in Lebanon (Fig. B5b.8)

Base line In Batroun bay: Only water temperature is available for base line (Fig. B5b.6)

In Batroun Bay, it is important to study the benthic ecosystem because the presence of terraces. Based on a sketch map of Lebanon's coastline showing geoidal elevation (G.E.) and geographic distribution of risk potential areas, we conclude that the region of Batroun bay is situated in the category of *less critical* zone (geoidal elevation > 2.5m) and G.E. is 3.8m in this region [8].In absence of regular and ecological data, we will content only to dress a list for fauna and flora which are present in terraces after [9 &10] and preliminary

observations and try to collect ecological data for each species which will be directly affected particularly by sea level rise. Terraces, which are partially submerged and partially immerged, will be gradually immerged. Algae will receive different qualitative and quantitative light and this will affect their distribution.

Table B5b. 4: List of flora situated in the internal and external parts of terraces and could be affected by climate change particularly sea level rise.

Localisation	Littoral part	Famillae	Species
External part	Mediolittoral Sup	Pheophycae	*Scytosiphon lomentaria*
		Rhodophycae	*Nemalion helmintoides*
			Neogoniolithon notarisii
			Polysiphonia subtilissima
			Porphyra leucostica
	Mediolittoral moyen	Chlorophycae	*Chaetomorpha capillaris*
	Mediolittoral moyen	Rhodophycae	*Centroceras clavulatum*
			Ceranium ciliatum
			Gelidium crinale
	Infralittoral supériur	Rhodophycae	*Corallina elongata*
Internal part	medio and infra sup	Chlorphycae	*Cladophora sp*
			Codium vermitaria
			Enteromorpha sp.
			Ulva rigida
		Pheophycae	*Colpomenia sinuosa*
			Cystoseria amentacea
			Cystoseira compressa
			Cystoseira ercegovicii
			Dictyopteris membranacea
			Dilophus fasciola
			Hydroclathrus clathratus
			Padina pavonica
			Sargassum vulgare
			Stypocaulon scoparium
		Rhodophycae	*Ceranium ciliatum*
			Hypnea cervicornis
			Hypnea hamulosa
			Hypnea musciformis
			Jania rubens
			Neogoniolithon notarisii
			Nitophyllum punctatum
			Laurencia papillosa
			Spyridia filamentosa

Table B5b.5: List of commun fauna situated in the upper part supra and mediolittoral of terraces

Classe or order	Species	Frequency
Gasteropods	*Dendropoma petraeum*	+++
	Littorina neritoides	+++
	Monodonta turbinata	+++
	Patella sp.	+++
	Vermetus triqueter	+++
Lamellibranches	*Mytilus sp.*	+++

Crustaceae	*Chtamalus stellatus*	+++
	Eriphia verrucosa	++
	Pachygrapsus marmoratus	+++

Frequency: + rare
++ common species
+++ abundant

B5b.3.3.2 TIME FRAME OF PROJECTION: TO THE YEARS 2020, 2050 & 2080

Projecting in Jounieh Bay.
Figures B5b.9,10 & 10 show the projection of water temperature in years 2020, 2050 and 2080 in Jounieh bay. The increasing of water temperature is based to the increasing of air temperature after GCM. For example, in January actual T° is17.79°C, in 2020 the projection of water temperature is 19.O2 and 19.59 in 2050 and 20.67 in 2080 and so on in every month.

Projecting in Batroun Bay.
Figures B5b.12, 13 & 14 show the projection of water temperature in years 2020, 2050 and 2080 in Batroun bay. Comparing to the baseline in Jounieh Bay, it is slightly higher because the base line is based in a limited number of year less than used for the Base line in Jounieh bay.

B5b.4 VULNERABILITY IMPACT ASSESSMENT

Concerning pelagic ecosystem, phytoplankton populations in Jounieh bay, species responsible for bloom at late winter and at the beginning of spring like *skeletonema costatum, Nitzschia* spp., *Leptocylindrus danicus* and *L. minimus* and others [11] could start earlier, because features of temperate marine planktonic ecosystems are not only sensitive to annual variations in weather, but also any trends that might result from greenhouse warming or other factors that affect the climate system and both density and timing of spring blooms will be altered in some regions [12]. Also, the taxonomic compositions of the phyto- and zooplankton may change influenced by the change of ocean structure [7].

Clupeidae which is very sensitive to the gradient of temperature will reproduce also earlier in our country. Concerning species, maybe thermophile species will increase in density replacing the biota of others species preferring cooler waters. Also, [13] postulated that changes in plankton productivity associated with greater temperature and greater stratification of the water column may favor pelagic as opposed to demersal fish communities.

These information need to be accompanied by fieldwork to know the variations of stock of sardines (clupeidae) and follow the variations of species in quality and quantity.

Alteration of the energy balance and circulation system in the world ocean will directly affect the productivity of marine ecosystems. Given that 45% of the total gross ocean and coastal areas as well as in the high polar latitudes, the changes in functioning of these ecosystems in global warming conditions will determine the future productivity of the ocean [1].

Paleoclimate research shows that global warming will reduce the most productive area of the ocean by about 7%. It is expected that the ocean's primary production will, on the whole,

drop by 5-10%. As a result, the production zones may be redistributed and the natural habitat of commercially valuable species of fish may change [1].

Current estimates show that global warming will cause an intensification of biodegradation processes, which will affect the high-latitude regions 30-50% more. The vegetation period in the sub-Arctic and Arctic ecosystems, such as the Bering Sea, is also expected to change [1].

Concerning fisheries resources methods, the survival of species cannot be determined without precise empirical information on the survival thresholds of species of plants and animals over the long term (i.e., 1000 years or more. To secure this information, extensive and continuing research is essential [16].

Concerning benthic ecosystem, coastal systems in the country are under high potential threat from development. This development includes large cities (>100,000 people), major ports, tourist complexes, all of which contribute to pollution in coastal areas, resulting in the deterioration of benthic populations. Coastal pollution is a major problem in Lebanon. Lebanon have integrated coastal management programs to overcome some of these problems [14]. Also oil spills from ships and pipeline, as well as land-based pollution discharges- all of which lead to the deterioration of coastal areas particularly the benthic populations.

Coastal zones in the Mediterranean Sea are not identified as significantly affected by sea-level changes [15]. The major pressures on them will be related to development rather than the direct result of climate change.

The vulnerability of fisheries to climate change depends on the nature of the climate change, the nature of the fishery, and its species and habitats. Changes in climatic conditions such as air temperature and precipitation affect fisheries by altering habitat availability or quality. In Lebanese coastal waters, *Sardinella* are the most important pelagic fish and they play an important role in the local fishing; abundant in spring and early summer in inshore waters [6].In case of increasing water temperature we can expect: advance in spawning for these species, abundance for other species of clupeidae such as *Sardina* and finally the abundance of thermophilic species and decreasing of xerophilic species.

DISCUSSION

The report concerning Middle East and arid Asia [17] suggest that coastal systems are under threat from pollution and development, resulting in the deterioration of fish populations in some countries. No scenarios suggest that projected changes in sea level will have significant effects on the region as a whole. Lebanon has integrated coastal management programs to overcome some of the major problem for coastal pollution [14].

Since each coastal location represents a unique set of interrelated physical, biological and human components and processes the extent and nature of impacts in one location will differ from any other coastal site, It is not clear that case studies which concentrate on site specific characteristic could provide broad generalizations concerning future impacts [15].

RECOMMENDATIONS

Many questions are insufficiently covered because of the limited time available and the many uncertainties in the climate change predictions.

Nevertheless, the following conclusion and recommendations can be drawn:

1. Coastal systems in the country are under high potential threat from development and urgently need a coastal management for a sustainable development
2. Most data concerning coastal zone are not sufficient.
3. Appropriate programs and selected marine environmental factors should start properly on a regular basis and for a long term to help the determination of trend of climate change.
4. Studies concerning ecosystems should focusing on the studies of species not only groups or families.
5. Importance of coordination between research Centers working in environmental programs to collect the maximum of data and maximum of parameters.

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