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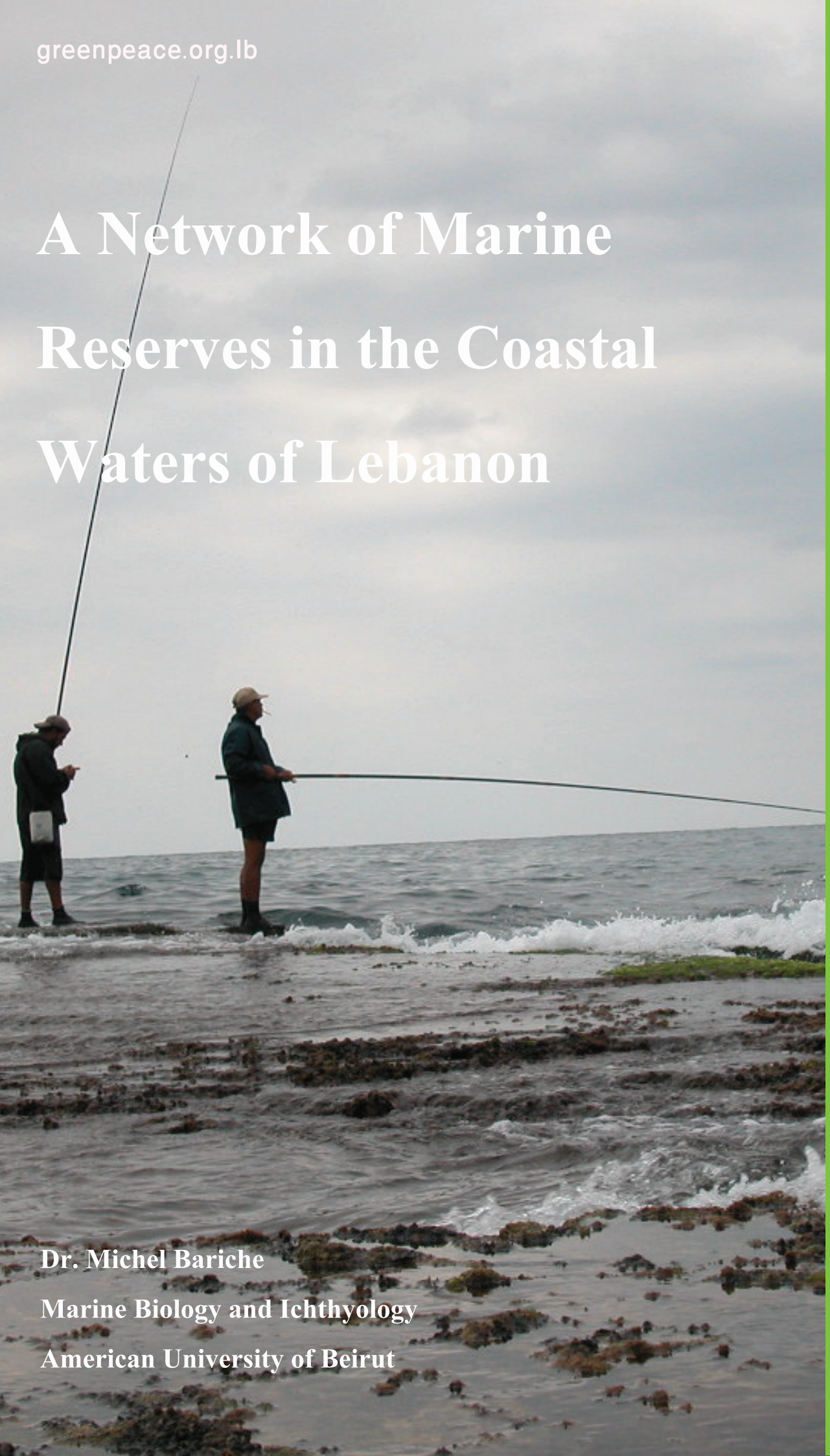
A Network of Marine Reserves in the Coastal Waters of Lebanon



Dr. Michel Bariche

Marine Biology and Ichthyology

American University of Beirut

GREENPEACE

Defending Our Mediterranean

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1. Executive summary

This report appears in the general scope of the Greenpeace “Defending our Mediterranean” campaign, and specifically in the research done in the Lebanese coastal waters. The report is rather a full account on the condition of coastal marine habitats, entailing their biological, historical, and socio-economic importance. Moreover, it includes an exhaustive study of the Lebanese fishery and the fishing techniques commonly utilized by the latter sector.

The Mediterranean Sea is a rich and diverse environment, home to many unique species and important ecosystems, encompassing up to 9% of the world’s marine biodiversity. The report states the widespread threats on this environment, be it due to destructive fishing practices or forms of habitat destruction. Particular weight is given to near shore pelagic environments, vermetid reefs, seagrass meadows, and estuaries. The latter are not monitored in Lebanon, despite the fact they ought to be protected all year long according to Lebanese law.

The report also mentions the existing 2 Marine Protected Areas (MPAs) in the form of the Palm Islands Natural Park and Tyre Coast Nature Reserve. It furthermore includes a proposal to include 18 additional sites into different schemes of protection, some of which, as the likes of estuaries, need already be protected. The proposal includes an extensive elaboration of each proposed site’s physical characteristics, representative habitats, biodiversity and biomass rates, subjected threats, benefits it receives if protected, and acceptable anthropogenic activities when a reserve is established. The proposed areas cover an area from the coast of Nakoura to Areeda, and encompass a diverse array of ecosystems targeting the protection of a sundry of threatened and commercially important marine species.

Overall, three areas, particularly the Nakoura rocky beach, the Madfoun rocky area, and the Ras el Chakaa cliffs, are considered as top priority sites being situated in areas not significantly affected by human activities and having a natural character that classifies them as category I of the IUCN criteria. In addition, the proposal calls for expanding the maritime borders of the Palm Island Reserve. Other suggested sites include the estuary of Qasmieh, the Raouche cliffs, the coast of Batroun, the coast of Enfeh, and the Tyre rocky beach. These areas entail biological and/or fisheries importance, cultural significance, or simply represent a habitat of endangered species.

In addition, the report calls for establishing a restricted area of 500m along the Lebanese coast where fishing with the aid of lights and special nets (messleyeh, beach seines) must be prohibited, due to the fact they target mainly undersized juvenile fishes, rendering the practice unsustainable.

The report is concluded with an analysis of the benefits the Lebanese community can reap via the establishment of a network of marine reserves and the implementation of sound fisheries management policies.

2. Lebanon and the Lebanese coast

1. Overview

Lebanon is a small (10,452 km^2), mostly mountainous country, situated at the easternmost part of the Mediterranean. It is comprised of a narrow coastline and two parallel mountain ranges running from north to south separated by a fertile valley, the Bekaa. The Mount Lebanon range extends along the coast, peaking at 3,088 m, and the Anti-Lebanon range (2,814m at its highest point) defines the border with Syria to the east. Lebanon's peaks are snow-covered for much of the year. The coastal zone extends along 225 km, has small tides and is frequently concealed by wave action. It consists of Mount Lebanon's western slopes and is interrupted by small estuaries and alluvial plains (Emery & George, 1963). Sea cliffs made out of limestone border most of the shores and sometimes descend directly into the sea. They are separated by gravel or sand beaches, composed partly of shell fragments and mostly of detrital sand (Emery & George, 1963).

Lebanon has a typical Mediterranean climate, with an average annual temperature of 20°C and about 300 sunny days each year. It is also characterized by a relatively high average rainfall, ranging from 700 to 1000 mm along the coast to 1,400 mm on Mount Lebanon. The soils are typically young Mediterranean soils. Surface water temperatures show high seasonal variation and range from 15°C in winter to 30°C in summer. The water in the upper 50 m is well mixed in winter and becomes stratified during the rest of the year. Lebanon's continental shelf is relatively narrow with tight isobaths. The bottoms are very rugged and are intersected with underwater canyons.

2. Brief history

After independence was gained in 1943, Lebanon's social and economic development displayed extraordinary growth (worldbank.org, September 2009). In 1975, a 15-year civil war began, ravaging the country, destroying physical infrastructure and housing, displacing large portions of the population, and weakening institutions. Following the end of armed conflict, the country recovered noticeably in the post war reconstruction phase (1991-1997), then suffered another major setback during the July-August 2006 Israeli war; this was followed by a prolonged political impasse, which lasted through May 2008 (worldbank.org, September 2009). As part of the extended physical damage sustained in the 2006 war, which included the destruction of hundreds of thousands of housing units, industrial enterprises and infrastructure facilities, such as bridges, schools, and the airport, a massive oil spill occurred along more than 150 km of Lebanese coastline. Approximately 15,000 tons of heavy fuel oil were spilled as a result of the Israeli bombing of the Jiyeh power plant's fuel tanks, located south of Beirut. The overall cost of

damage caused by the summer 2006 war was estimated at between $527 million and $931 million, with an average estimate at $729 million, or about 3.6% of Lebanon's gross domestic product in 2006 (United Nations General Assembly, 2007).

3. Cultural importance

Lebanon has a long and rich history shaped by many cultural traditions, including Phoenician, Greek, Roman, Persian, Arab, Ottoman, Armenian, and French. The resulting Lebanese culture is a unique combination of many civilisations and traditions. It is often referred to as the European gateway to western Asia as well as the Arab gateway to the western world (wikipedia.org, December 2009). Due to its long history, Lebanon hosts hundreds of cultural heritage sites, out of which its coastal zone is noted for having two World Heritage Sites (Byblos and Tyre) and two potential World Heritage Sites (Tripoli and Beirut). Dozens of other cultural, regional, local and natural heritage sites exist in its coastal zone (Salem, 1997). Among them are the old quarter of Saida, the Temple of Echmoun, the Raoucheh rocks, the Qadisha Valley, the Cedars Forest of God, the Nahr Ibrahim Valley, the old city of Batroun , the Dayr el Nourieh cliffs, and of Enfeh.

4. Socio-economic importance

For diverse political and logistic reasons, no precise statistics on the actual number of Lebanese citizens currently exist. In 2008, the World Bank estimated Lebanon's population to be 4.1 million people (worldbank.org, September 2009). The population is not distributed equally as about 75% of the people live along the coastal zone and Mount Lebanon western slopes, where the largest cities (Beirut, Tripoli, and Saida) are situated.

Lebanon has developed a free-market economy with minimal governmental regulations. Because the country had a stable and open economy and strict laws regarding confidentiality in banking, Beirut has become the banking and investment centre of the Middle East (InfoLebanon.com). Most of Lebanon's economic sectors and infrastructure were severely damaged during the civil war. Lebanon's liberal economy is based on competition and private ownership, and on large amounts of short-term capital transferred from abroad. Services and banking sectors predominate, representing 70% of the country's gross national product. The industrial sector constitutes 20% and agriculture makes up the remaining 10%. Lebanon has witnessed a significant construction boom, especially strong during the post-conflict era of the 1990s. Land and construction have been viewed by many as attractive investment opportunities, and, as a result, real estate prices have risen steeply; this boom has been fuelled by a mixture of local, expatriate and Gulf Arab funds. The industrial sector is composed mainly of the following manufacturing activities: Cement, furniture, paper, detergents, fertilizers, cosmetics, pharmaceuticals, batteries, garments and processed foods. Virtually all industry is privately owned. Areas suitable for agriculture are located along the coastal zone and in the Bekaa Valley. Along the coastal strip, a wide variety of vegetables and fruits is cultivated (lebanonembassyus.org). The mineral resources of Lebanon are few, limited to iron ore, lignite and lime.

The Lebanese fishery sector has remained artisanal over the years. This is partly due to the fact that the country is situated in an area with very low primary production and is thus relatively poor in resources (Por, 1978; Quignard & Tomasini, 2000). However, other local factors are also important, such as the absence of governmental subsidies and assistance for fishermen, a rugged seabed topography unsuitable for trawling, the impossibility for Lebanese fishermen to fish beyond territorial waters, the

massive import of foreign fish and seafood, and the drastic decline of local fish populations. Fishing methods are typically Mediterranean and are composed mainly of lampara and purse seines, trammel and gill nets, beach seines, longlines, trolling, fixed nets and wire traps (von Barndt, 1984) in addition to the extensive and illegal use of spear guns and explosives. As in many Mediterranean countries, reliable fishing statistics are lacking in Lebanon. This is mainly due to the fact that the Lebanese fishery sector is composed entirely of small-scale artisanal activities. In addition to this, a large portion of the fishing hauls are sold directly to local seafood stores or to restaurants and most of what is sold in auctions is composed of a mixture of species. Mouneimné (1978) estimated the total catch to be around 6,000 tons per year with sea breams and sardines constituting 72% of landings biomass. A recent study showed purse seine catches yielding about 3,000 tons of sardines and anchovies over four months only while only 4,000 tons / year (t/y) were caught in Lebanon by the same technique in the 1970s (Mouneimné, 1978; Bariche et al., 2006).

Overall, Lebanon reported the landing of 3,500 t/y of various species of fish and about 100 t/y of crustaceans and cephalopods for the period ranging from 2000 to 2007 (FAO Fisheries and Aquaculture Information and Statistics Service, 2009; Bariche, *in press*). Small pelagic fish species constituted most of the overall reported catches with 1,600 t/y of anchovy, sardines and mackerels being landed in the 2000-2007 period. Large pelagic fish species (tuna, swordfish and pelagic sharks) constituted about 500 t/y. Another 1,500 t/y were constituted mainly of demersal species such as seabreams, groupers, and red mullets, which have the highest commercial value on the Lebanese market. Figure 1 shows the overall reported landings for Lebanon since the year 1950 (FAO Fisheries and Aquaculture Information and Statistics Service, 2009; Bariche, *in press*).

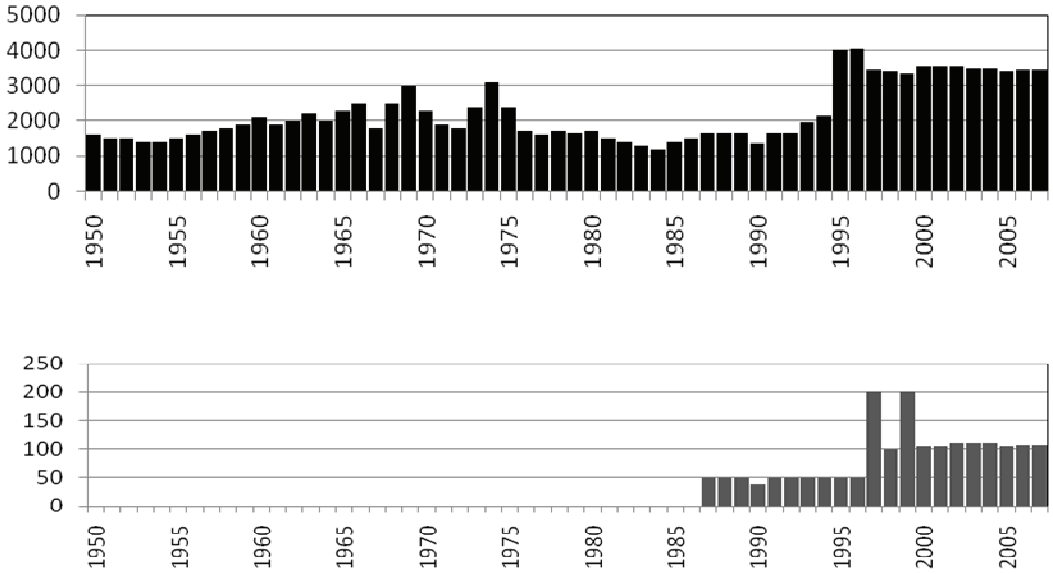


Figure 1. Yearly fluctuations of total fishery landings from the Lebanese marine environment. Fish and invertebrate landings are reported by black and grey histograms respectively. Units are in metric tons. Modified from Bariche, *in press*.

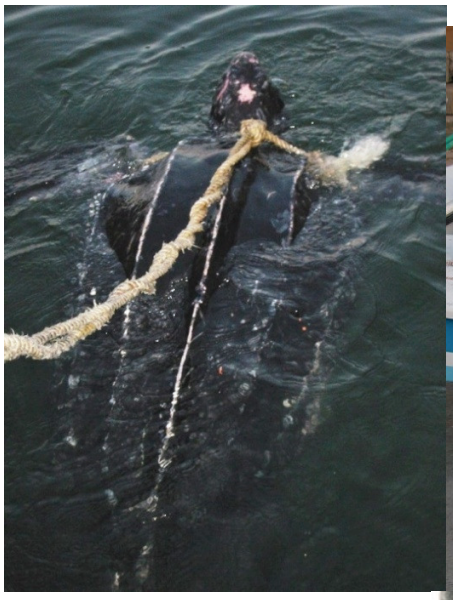
5. Biodiversity

The Mediterranean Sea is a semi-enclosed water basin, covering about 2.5 million km^2 and divided into a western and an eastern basin. The Levantine Sea is a region situated at the easternmost part of the eastern basin which stretches from Antalya in Turkey to Port Said in Egypt (Golani, 1996). The area is considered oligotrophic due to its semi-arid climate with limited precipitation and low river input, its relatively narrow continental shelf, and its distance from the nutrient-rich Atlantic water inflow. The eastern basin is characterized by great oceanographic variability on the surface with temperatures of 16°C in winter and up to 29°C in summer, and salinities of 39%. [consider revising]

The Mediterranean Sea is characterized by relatively high biodiversity which is indicated by the fact that it constitutes less than 1% of the world's ocean surface while holding as much as 6.3% of all marine species known to science. This richness is probably due to numerous historical, ecological and/or palaeographical factors (Bianchi & Morri, 2000; Quignard & Tomasini, 2000). Marine organisms inhabiting its waters are considered of Atlantic origin, with biodiversity decreasing from west to east and with depth (Quignard & Tomasini, 2000). The Mediterranean is also a place where evolution has given birth to numerous species. It is estimated that about 12,000 species of seaweeds and animals live in the Mediterranean (Golani et al., 2002). Furthermore, it is estimated that another few thousand exotic species of various tropical origins, also exist in the Mediterranean.

During the civil war and the post-conflict period, relatively little scientific research relating to biodiversity, marine biology or fisheries was made in Lebanon, as concern for environmental issues was non-existent or at least ranked very low on the government's list of priorities. This has resulted in a tremendous lack of scientific knowledge among scientists and stakeholders, and combined with a lack of awareness among fishermen and citizens, has lead to various environmental abuses. Overall, despite Lebanon's rich history, its marine ecosystem, fauna and flora, remain very poorly studied today and future research should focus in this direction.

The Lebanese marine environment supports a wide variety of ecosystems, such as coralligeneous bottoms, seagrass meadows, vermetid reefs, and deep marine canyons. Over eight species of whales (sperm whale, fin whale, Cuvier's beaked whale) and dolphins (short beaked common dolphin, long-finned pilot whale, Risso's dolphin, striped dolphin, bottlenose dolphin) can be found in Lebanese waters, and there have been irregular sightings of the once common Mediterranean monk seal (Bariche, *in press*). Loggerhead and green turtles are commonly found in Lebanese waters in addition to the occasional leatherback turtle and Nile soft-shelled turtle. Most of these animals are considered endangered or critically endangered in the Mediterranean, and in some cases, worldwide (Bariche, *in press*). Fifty seven species of sharks and rays are sporadically found in the Lebanese waters as well as at least 450 bony fish species, of which about 300 species are common in Lebanese waters (Quignard & Tomasini, 2000; Bariche, *in press*). There are hundreds of seaweeds and thousands of marine invertebrates such as sponges, cnidarians, molluscs, crustaceans, echinoderms and many other marine organisms, and new species are regularly being discovered (Kovačič & Miller, 2000; Iwamoto & Ungaro, 2002; Bariche & Trilles, 2006; Carreras-Carbonell *et al.*, 2007; Vacelet *et al.*, 2007; Harmelin *et al.*, 2009) or introduced regularly (Bariche & Saad, 2005; Eryilmaz & Dalyan, 2006; Ben Souissi *et al.*, 2007; Ragonese & Giusto, 2007; Bariche, 2010).



3. Threats to the marine environment

In addition to providing a home for the many millions of people who live along its coastline, the Mediterranean Sea, with its rich history, mild climate and beauty, makes the Mediterranean region a highly-prized tourist destination. A wide range of constant human activity in and around it places huge pressure on its marine environment. Threats occurring along the Lebanese waters are, in a broad sense, similar to the threats facing the entire Mediterranean (Greenpeace, 2006). Fortunately, some particularly destructive fishing methods such as driftnets and bottom trawls are not available or practiced in Lebanon, and aquaculture activity, which is known to exert a heavy toll on marine environments, is very limited (Greenpeace, 2006). However, the exploitation for oil and gas is likely to begin in the near future.

The coastal areas in Lebanon are being subjected to very high human pressure and a wide range of human activities contribute directly or indirectly to the degradation of the Lebanese marine environment, resources and biodiversity. Some of the most important specific local threats to the Lebanese waters can be summarized as follows:

1. Illegal or unregulated fishing practices

The Lebanese fishery sector is typically characterized by small-scale artisanal activities and hauls composed of a mixture of species. Fishing methods and techniques used in Lebanon are highly diverse and target different resources. Most of the fishing is achieved by means of lampara nets, various seines and entangling nets, longlines and wire traps, in addition to the extensive use of spear guns, explosives and sometimes ichthyocides. Today, many populations of fishes are depleted because of overfishing resulting from illegal fishing activities and the misuse of traditional fishing methods and also because of habitat destruction.

Disorder and anarchy occurring during the civil war (1975-1990) impacted human civic behavior and fishing practices. During that period, all means of catching, killing and collecting marine organisms became acceptable. Some of the "bad" fishing practices still occur today despite governmental

regulations forbidding some of them. Moreover, new, particularly destructive fishing methods have appeared over the years. Three decades without fishing regulations have resulted in a tremendous lack of awareness among a new generation of fishermen, businessmen and sea users, leading to environmental abuse. The Lebanese fishery sector is today in serious danger from the dual effect of destructive fishing methods and environmental degradation. Today, new fishing rules and regulations are desperately needed in the country.

2. Inadequate use of traditional nets

The use of standard fishing gear is sometimes modified in a way that can cause significant damage to the targeted resource, community or habitat. The scarcity of fish and the large demand on the market for local fish encourage fishermen to use more and larger entangling nets with smaller mesh-sizes. This results in an important bycatch and the capture of many small-sized fish, most of which are captured at their post-larval or juvenile stages.

In Lebanon, this can be observed in various fishing techniques, the most evident of which are lampara nets, beach seines and trammel nets.

Lampara nets are special nets designed to catch pelagic fish species aggregated under a source of light. This mode of fishing is very common along the Lebanese coast and constitutes about two-thirds of the total Lebanese landings. The lampara net (sometimes a purse seine) is laid from a vessel in a circle around the light. Captures are primarily made up of juvenile fish, mainly sardines and anchovies, which are marketed locally as *Bizree*. However, lampara nets are seasonally modified to catch the smallest fish, sometimes transparent larvae, which are present most of the year and are highly esteemed on the Lebanese market. The meshes used for this purpose are of 5 mm size. In addition, the lower part of the net is often designed to touch the sea bottom, which catches juvenile demersal species present on the bottom. This mode of fishing is designed

to target sardines and anchovies but kills juveniles of highly valued commercial species (Bariche *et al.*, 2006; 2007). This fishing method should be regulated.

Beach seines are seine nets composed of a bag with two long wings. They are operated from the shore and pulled to the beach with ropes. Beach seine nets of many hundreds of meters are normally deployed along sandy beaches and across estuaries. The seine is often pulled a second time over the same location as additional schools of fishes are attracted by the disturbance caused by the first seine haul. The use of beach seines is restricted by law in many countries because shallow waters close to the shore are often nursery or spawning areas. Furthermore, beach seines destroy sea grass meadows. In Lebanon, beach seine use is limited by law to a specific season, but illegal seine use occurs most of the year. Large numbers of fish species are caught at their post-larval stage, immediately after their settlement in their nurseries. A large proportion of species, often highly marketable, is killed and discarded because of the small size of the fish caught. Beach seines should be completely banned in Lebanon.

Trammel nets are entangling devices which consist of three netting walls positioned vertically by floats and weights. The absence of updated fishing regulations and the absence of enforcement of existing laws, coupled with the scarcity of the catches, result in very small mesh sizes being used to catch smaller and smaller animals. Various fishing methods using entangling gears should be regulated in Lebanon.

Furthermore, modified trammel nets are often used in shallow waters to encircle a specific area known to harbor fish. Divers frighten fish by removing and flipping small rocks, which forces the fish to escape through the encircling nets and thus they are caught. This method of fishing is very damaging to the seabed habitat as it uncovers and kills the various species of small organisms living on or below the rocks. This fishing method should be banned.

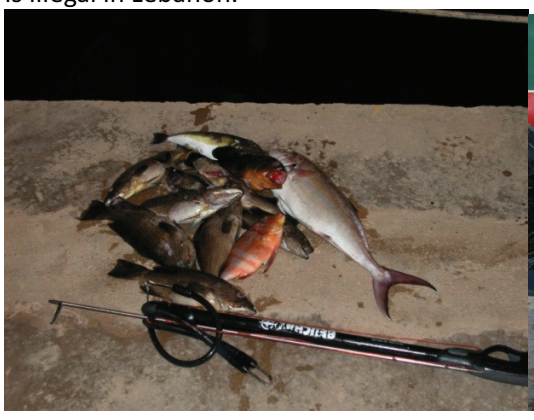
3. The *Messlayeh*, a fixed net

The *messlayeh* is a temporary barrier made of netting that concentrates the fish in one or many circular catching chambers located at the end of a fence. The fence stretches out over hundreds of meters at a right angle from the shore and bars the way of all passing fish and leads them in the direction of the chambers. The chamber, called the "death chamber," has a bottom made of netting and is hauled to close the net and concentrate the fish once schools have entered. The technique of catching chambers has been known since antiquity and was used to catch tuna and other large migrating fish in the Mediterranean. *Messlayeh* is comparable to the French *madrague*, the Sicilian *tonnara* and the Turkish *daylan*. In the last decade, the use of *messlayeh* has increased drastically and dozens of such nets exist today in Lebanon, particularly along the northern Lebanese coast, blocking the passage of schooling fishes moving nearby. The effects of this non-selective equipment are being felt recently among traditional fishermen and these same effects are expected to worsen in the near future. Because they cover such a large area and are so commonly used, and because of their small mesh sizes, fixed nets dramatically impact the populations of all kinds of schooling fish species, particularly predators, such as barracudas, jacks, king mackerels and small tunas, which have been collected in large quantities since the use of this fishing equipment became common in Lebanon. This fishing method should be completely banned in Lebanon.

4. Spearfishing

Spearing using sharpened sticks has been a technique for catching food for ages. In the last century, it developed as a sport, and modern techniques and fishing equipment are very efficient. In Lebanon, spearfishing appeared in the 1980s and became popular in the 1990s along with scuba diving.

Most recreational divers and many Lebanese fishermen dive with scuba gear in order to spear high-priced fishes. Most of the fishes are speared in the crevices and holes where they hide during the day or in open water after being dazzled by powerful underwater dive lights at night. Speared fishes are commonly found in fish markets, and seafood restaurants proudly display speared fishes, mostly groupers, as proof of the freshness of their fishes. Spearfishing as it is used in Lebanon threatens all middle-sized fishes, such as groupers and sea breams. The impact of such a fishing method cannot accurately be assessed in Lebanon but it is thought to be very significant. Spearfishing while scuba diving is illegal in Lebanon.



5. Blast fishing

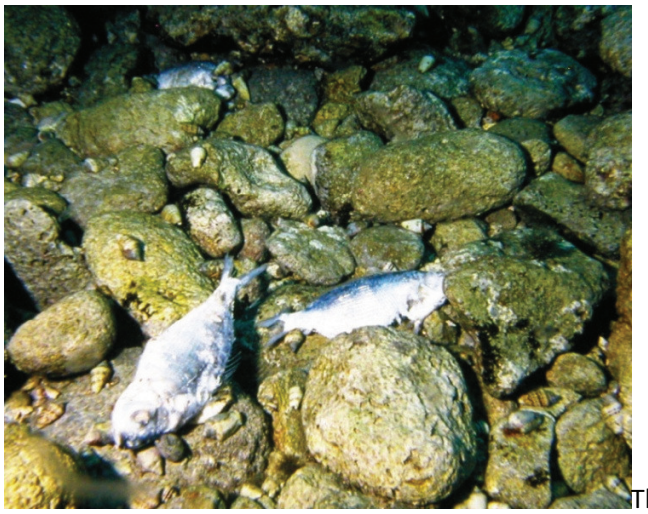
Blast fishing, or fishing with explosives, is an illegal fishing method involving the use of explosives to stun or kill fish. The underwater shock waves rupture the swim bladders of the fish, thus killing them. This highly destructive fishing method is known to indiscriminately affect target and non-target species and the surrounding environment. Fishing with explosives appeared in Lebanon in the 1930s and is known to have serious consequences on the environment and resources. Two types of blast fishing occur in Lebanon. The first method, locally called *denameet* or *troubeen*, involves a substantial amount of explosives while the second one, *capsoon*, is more discreet.

Denameet fishing usually involves a homemade bomb which is detonated when a school of fish is spotted. The bomb can also be dropped directly in areas where fish are known to congregate (for reproduction or feeding or in nurseries). Stunned fish will be collected afterwards using landing nets from the boat, or by skin diving, dive compressors or sometimes scuba. Large numbers of dead and dying fish and other animals end up being lost or simply discarded. The bombs also cause great physical damage to the sea bottom. This illegal mode of fishing has decreased dramatically since the end of the armed conflict but still occurs in some areas along the Lebanese coast. Recently, some poachers have used deep water explosions to target specific reefs and wrecks, sometimes at depths of more than 100 meters. *Denameet* fishing undoubtedly kills large numbers of fish and other marine organisms, but it also destroys the underlying reef, which provides food and shelter for other fishes and animals. Explosions destroy square metres of the reef and leave large patches of “dead bottom” behind for many years to come.

The second type of blast fishing uses smaller exploding devices such as detonators and fuses, locally called *capsoon*. Its original use was to trigger a larger explosive device and it is still used extensively in quarries all over the country. Fishermen and amateur anglers attract pelagic fish larvae and juveniles to a source of light (locally called *loux*) suspended over the water from a fishing boat. The fuse is then dropped within the lighted area, close to the surface; it allows the fisherman to collect fresh bait for fishing but its main purpose is to chum the sea bottom. Large numbers of stunned small fish sink to the bottom and attract and concentrate various larger fish of valuable targeted species underneath the boat. These will be fished traditionally by means of hooks and lines.

Although it is forbidden by regulation, *capsoons* are widely used in Lebanon by professional fishermen and occasionally by anglers. This method is not considered by its users to be destructive as it occurs on the surface and kills only small schools of sardines or anchovies with each blast. However, microscopic larvae of other animals, such as lobsters, shrimps, and crabs, with very high commercial value, are the first to be attracted to the source of light and are indiscriminately and unnecessarily killed in large numbers. The use of *capsoon* is extremely common at night in Lebanese waters throughout most of the year, killing large quantities of highly commercial species and affecting the various populations of valuable crustaceans at their larval and juvenile stages.

6. Poisons



The use of poisons of plant origin is an old practice in the region, mainly used in freshwater environments such as rivers. The use of pesticides for fishing in Lebanese coastal waters appeared in the last two decades. These pesticides are available on the market, cheap and highly toxic to fishes, other marine organisms, and to humans.

A suitable location is supplied with food material, attracting schools of small fish. The poacher then spreads a mixture of pesticide and chum which kills the fish and pollutes the surrounding environment. The toxic pesticide is sometimes put directly into holes and crevices where valuable fish hide. The consumer is at risk of poisoning from fish collected by this illegal fishing method. Fortunately, this practice is localized and not commonly used in Lebanon, where the use of poisons should be banned.

It is important to note that the aim of the chapter is not to forbid all of the above-mentioned fishing methods but to draw attention to some fishing practices which, if used arbitrarily, will lead to the depletion of resources. However, most of the techniques used in Lebanon could easily be modified to allow for the recovery of fish populations and thus improve the fishery sector by yielding more fishes of larger sizes. Finally, each of the above-described fishing practices targets a specific group of animals and should be responded to collectively in order to help restore fish and crustacean populations and promote sustainability in the Lebanese fishery.

7. Pollution

Pollution is a serious threat in most marine environments. The Mediterranean is a semi-enclosed sea, connected to the Atlantic Ocean by the narrow Gibraltar Strait and to the Red Sea by the artificial Suez Canal. The Mediterranean Sea suffers from industrial, agricultural and domestic pollution. The limited water exchange puts the Mediterranean Sea at high risk from the buildup of pollutants that could have a profound influence on its ecosystems in the future. Toxic chemicals and metals are absorbed by small microscopic organisms and are concentrated in animals at the end of the food chain, such as tuna, seabirds, marine mammals and humans. Toxins or heavy metals can cause mutations and diseases but can also affect reproduction, growth or behavior in marine life. If we exclude some shared global problems affecting the Mediterranean basin as a whole (eutrophication, acidification, and increase in sea level or water temperature), pollution along Lebanese coastal waters results mainly from human activity.

Solid waste in the Lebanese marine environment is composed of discarded human rubbish, mostly that dumped along the coast or carried by rivers and temporary water flows. It is primarily non-biodegradable plastic. Discarded bags and other floating plastic debris kill marine organisms, which become entangled in them or suffocate after consuming them. Lost fishing nets, also made of plastic, continue “fishing” for a long period afterwards and thus kill marine organisms that get entangled (ghost fishing). Plastic is photodegradable, breaking down in the presence of light into smaller and smaller pieces but never disappearing. As a result, toxic molecules can accumulate in marine organisms. Furthermore, large amounts of discarded solid urban waste, hospital waste and industrial waste are dumped along the Lebanese coastline. Some areas are

recognized as dumping sites and are located primarily near the country's largest cities: Beirut, Tripoli and Saida (Greenpeace, 2007).

Chemical pollution in the marine environment is comprised of toxic molecules that do not disintegrate rapidly. These include pesticides, herbicides, heavy metals, radioactive waste and other hazardous products. Chemicals enter the sea in Lebanon through deliberate dumping, agricultural runoff and through other land-based activities. Untreated domestic sewage flows into the sea and represents an important source of toxic chemicals. It was estimated that almost one million cubic meters of wastewater ends up in the sea through 53 pipelines of wastewater along the Lebanese coast (MoE, 2001; Council for Development and Reconstruction/ECODIT-IAURIF, 1997). Power plants and factories situated along the Lebanese coast or near rivers are another major source of chemical pollutants as their effluents are directly or indirectly discharged into the sea (Greenpeace, 2006; 2007). The oil spill that occurred in the summer of 2006 affected two-thirds of the Lebanese coastline and contributed significantly to chemical pollution (Greenpeace, 2007). An unknown amount of chemicals is released in the marine environment from various additional sources including anti-fouling paints used on boat hulls and underwater structures (intended to inhibit the growth of undesirable marine organisms), illegal boat engine discharge, and accidental spills at nearby power plants. Lebanese coastal waters are also at high risk of accidental spills if exploitation of underwater marine petroleum oil reserves develops in Lebanon.

The unintentional or deliberate introduction of a foreign organism into an environment could be considered biological pollution. The construction of the Suez Canal, which opened in 1869, linked the Mediterranean to the Red Sea in order to provide the shortest possible sea route between the Indian Ocean and Europe. This connection resulted in the introduction of tropical marine organisms from the Red Sea into the eastern Mediterranean Sea. These organisms crossed the Suez Canal and settled in the Mediterranean, where some have formed large populations. This phenomenon is referred to as Lessepsian migration. Other introductions have come from navigation (transport of fouling or clinging organisms on floating structures), ballast (solid and liquid), organism transfer (shellfish, bait, packing material, etc.), and release from aquariums and aquaculture farms (Zibrowius, 1992). From the estimated 1,000 exotic species in the Mediterranean, Lessepsian migration is certainly the most spectacular (Boudouresque, 1999; Streftaris & Zenetos, 2006; Galil, 2008). Exotic species have a severe impact on the environment they invade. Certain invasive species have become extremely abundant and are being exploited commercially (Bariche, in press).

4. Habitat destruction

Natural habitats are the physical, chemical and biological systems where organisms live. Habitat destruction is the process in which a habitat is altered and becomes unable to support its native animals and plants. The habitat is said to be degraded (habitat degradation) when natural or human-caused activities affect many, but not all, species. The same habitat is considered lost (habitat loss) when impact is so severe that nearly all species are affected. Often, a degraded habitat is transformed (habitat transformation) when it is converted into another one. It is important to note that habitats are rarely isolated and are often connected to other different habitats and communities.

Marine habitats in Lebanon have experienced high rates of destruction and many additional habitats are lost or heavily degraded. Intensive coastal urbanization contributes to habitat degradation in many ways. Chaotic coastal development as well as resort and industrial complexes affect coastal landscapes and threaten biodiversity, ecosystems and resources. The development of marinas and jetties along the coast interrupt local water currents and increase sand deposition. Estuaries are highly damaged by inland freshwater diversion of springs and rivers for domestic and agricultural use and by wastewater dumping from various sources. The sewage produced by the densely populated coastal cities and flowing untreated into the sea results in a severe reduction of water quality such as reduction of oxygen concentration, an increase in nutrients, toxic chemicals and metals, and the addition of pathogenic bacteria and viruses that are a threat to various habitats and marine life.

Habitat destruction is certainly one of the main reasons for the collapse of the Lebanese fishery resources. Some habitats can be restored with proper supervision while other changes are irreversible and no degree of future management will be able to undo the damage. The costs to the environment, tourism, fishery, and human health may be far more expensive to Lebanon than implementing new strategies by governmental bodies to stop or minimize anthropogenic impact on the Lebanese coastal environment.

While most close-to-shore marine habitats present along the Lebanese coastal waters are being significantly degraded, four of them are particularly affected and need immediate attention and action. These are:

1. Vermetid reefs and associated tide pools

Vermetid reefs are biogenic platforms situated at intertidal level and built by attached marine snails. Along the Lebanese shores, vermetids reefs are built by two species of snails and are encrusted with a rigid coralline alga and a foraminifer (Laborel, 1986; Bellan-Santini *et al.*, 1994). These platforms often run parallel to the coast and are exposed to wave action. They have an important role in protecting the coast from erosion.

Vermetid reefs, as with most rocky shores in Lebanon, are at high risk from coastal development. Many industrial and infrastructure constructions have been built directly on these reefs (*e.g.* Corniche of Beirut; chemical factory in Selaata) or have affected them directly (*e.g.* jetties, ports) by changing their degree of exposure to waves and currents. They are also exposed to various types of pollutions, including chemical, sewage and other outfall discharge, litter dumped by humans and competitive exotic species. These factors directly affect the reefs and make them vulnerable by modifying the animal and seaweed

communities present and also kill the vermetids themselves. The platforms need protection as they are critically endangered structures (comparable to tropical coral reefs) in the Mediterranean, being found almost exclusively on the Levant coast and in very few other localities (Chemello *et al.*, 1990). In addition, remaining vermetid reefs are very much affected by human trampling as well as recreational harvesting of marine organisms living on them.

Tide pools are ponds filled with seawater and found within the vermetid platforms. The ponds are connected directly or indirectly to seawater and offer suitable habitats for several adult and sub-adult fish species and a variety of invertebrates. A rich and diverse flora and fauna are typical of these habitats. Above all, the ponds provide unique nursery habitats for many juvenile fishes, particularly those of commercial interest, as their structural complexity offers good protection and thus lower predation pressure. Tide pools are thus associated with the vermetid reefs and, being constantly disturbed by humans, are equally vulnerable.

The most commonly observed organisms are juveniles ofhighly-valued fish species (groupers, sea breams, sea basses, rabbit fishes, and parrotfish) and other fishes (juvenile, sub-adults, adults) such as sand smelts, wrasses, grey mullets, moray eels, gobies, and blennies (Bariche, in press). Common invertebrates include snails (monodonts, limpets, murex, conchs), hermit crabs, various crabs and shrimps, in addition to some bivalves (mussels, oysters), polychaetes (fire worms), sea urchins, sea cucumbers, sponges and various unidentified animals. Common algae are *Ulva* spp*., Enteromorpha* spp., *Laurencia* spp., *Padina pavonica*, *Codium* spp., *Cystoseira* spp., *Sargassum vulgare*) and sometimes the seagrasses *C. nodosa* and *H. stipulacea*.

2. Estuaries

Estuaries are places where rivers meet the ocean, mixing with the seawater. They are dynamic ecosystems affected by both riverine and marine influences. They are generally characterized by a salinity gradient which depends mainly on tides and waves and the volume of freshwater input. Estuaries are known to consist of a complex mosaic of many distinctive habitat types, most of which are considered very productive. Estuaries harbor a wide diversity of terrestrial, freshwater and marine organisms (Pombo *et al.*, 2007; França *et al.*, 2009). They provide, for example, habitats for many migratory bird populations, but more importantly, they play an essential role as nursery grounds for juveniles of several important marine fish species (*e.g.* Cabral & Costa, 2001; Cabral *et al.*, 2007; Vasconcelos *et al.*, 2009). Estuaries provide a sheltered environment with lower salinity and predation and a relatively high biomass of food (algae, plants and invertebrates) (Paterson & Whitfield, 2000; Elliott & Hemingway, 2002; Franco *et al.*, 2006).

The fauna and flora are rich and diverse in this important habitat. The most commonly observed organisms are juvenile fish of commercial species (eels, sea basses, sea breams, flatfishes, jacks, drums, and anchovies) and other fishes (juvenile, sub-adults, adults) such as grey mullets, sand smelts and various small gobies. Common invertebrates are constituted mainly by bivalves, polychaete worms and crabs. Algae are relatively rare; however, seagrasses are sometimes present in the vicinity.

In Lebanon, estuaries are modest in size which is consistent with its modest rivers. However, they are nevertheless very important habitats. Human activities along the river courses and in the areas surrounding estuaries have significantly impacted these precious habitats, substantially decreasing the water and river bed quality (*e.g.* Qasmieh, Damour, Nahr el Kaleb estuaries) and directly affecting the marine fish population in the coastal waters. Some estuaries have disappeared completely as freshwater is pumped or diverted for human use and is replaced by the wastewater of large cities. Moreover, in some locations, the river and estuary beds have been replaced by concrete (*e.g.* Nahr Beirut, Nahr Abou Ali (Tripoli). The over-exploitation of the freshwater of some rivers, such as Nahr el Kaleb, has resulted in extended river mouth closures, the disappearance of the corresponding animal and plant communities and the destruction of juvenile fish in large densities within the estuaries. Beach seines are regularly hauled all year round in the vicinity of estuaries in Lebanon, destroying the surrounding habitats, usually seagrass meadows, and catching innumerable quantities of juvenile fish and other animals directly from their nurseries.

3. Seagrass meadows

Seagrasses are plants that are restricted to the marine environment. They are known to generate considerable amounts of oxygen, maintain high water quality and stabilise the underlying sediment, preventing erosion in the vegetated area. Many beaches and sandy bottoms are stabilised by seagrass meadows. Healthy seagrass meadows are also very productive habitats and support a wide diversity of marine organisms, enhancing biodiversity of coastal sandy and muddy bottoms.

Seagrass meadows act as nursery, breeding and feeding grounds to various marine species, no matter whether they are commercial or forage fish, or crustaceans. Numerous larvae and juveniles find shelter against predators and feed on trapped detritus and small organisms growing on seagrass leaves or living in the sediment. Seagrass beds are also feeding habitats to the endangered green turtle, which feeds on their leaves. Dead seagrass leaves provide shelter and food for a large range of other detrivorous marine organisms, which are important components of the complex marine food webs.

The fauna and flora is composed mainly of juvenile fish of demersal commercial species (seabreams, wrasses, and flatfishes) and pelagic commercial species (picarels, jacks, barracudas, and tunas). Other fishes (juvenile, sub-adults, adults) include damselfish, seahorses, sting rays, and gobies. Common invertebrates are conchs, murex, nudibranchs, various bivalves, polychaetes, sea cucumbers, and heart urchins. Algae are constituted mainly of epiphytes growing directly on seagrasses.

Seagrass meadows have been experiencing a worldwide decline as they are being affected by natural (*e.g.* hurricanes, heatwaves) and anthropogenic events (*e.g.* fishing activity, eutrophication, aquaculture, and invasive species). Once destroyed, seagrass systems do not recover easily; this process can take as long as several decades. Unfortunately, the required environmental conditions for recovery are often lost with the decline of the meadow.

Seagrass meadows along the Lebanese waters are not affected by mechanical damage from fishing activities, such as trawling and dredging as these destructive methods are not often used in the country. They are, however, highly damaged by severe anthropogenic pressure such as high nutrient-loading caused by domestic, agricultural and industrial effluent discharge, reduced illumination by opportunistic epiphytes and increased phytoplankton, and burial and erosion by high sediment mobility due to currents and waves. Other threats include boat moorings, which destroy mats and roots, and introduced seaweeds and seagrasses, which increase competition. Because there is no early assessment of seagrass

meadow distribution in Lebanese coastal waters, no record of seagrass decline can be documented. However, human impact has certainly resulted in a significant loss of meadows, the habitat of many species of fishes, shrimps and other animals. As a preventative measure, human activity that endangers seagrass meadows should be banned in Lebanon while at the same time intensifying scientific research and monitoring.

4. Nearshore pelagic environment

This is the coastal pelagic environment within the neritic zone. The nearshore pelagic environment is constituted by many habitats situated in the water column above the sea bottom. It is a relatively shallow area extending from the sea surface to less than 100 meters in depth and is characterized by many nutrients and much biologic activity because of its proximity to land. This is a well-lit, well-oxygenated area with photosynthetic life forms and free-floating zooplankton, which constitute the base of the food webs. In addition, this is where most fishes and invertebrates (*e.g.* shrimps, squids, bivalves), are found floating as eggs or larvae at the beginning of their lifecycles. Within this area lie spawning and nursery grounds of small pelagic fishes such as sardines and anchovies where they can find adequate feeding (Bariche et al., 2006; 2007). Small pelagics also constitute food for many fish species of high economic importance such as groupers, barracudas, and jacks, for marine birds, and also sharks, rays, sea turtles, dolphins and the monk seal. This area is thus very rich in species diversity, abundance and biomass and provides feeding, spawning and nursery grounds for a wide range of marine animals.

Because of its propinquity to land, this ecologically productive environment is the site of intensive use and extensive alteration. It is highly affected by various kinds of pollution resulting from the human activities described above. In addition, this is where blast fishing, particularly *capsoon*, occurs, unnecessarily killing inestimable quantities of crustaceans larvae, and this is also where light fishing (lampara fishing) occurs, targeting small pelagic fish larvae and resulting in lots of bycatch over most of the year (Bariche et al., 2006; 2007). Despite its often close proximity to large urban areas, the nearshore pelagic environment is likely to recover relatively quickly when the above-mentioned pressures are reduced.

Human pressure on other habitats, such as various hard bottoms, soft bottoms, reefs, caves, wrecks, deep and oceanic offshore waters, is also significant but will not be detailed here.

1 Marine Protected Areas

1.1 Definitions

The creation of Marine Protected Areas (MPAs) is gaining increased acceptance worldwide as a practical means for preserving marine biodiversity and managing coastal fisheries. There are various types of MPAs, with different goals and protection measures. They range from protecting a species to protecting an entire habitat or ecosystem. They can also be created to protect a specific area important to a life stage of a targeted species such as spawning and nursery grounds, migration routes and feeding grounds (Greenpeace, 2006).

Marine Protected Area is a general term for a protected area within the ocean. The term "MPA" has been widely used and its meaning differs greatly in the literature. A protected area is defined by the International Union for Conservation of Nature (IUCN) as:

A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2008).

Six categories of MPAs have been developed (Table 1). According to the IUCN guidelines for applying protected areas (Dudley, 2008), common objective to all six protected areas categories are to:

- *Conserve the composition, structure, function and evolutionary potential of biodiversity;*
- *Contribute to regional conservation strategies (as core reserves, buffer zones, corridors, stepping stones for migratory species, etc.);*
- *Maintain diversity of landscape or habitat and of associated species and ecosystems;*
- *Be of sufficient size to ensure the integrity and long-term maintenance of the specified conservation targets or be capable of being increased to achieve this end;*
- *Maintain the values for which it was assigned in perpetuity;*
- *Be operating under the guidance of a management plan, and a monitoring and evaluation programme that supports adaptive management;*
- *Possess a clear and equitable governance system.*

Table 1. Protected areas categories according to IUCN criteria (Dudley, 2008).

Category I: Strict protection
Category Ia: Strict nature reserve
Category Ia represents strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impact are strictly controlled and limited to ensure protection of conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
Category Ib: Wilderness area
Category Ib protected areas are usually large unmodified or slightly modified areas retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.
Category II: National park
Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, and recreational opportunities for visitors.
Category III: Natural monument or feature
Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.
Category IV: Habitat/species management area

Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not an absolute requirement of the category.
Category V: Protected landscape/seascape
This is a protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.
Category VI: Protected area with sustainable use of natural resources
Category VI protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large and with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

All protected areas should also aim where appropriate to:

- *Conserve significant landscape features, geomorphology and geology;*
- *Provide regulatory ecosystem services, including buffering against the impact of climate change;*
- *Conserve natural and scenic areas of national and international significance for cultural, spiritual and scientific purposes;*
- *Deliver benefits to resident and local communities consistent with the other objectives of management;*
- *Deliver recreational benefits consistent with the other objectives of management;*
- *Facilitate low-impact scientific research activities and ecological monitoring related to and consistent with the values of the protected area;*
- *Use adaptive management strategies to improve management effectiveness and governance quality over time;*
- *Help to provide educational opportunities (including those about management approaches);*
- *Help to develop public support for protection.*

Greenpeace has an ambitious project to promote the creation of a marine reserves network around the world, protecting as much as 40% of the world oceans (Greenpeace, 2006). A map showing wide areas of particular importance for protection around the Mediterranean was published (Greenpeace, 2006). Situated at the easternmost part of the Mediterranean, the Levant coast (Phoenician coast) is one key area for creating marine reserves.

Marine reserves are MPAs offering the highest level of protection possible by not allowing any disruptive human activity. They are defined as follows:

Large-scale marine reserves are areas that are closed to all extractive uses, such as fishing and mining, as well as to disposal activities. Within these areas there may be core zones where no human activities are allowed, for instance areas that act as scientific reference areas or areas where there are particularly sensitive habitats or species. Some areas within the coastal zone may be open to small-scale, non-destructive fisheries, provided that they are sustainable, within ecological limits, and have been decided upon with the full participation of affected local communities (Greenpeace, 2006).

Greenpeace proposed Marine Reserve Network (Greenpeace, 2006). The "Phoenician coast" (red spot) is situated in the easternmost part of the Mediterranean.

According to the same source, a coastal marine reserves network should follow the same ecological principles:

- *A network that covers an adequate proportion of the marine area. The proportion considered as adequate was previously discussed.*
- *Protection for each habitat type. This means not only rare, unique or pristine sites, but also examples of common habitats, which are often degraded, but are also often critical habitats for marine species.*
- *Protection of each type of habitat, covering an adequate proportion of that habitat and including numerous sites.*

A network of marine reserves covering different habitats and taking into consideration local threats along the Lebanese coast will help this sensitive area recover most of its marine habitats and resources. This network will also contribute to the Greenpeace global project by attempting to restore balance within and minimize human pressure on the Levantine coastal waters ecosystem.

1.2 Marine reserves in Lebanon and Lebanese Law

Along the Lebanese coast, two MPAs meeting different aims exist. These are:

1.2.1 Palm Islands Park and Nature Reserve

The Palm Islands Park and Nature Reserve was created in 1992 (Act No. 121, issued March 9th, 1992) with a surface area of about 5 km^2 and at about 6 km northwest of the city of Tripoli (north Lebanon). It consists of a group of three rocky islets and 500 m of their surrounding sea. The largest island (20 ha) is known as Palm Island (*Jazeerat al Nakheel* or *Jazeerat al Araneb*). *Sanani* and *Ramkin* (*Jazeerat al Fanar*) Islands have a surface of about 4 and 1.6 ha respectively. Both Palm and Sanani

Islands have a sandy beach and Ramkin Island is an elevated rocky islet with a lighthouse (http://tripoli-city.org/palm.html). The reserve has been recognized as a wetland of international importance by Ramsar Convention on Wetlands. A committee is responsible of the management of the reserve.

The islands are known to be an important site for two species of sea turtles which are regularly found in their vicinity and some lay their eggs on their beach. The island is also an observation site for migratory birds and was once an important breeding site for various seabirds, some of which are endangered (BirdLife International, 2009). The islands are also suitable habitat for the critically endangered Mediterranean Monk Seal, which is very occasionally recorded in the area. The main threats to the islands' fauna and flora are picnicking summer visitors, introduced mammals (rats, rabbits) and illegal visits from fishermen and occasional divers.

Some plants that have disappeared along the coast are still present in Palm Islands Park and Nature Reserve.

1.2.2 Tyre Coast Nature Reserve

The Tyre Coast Nature Reserve is situated south of Sour (Tyre) in Ras al-Ayn (south Lebanon). It was established in 1998 (Act No. 708, issued November 5th, 1998). It is constituted of a number of private lands. The surface area is composed of private lands of about 388 ha and a long sandy beach.

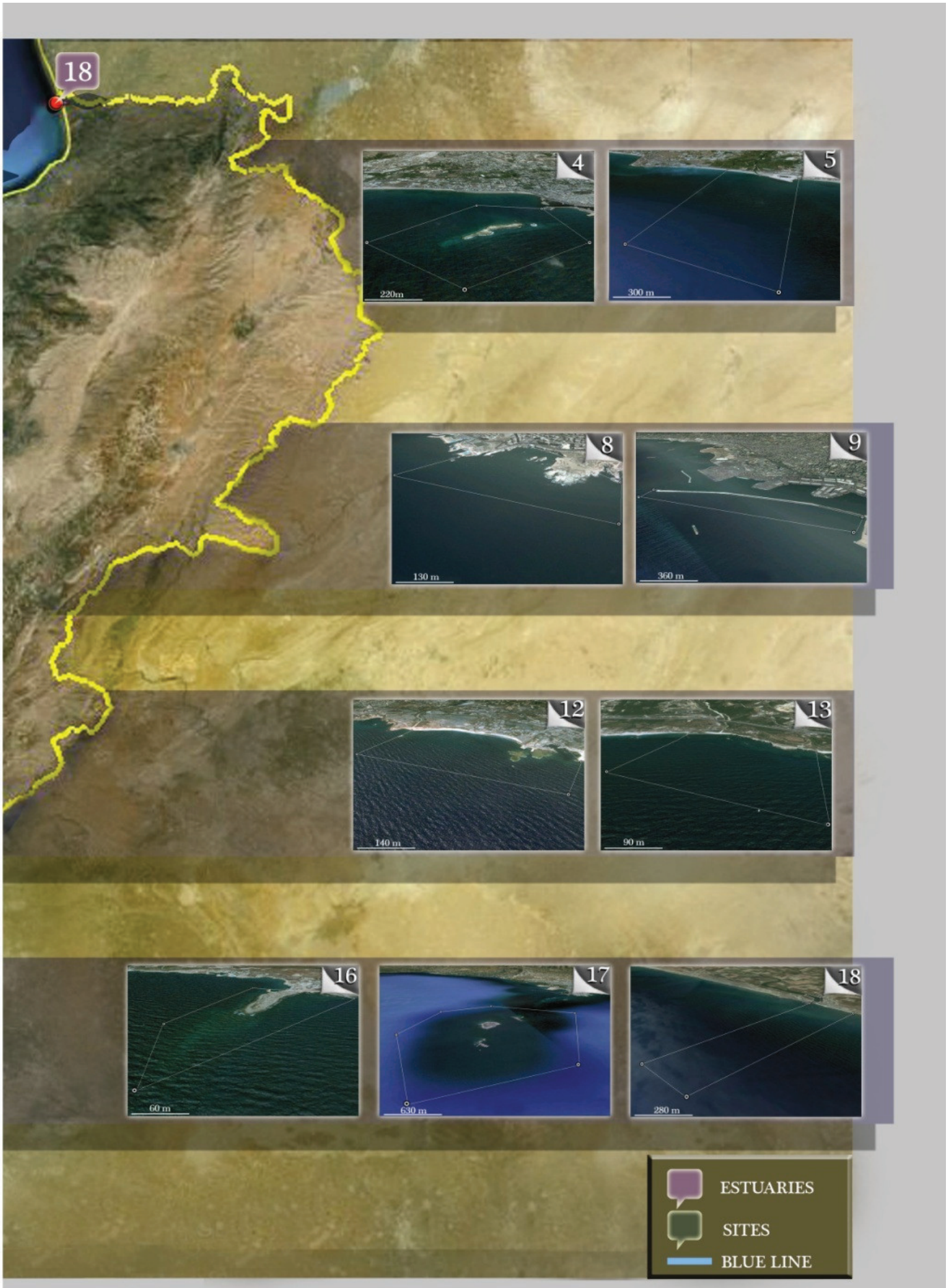
A section of the reserve is used for some agriculture, considered to be ecologically friendly to the ecosystem. Another section is open to the public for swimming and entertainment. The remaining third section is entirely protected and hosts various terrestrial animal and plant species. The site is regularly visited by migrating birds as well as sea turtles, which regularly use the beach as a breeding site. The reserve is recognized as a wetland of international importance by Ramsar Convention on Wetlands and is also under the supervision of a committee which is responsible for its management.

1.2.3 Protection of estuaries

According to Lebanese law (Act No. 1/385, issued January 26th, 1997), fishing activities are prohibited in all estuaries all year round. The protected area involved extends over 500 m on each side of the estuary, 500 m inside the river and two kilometers seawards. All human activities are banned except for those of scientists and Coast Guard.

Sandy beach of Tyre Coast Nature Reserve

Figure 3. Proposal for a protected area network along the coast of Lebanon (eastern Mediterranean).


18
4
220m
5
300 m
8
130 m
9
360 m
12
140 m
13
90 m
16
60 m
17
630 m
18
280 m
ESTUARIES
SITES
BLUE LINE

2 Proposal to establish a Marine Reserve Network for the Lebanese coast

2.1 Introduction

The Lebanese coast is in desperate need of a conservation plan for a variety of marine habitats. This plan should take as many local threats into consideration as possible and be compatible with human interests. The following is a proposal to establish a Marine Reserve Network along the Lebanese coast. The proposal does not intend to request an arbitrary ban on all human activities or the complete protection of all sites selected within the network. It simply draws attention to specific sites that are of particular interest to a species, marine community or the fishery sector.

Sites were carefully selected. Taking into consideration threats, needs and other factors, a total of 18 sites and a restricted band were delineated in accordance with the IUCN criteria for protected areas (table above, Dudley, 2008). The entire network proposed is in line with Greenpeace's plans to restore the ecosystem balance of the coastal waters along the Phoenician coast (Fig 2, Greenpeace, 2006). This is also in line with Greenpeace's ambitious project to create a global network of marine reserves covering 40% of the world's oceans.

2.2 Methods and itinerary

The Lebanese coast was surveyed extensively through various field trips which included land inspection (supplemented by satellite images), snorkeling (tide pools and shallow areas of less than 5m depth) and SCUBA diving (5-40m depth) whenever appropriate. Interviews and discussions with local fishermen from various areas were particularly instructive and relevant. The chronic lack of published scientific research on the Lebanese marine environment meant the author had to rely on personal experience and observations at times.

Candidate sites were selected according to various ecological, social and economic criteria (Roberts *et al.*, 2003 a, b). Among the most interesting ecological criteria used were: the presence and replication of all vulnerable habitats, interconnectivity to favor dispersal and migration, size related to the area and considered habitat(s), the presence of vulnerable life stages, exploitable species or organisms of particular interest, and low levels of human threats whenever possible. Furthermore, the presence of an economic, social, scientific or educational aspect (*e.g.* ecotourism potential, cultural or aesthetic value, ease of enforcement or management) added appeal to specific sites. Small valuable sites were grouped into larger areas with different criteria whenever possible.

2.3 Candidate sites

All 18 candidate sites, considered priority sites and a "restricted band" were graphically represented in the Google Earth satellite view shown in Figure 3.

2.3.1 Nakoura rocky area (Site 1)

Site characteristics: Limestone cliffs with hard underwater bottoms and occasional soft bottom patches (scale bar 500m).

Biodiversity: High.

Biomass: Moderate.

Representative habitats: Vermetid platforms of relatively small size; rocks and coralligeneous concretions at shallow depth; crevices and overhangs common; soft bottom areas of small sizes occasionally present in patches.

Threats: Pressure on vermetid platforms: limited; fishing activities: limited; harvesting activities: limited; spearfishing: limited; blast fishing (*capsoon*): limited; agricultural runoffs: limited; sewage/industrial runoffs: limited; eutrophication: not applicable.

Benefits of protection: Nurseries: moderate; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: limited; habitat for seagrass meadow communities: not applicable.

Acceptable anthropogenic activities: None, except scientific monitoring.

2.3.2 Tyre peninsula (Site 2)

Site characteristics: Islets of rocks and vermetid platforms (connected to land in ancient times) forming a peninsula. Sandy beaches on both sides. Shallow areas characterized by hard bottoms and a soft bottom dominate deeper waters. Archeological and historic site. Tyre is a UNESCO World Heritage Site (cultural, III & VI). The "Tyre Coast Nature Reserve" is found southwards in Ras Al Ayn (scale bar 500m).

Biodiversity: Moderate.

Biomass: Moderate.

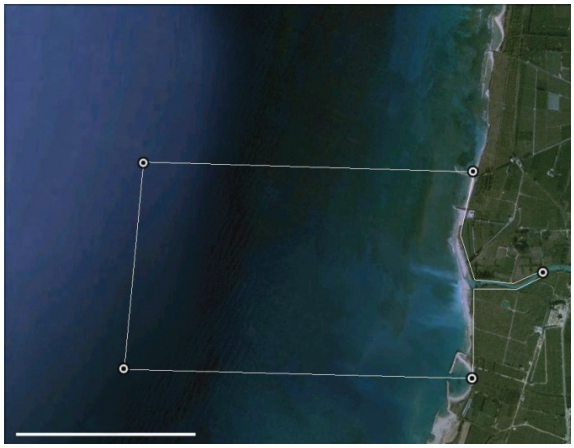
Representative habitats: Vermetid platforms and pools of relatively large size; rocks and coralligeneous concretions at shallow depth; crevices and overhangs common with occasional small gravel pebble areas; soft bottom of significant size present northwards in deeper waters with limited seagrass meadow.

Threats: Pressure on vermetid platforms: significant; fishing activities: significant; harvesting activities: significant; spearfishing: significant; blast fishing (*capsoon*): moderate; agricultural runoffs: significant; sewage/industrial runoffs: moderate; eutrophication: limited.

Benefits of protection: Nurseries: significant; spawning grounds: limited; feeding grounds: moderate; habitat for hard bottom communities: moderate; habitat for soft bottom communities: limited; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: Scientific monitoring, supervised swimming, snorkeling, and scuba diving (daytime only). Shore angling could be allowed.

2.3.3 Qasmieh estuary (Site 3)



Site characteristics: Estuary area of relatively large size. Qasmieh is the local name of the lower part of the Litani River. Estuaries are protected by Lebanese law (scale bar 1000m).

Biodiversity: High.

Biomass: High.

Representative habitats: Soft bottom area with large seagrass meadow on the edges.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: intense; harvesting activities: not applicable; spearfishing: limited; blast fishing (*capsoon*): moderate; agricultural runoffs: significant; sewage/industrial runoffs: significant; eutrophication: moderate.

Benefits of protection: Nurseries: significant; spawning grounds: limited; feeding grounds: significant; habitat for hard bottom communities: limited; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: None, except scientific monitoring.

2.3.4 Saida zeereh (Site 4)

Site characteristics: Islets of rocks and vermetid reefs in the Saida vicinity. A beach composed of gravel found nearby as well as the estuary of the Awally River. Hard bottom found in shallow areas and surrounded by a sandy soft bottom. Saida is an archaeological and historic site and was nominated a UNESCO World Heritage Site in 1984 (scale bar 250m).

Biodiversity: Very low, dominated by introduced species.

Biomass: Moderate.

Representative habitats: Vermetid platforms of small to moderate size; rocks and coralligeneous concretions at shallow depth; large surrounding soft bottom area constituted mainly of sand and silt; vestige of a seagrass meadow.

Threats: Pressure on vermetid platforms: significant; fishing activities: significant; harvesting activities: significant; spearfishing: significant; blast fishing (*capsoon*): moderate; agricultural runoffs: significant; sewage/industrial runoffs: significant; eutrophication: significant.

Benefits of protection: Nurseries: moderate; spawning grounds: limited; feeding grounds: significant; habitat for hard bottom communities: limited; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: limited.

Acceptable anthropogenic activities: Scientific monitoring, supervised swimming, snorkeling, and scuba diving (day only). Shore angling could be allowed.

2.3.5 Awally estuary (Site 5)

Site characteristics: Estuary area of moderate size. Estuaries are protected by Lebanese law (scale bar 1000m).

Biodiversity: Low.

Biomass: Low.

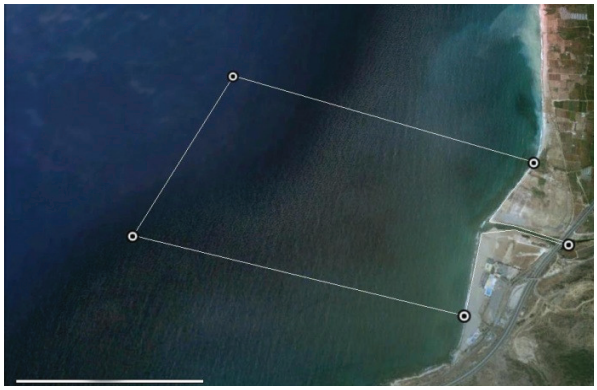
Representative habitats: Soft bottom area with seagrass meadow in patches.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: significant; harvesting activities: not applicable; spearfishing: limited; blast fishing (*capsoon*): moderate; agricultural runoffs: significant; sewage/industrial runoffs: significant; eutrophication: significant.

Benefits ofprotection: Nurseries: significant; spawning grounds: limited; feeding grounds: significant; habitat for hard bottom communities: limited; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: None, except scientific monitoring. Shore angling could be allowed.

2.3.6 Damour estuary (Site 6)



Site characteristics: Estuary area of moderate size. Estuaries are protected by Lebanese law (scale bar 1000m).

Biodiversity: Moderate.

Biomass: Moderate.

Representative habitats: Soft bottom area with seagrass meadow in patches.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: significant; harvesting activities: not applicable; spearfishing: limited; blast fishing (*capsoon*): moderate; agricultural runoffs: significant; sewage/industrial runoffs: significant; eutrophication: moderate; the river dries out completely end of summer season.

Benefits of protection: Nurseries: significant; spawning grounds: limited; feeding grounds: significant; habitat for hard bottom communities: limited; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: None, except scientific monitoring. Shore angling could be allowed.

2.3.7 Airport wave breaker (Site 7)

Site characteristics: Artificial site composed of a long wave breaker (> 2 km) that protects Beirut International Airport. Concrete structures as well as rocks and boulders of various sizes create artificial caves and crevices which act as an artificial reef[1] (scale bar 500m).

Biodiversity: Medium.

Biomass: High.

Representative habitats: Artificial reef at shallow depth; soft bottom areas with large seagrass meadow.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: significant; harvesting activities: not applicable; spearfishing: significant; blast fishing (*capsoon*): significant; agricultural runoffs: limited; sewage/industrial runoffs: significant; eutrophication: moderate.

Benefits of protection: Nurseries: limited; spawning grounds: limited; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: None, except scientific monitoring.

[1] Concrete provides excellent surfaces and habitat for the settlement and growth of encrusting and fouling organisms, which in turn provide forage and refuge for other invertebrates and fishes.

2.3.8 Raouche cliffs and caves (Site 8)

Site characteristics: Beautiful limestone cliff area with two large standing rock formations (Pigeon Rocks). Shallow hard underwater bottoms extending over most of the area. Soft bottoms found deeper. Archaeological and historic site and a popular tourist destination (scale bar 250m).

Biodiversity: Moderate.

Biomass: Moderate.

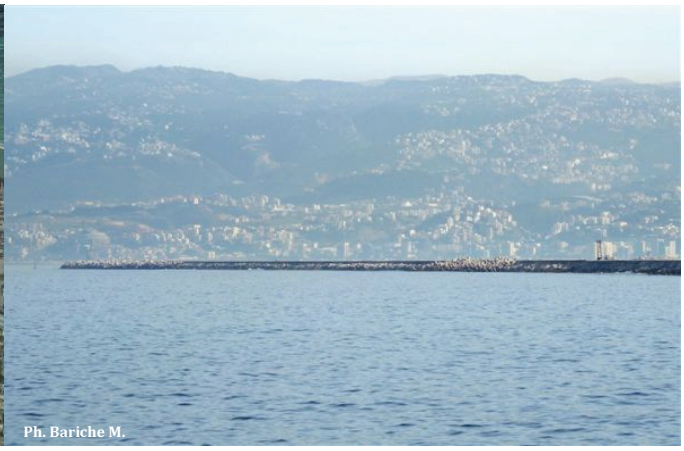
Representative habitats: Vermetid platforms of moderate size; rocks and coralligeneous concretions at shallow depth; caves (underwater or at surface), crevices and overhangs common; soft bottom area in deeper water.

Threats: Pressure on vermetid platforms: moderate; fishing activities: significant; harvesting activities: significant; spearfishing: significant; blast fishing (*capsoon*): limited; agricultural runoffs: limited; sewage/industrial runoffs: moderate; eutrophication: limited.

Benefits of protection: Nurseries: moderate; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: limited; habitat for seagrass meadow communities: not applicable.

Acceptable anthropogenic activities: Scientific monitoring, supervised swimming, snorkeling, and scuba diving during the day only. Shore angling could be allowed.

2.3.9 Beirut Port outer platform (Site 9)



Site characteristics: Artificial site composed of a long jetty (>2km) that protects the port of Beirut. Concrete structures as well as rocks and boulders of various sizes create artificial caves and crevices which act as an artificial reef (scale bar 500m).

Biodiversity: Medium.

Biomass: High.

Representative habitats: Artificial reef at shallow depth; soft bottom area; vestige of a seagrass meadow.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: Ssgnificant; harvesting activities: not applicable; spearfishing: moderate; blast fishing (*capsoon*): moderate; agricultural runoffs: limited; sewage/industrial runoffs: moderate; eutrophication: significant.

Benefits of protection: Nurseries: limited; spawning grounds: moderate; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: not applicable.

Acceptable anthropogenic activities: None, except scientific monitoring.

2.3.10 Nahr el Kaleb estuary (Site 10)

Site characteristics: Estuary area of moderate size. Estuaries are protected by Lebanese law (scale bar 1000m).

Biodiversity: Moderate.

Biomass: Moderate.

Representative habitats: Soft bottom areas with large seagrass meadow at edges.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: significant; harvesting activities: not applicable; spearfishing: limited; blast fishing (*capsoon*): limited; agricultural runoffs: moderate; sewage/industrial runoffs: moderate; eutrophication: moderate; the river dries out completely at the end of the summer season.

Benefits of protection: Nurseries: significant; spawning grounds: simited; feeding grounds: significant; habitat for hard bottom communities: simited; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: None, except scientific monitoring. Shore angling could be allowed.

2.3.11 Nahr Ibrahim estuary (Site 11)

Site characteristics: Estuary area of moderate size. Estuaries are protected by Lebanese law (scale bar 1000m).

Biodiversity: Moderate.

Biomass: Moderate.

Representative habitats: Soft bottom area with seagrass meadow in patches.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: moderate; harvesting activities: not applicable; spearfishing: limited; blast fishing (*capsoon*): limited; agricultural runoffs: moderate; sewage/industrial runoffs: moderate; eutrophication: moderate.

Benefits of protection: Nurseries: significant; spawning grounds: limited; feeding grounds: significant; habitat for hard bottom communities: limited; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: None, except scientific monitoring. Shore angling could be allowed.

2.3.12 Byblos Old Port (Site 12)

Site characteristics: Large vermetid reefs with significant ponds. A beach composed of gravel is found north of the area and the historic Byblos port lies to the south. Hard bottom found in shallow areas and soft bottom with a seagrass meadow dominates deeper waters. Archaeological and historic features site. Jbail (Byblos) is a UNESCO World Heritage Site (cultural, III, IV & VI). Afield report was submitted earlier regarding this site (scale bar 250m).

Biodiversity: Moderate.

Biomass: Moderate.

Representative habitats: Vermetid platforms of relatively large size; rocks and coralligeneous concretions at shallow depth; soft bottom areas with large seagrass meadow in deeper water.

Threats: Pressure on vermetid platforms: significant; fishing activities: significant; harvesting activities: significant; spearfishing: significant; blast fishing (*capsoon*): moderate; agricultural runoffs: moderate; sewage/industrial runoffs: moderate; eutrophication: limited.

Benefits of protection: Nurseries: significant; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: moderate; habitat for soft bottom communities: moderate; habitat for seagrass meadow communities: significant.

Acceptable anthropogenic activities: Scientific monitoring, supervised swimming, snorkeling, and scuba diving (daytime only). Shore angling could be allowed.

2.3.13 Medfoun rocky area (Site 13)

Site characteristics: Rocky area with moderate cliffs. Hard underwater bottoms with occasional soft bottom patches. This area can be considered partly protected since it lies within a military zone (scale bar 250m).

Biodiversity: High.

Biomass: Moderate.

Representative habitats: Vermetid reefs and pools of moderate size close to the surface; rocks and coralligeneous concretions deeper; crevices and overhangs common and occasional soft bottom patches present.

Threats: Pressure on vermetid platforms: limited; fishing activities: moderate; harvesting activities: moderate; spearfishing: moderate; blast fishing (*capsoon*): moderate; agricultural runoffs: moderate; sewage/industrial runoffs: limited; eutrophication: not applicable.

Benefits of protection: Nurseries: moderate; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: limited; habitat for seagrass meadow communities: not applicable.

Acceptable anthropogenic activities: None, except scientific monitoring.

2.3.14 Batroun Phoenician wall (Site 14)

Site characteristics: Rocky area with important vermetid reefs and hard underwater bottoms. Shallow hard underwater bottoms extend over most of the area. Soft bottoms found deeper. Archaeological and historic site and a popular tourist destination. A historic wall is believed to have been erected by the Phoenicians for protection from waves (scale bar 300m).

Biodiversity: Moderate.

Biomass: Moderate.

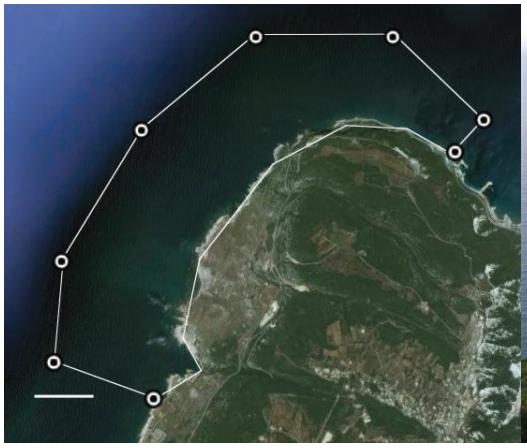
Representative habitats: Vermetid platforms of moderate size; rock and coralligeneous concretions at shallow depth with boulders, crevices and overhangs. Soft bottom areas of small sizes occasionally present in patches below 15-20 m depth.

Threats: Pressure on vermetid platforms: significant; fishing activities: significant; harvesting activities: significant; spearfishing: significant; blast fishing (*capsoon*): significant; agricultural runoffs: moderate; sewage/industrial runoffs: moderate; eutrophication: not applicable.

Benefits of protection: Nurseries: moderate; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: limited; habitat for seagrass meadow communities: not applicable.

Acceptable anthropogenic activities: Scientific monitoring, supervised swimming, snorkeling, and scuba diving (daytime only). Shore angling could be allowed.

2.3.15 Ras Chekaa cliffs (Site 15)



Site characteristics: Limestone cliff area with hard underwater bottoms and caves (scale bar 500m).

Biodiversity: High.

Biomass: Moderate.

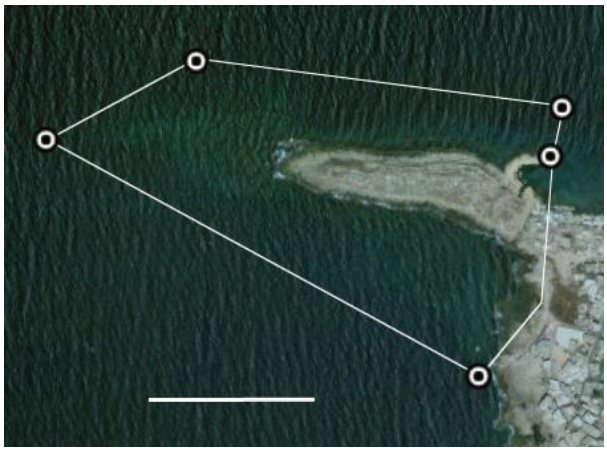
Representative habitats: Vermetid platforms of relatively moderate size; rocks and coralligeneous concretions at shallow depth; caves (underwater or at surface), crevices and overhangs common; a few soft bottom areas of small sizes occasionally present.

Threats: Pressure on vermetid platforms: limited; fishing activities: significant; harvesting activities: moderate; spearfishing: mignificant; blast fishing (*capsoon*): limited; agricultural runoffs: limited; sewage/industrial runoffs: moderate; eutrophication: not applicable.

Benefits of protection: Nurseries: significant; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: limited; habitat for seagrass meadow communities: not applicable.

Acceptable anthropogenic activities: None, except scientific monitoring.

2.3.16 Enfeh Peninsula (Site 16)



Site characteristics: Limestone rocks and vermetid reefs forming a peninsula. Shallow hard underwater bottoms; soft bottom in deeper waters. Archaeological and historic site (scale bar 250m).

Biodiversity: Moderate.

Biomass: Moderate.

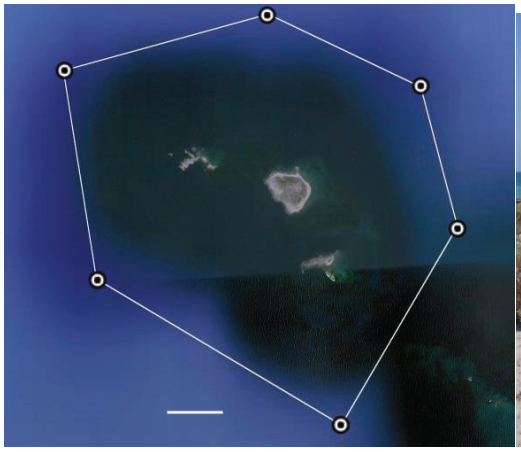
Representative habitats: Vermetid platforms of relatively moderate size; rocks and coralligeneous concretions at shallow depth; crevices and overhangs common; soft bottom areas of small sizes are occasionally present in patches.

Threats: Pressure on vermetid platforms: moderate; fishing activities: significant; harvesting activities: significant; spearfishing: significant; blast fishing (*capsoon*): moderate; agricultural runoffs: moderate; sewage/industrial runoffs: moderate; eutrophication: limited.

Benefits of protection: Nurseries: moderate; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: moderate; habitat for seagrass meadow communities: not applicable.

Acceptable anthropogenic activities: Scientific monitoring, supervised swimming, snorkeling, and scuba diving (daytime only). Shore angling could be allowed.

2.3.17 Tripoli islands (Site 17)



Site characteristics: Islets of rocks and vermetid platforms with shallow (8-14m) mostly hard underwater bottom. Some areas constituted of important seagrass meadows. Soft bottoms dominate deeper. Parts of this site are already protected (scale bar 500m).

Biodiversity: Moderate.

Biomass: Moderate.

Representative habitats: Vermetid platforms of relatively large size; rocks and coralligeneous concretions at shallow depth; caves (underwater), crevices and overhangs common; soft bottom areas with large seagrass meadow.

Threats: Pressure on vermetid platforms: limited; fishing activities: limited; harvesting activities: Llmited; spearfishing: limited; blast fishing (*capsoon*): agricultural runoffs: limited; sewage/industrial runoffs: limited; eutrophication: limited.

Benefits of protection: Nurseries: significant; spawning grounds: significant; feeding grounds: significant; habitat for hard bottom communities: significant; habitat for soft bottom communities: moderate; habitat for seagrass meadow communities: significant.

Acceptable anthropogenic activities: Scientific monitoring, supervised swimming, snorkeling, and scuba diving (daytime only).

2.3.18 Areeda estuary (Site 18)

Site characteristics: Estuary area of moderate size. Estuaries are protected by Lebanese law (scale bar 1000m).

Biodiversity: High.

Biomass: Moderate.

Representative habitats: Soft bottom areas with large seagrass meadow at edges

Threats: Pressure on vermetid platforms: not applicable; fishing activities: moderate; harvesting activities: not applicable; spearfishing: not applicable; blast fishing (*capsoon*): limited; agricultural runoffs: significant; sewage/industrial runoffs: moderate; eutrophication: moderate.

Benefits of protection: Nurseries: significant; spawning grounds: limited; feeding grounds: significant; habitat for hard bottom communities: limited; habitat for soft bottom communities: significant; habitat for seagrass meadow communities: moderate.

Acceptable anthropogenic activities: None, except scientific monitoring. Fishermen should be able to access their fishing boats as the estuary is used as a small fishing port. Shore angling could be allowed.

2.3.19 Restricted band along the coast

Area characteristics: This area is part of the nearshore pelagic environment defined earlier. The area extends 500 m from shore and runs along the entire coast (blue zone[2]).

Biodiversity: High.

Biomass: High.

Representative habitats: Part of the nearshore pelagic environment; all habitats situated underneath in which larvae, post-larvae or juvenile organisms can live.

Threats: Pressure on vermetid platforms: not applicable; fishing activities: significant; harvesting activities: not applicable; spearfishing: not applicable; blast fishing (*capsoon*): significant; agricultural runoffs: significant; sewage/industrial runoffs: significant; eutrophication: various, related to region.

Benefits of protection: Nurseries: significant (pelagic species); spawning grounds: moderate (some demersal species); feeding grounds: significant (pelagic species, demersal species, migratory species); habitat for hard bottom communities: significant (juveniles); habitat for soft bottom communities: significant (juveniles); habitat for seagrass meadow communities: significant (juveniles).

Acceptable anthropogenic activities: All legal activities except fishing with lights (coupled with any nets), *messlayeh*, beach seining within 500 m from the coast.

[2] It should be noted that the blue zone indicated in the figure is not to scale but exaggerated for clarity.

Table 2. Threatened and endangered† species along the Lebanese coast that could benefit directly or indirectly from protection. Different sites could benefit the same species at different life stages.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18
Invertebrates																		
Vermetid snail†	X	X		X				X				X	X	X	X	X	X	
Triton snail†	X	X						X				X	X	X	X	X	X	
Helmet tuna†	X	X						X				X	X	X	X	X	X	
Pen shell†	X	X		?			X	X				X	X	X	X	X	X	
Slipper lobster†	X	X						X				X	X	X	X	X	X	
Ghost crab†			X		X	X				X	?						X	?
Sea urchin	X	X		X				X				X	X	X	X	X	X	
Sponges†	X	X		X				X				X	X	X	X	X	X	
Other species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fish																		
Groupers†	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sea bream	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Jacks and pompanos	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Drums and croakers	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Red mullet	X	X	?	X	?	?	X	X	X	X	X	X	X	X	X	X	X	X
Barracuda	X	X					X	X	X			X	X	X	X	?	X	
Sea horse	X	X	?		?	?		X		X		X	X	X	X	X	X	?
Triglidae			X	X	X	X	X		X	X	X	X		X		X	X	X
Angel shark†		X	X	X	X	X	X			X	X	X		X		X	X	X
Scorpion fish	X	X						X				X	X	X	X	X	X	
Other species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Reptiles																		
Sea turtle†		X								X		X		X		?	X	
Soft-shelled turtle†			X		X	?				?	?							X
Birds																		

Aquatic birds			X	X	X	X		X		X	X				X	X	X
Marine Mammals																	
Monk seal†	?	?						X					?	?	X	?	X

3 Discussion

3.1 Choosing a site

Choosing sites to be protected is one of the more controversial issues in designing MPAs, as any protected area will always disrupt someone's activities. This may cause problems with some end users. However, the main purpose of a reserve network is the long-term maintenance of biodiversity and in selecting areas, one should make sure that biological diversity can be maintained. This includes habitat, species, population and genes and that anthropogenic disturbance is minimized. However, for the project to be viable, marine reserves should serve some human needs such as the restoration of over-exploited species of commercial interest, education and tourism.

3.2 Sizes and borders

The size of the area to be protected can vary greatly. Defining areas depends on the type of habitat present as well as the purpose of protection. Any area must be large enough to fully protect the habitat and its inhabitants. Among the reasons for protection are the movement of some species between habitats during their life cycle and seasonal migrations for feeding or breeding.

The borders of the MPA must be clearly visible. While it is relatively easy to set these borders on the terrestrial side, it is often critical to set the limits on the seaside as well. It is ideal to have a fixed structure or other known locality such as a wreck, an islet or an underwater elevation to delineate the outer edge of the reserve. Signs and indicator buoys should clearly delimit these areas. In this report, the outer limits of the suggested sites reflect a preliminary estimate that gives an idea of the the minimum surface area needed for each particular site. Setting clear and final outer limits for most of these sites will require additional scientific observation which will take time. This is necessary to include various important present habitats which will support a wide variety of fish and other marine organisms at their sub-adult or adult stages.

3.3 Different types of protections

It is obvious that different types of MPAs, serving different purposes, are needed along the Lebanese coast. The selected sites are "available", those not significantly impacted by humans as well as those containing threatened habitats. Other selected sites are artificial habitats that, if protected, could improve the status of some endangered species of high commercial value and thus enhance fishery. The proposed network is therefore a combination of sites to be fully protected Marine Reserves and others in which some activities can take place but under the supervision of a management team to ensure long-term conservation and sustainability.

- *Sites 1, 13, 15 & 17 are top priority sites. They are situated in areas not significantly affected by human activities and their location and natural character allow them to be classified as category I (IUCN criteria). While the three islets located off Tripoli (site 17) are protected, the maritime boundary situated around the islands is unclear. It is stated (Act 121, article 4) that "Hunting in the reserves or fishing on the coasts of the Sanani, Ramkine and Palm Island (Jazeerat al Nakheel), or within 500 meters at least from the boundaries of the reserves"* is prohibited*. The*

maritime boundary should be expanded and it is suggested that the protected area cover an imaginary circle with a radius of 2 km and a center situated on Palm Island.

- *Sites 2, 4, 8, 12, 14, 16 are important sites with a more pronounced anthropogenic presence and impact. The main monuments to protect are the valuable vermetid reefs as well as the cliffs and caves of Raouche. The protection of the Byblos Old Port (Site 12) is already being implemented. These sites could also be categorized as Natural Monument or Feature sites (category III).*

- *Sites 7 & 9 are artificial habitats situated next to the highly urbanized capital Beirut. These sites do not have any natural features. However, the long jetties and their vicinity make them interesting artificial reefs, mainly for groupers species of high commercial importance. Furthermore, their location next to the largest port and an international airport, along with a constant military presence, makes them relatively easy to protect. These sites should be protected from traditional fishing methods as well as spearfishing. Protecting mainly adult fish stages could enhance fishery yield and help rebuild stocks of valuable commercial species. These sites could be compared to Fishery Reserves; i.e. zones that preclude fishing activity to protect habitat, rebuild stocks, provide insurance against overfishing, or enhance fishery yield (CGER, 2001).*

- *The six remaining sites (3, 5, 6, 10, 11 & 18) are situated along estuaries and include essential habitats. These are protected by Lebanese law which should simply be enforced.*

Above all, candidate sites in Lebanon should be protecting the early life stages of marine organisms and their nurseries from all local threats. This makes the establishment of the suggested "restricted band", in addition to most sites, of utmost importance. The aim to reduce fishing pressure on this area is to limit the "ghost killing" of an invaluable number of marine organisms, most of which are juveniles of highly commercial species (fishes, crustaceans). They are killed unnecessarily and not marketed. The only fishing activity that should be banned within this zone is the one that aggregates pelagic fishes under a source of light (utilizing lampara and purse seine nets). This can be enforced easily as the source of light can be spotted and the distance estimated from the shore. Other legal fishing activities could take place within this area.

3.4 Scuba diving

For most people, scuba diving might seem to be a relatively undisruptive underwater activity. However, intensive and irresponsible scuba diving results in the degradation of habitats such as caves, coral reefs, rocky reefs, seagrass meadows, and coralligeneous bottom (Francour *et al.*, 2001; Barker & Roberts, 2004; Hasler & Ott, 2008; Di Franco *et al.*, 2009). The highest rates of total and of unintentional contacts have been recorded in caves and on encrusted walls, were slow-growing species are attached and are frequently damaged by scuba gear and divers' fins. Most of the contact is concentrated in the first minutes of a dive and on average each diver makes 2.5 contacts every seven minutes (Di Franco *et al.*, 2009). The resulting damage is in addition to the inevitable collection of rare or beautiful animals such as bryozoans, sponges and snails. Divers using cameras have significantly more contact with the reef than those without cameras, as do shore versus boat dives and night versus day dives (Barker & Roberts, 2004).

Diving clubs should be favored over individual divers and all diving activity should take place under close supervision. Specific regulations regarding scuba diving within MPAs should be implemented in order to minimize divers' impact. These could be supplemented by posters, signs and brochures displayed at dive centers. A limited number of divers should be able to access particularly fragile zones. A

short briefing prior to each dive should emphasize this aspect and dive leaders should manage diver behavior *in situ*. Various precautions could significantly reduce unintentional damage to the protected area.

3.5 Management

3.5.1 Community management

It is important to recognize that economic, social and cultural interests are fundamental aspects of any management plan. To ensure success, protected areas should be managed by local communities rather than imposed and enforced by governmental bodies. Properly applied, protected areas will win local support and rules will be enforced by the local community. Fishermen and local people should be approached first through their unions and/or municipalities by activities promoting awareness. While there should be strict regulations regarding the protected area and the fishermen, other interested parties should be fully aware of the importance of the marine reserve to be created beside their city or village. Without a doubt, success ultimately depends on them. Fishermen and local residents should be

involved because they have rights as end users and often possess useful knowledge about their region. Moreover, locals will enforce the rules of the protected area because they are involved in its establishment and management. Not to involve them would ultimately undermine the projects' integrity.

The joint effort of concerned ministries, municipalities and various end users such as dive centers, hotels and restaurants is also of critical importance. Awareness activities should also target them; public awareness is essential to reduce local resistance to environmental conservation. Awareness campaigns should emphasize the improvement in the quality of life of local residents as well as increased job opportunities; they should also stress the negative effects of non-extractive human activities linked to tourism (trampling, diving and anchoring boats), which are not always accepted easily. Similar campaigns should be carried out on a regular basis among students and interested adults and later on tourists.

3.5.2 Fishery management

The improvement of a small-scale fishery due to the presence of a protected area nearby provides substantial economic benefits to local communities. Various studies suggest that marine reserves can improve local fisheries beyond their boundaries (Russ *et al.*, 1996; Guidetti, 2007; Bell, 2008). However, it is clear that time is an important factor. Older reserves (>15 years) have been shown to be more effective than newer ones, with fish densities higher (>50%) and increasing regularly over time (Molloy *et al.*, 2002). Fish sizes increase as larger individuals of commercially important fish become more common with time. New and young reserves quickly show a tangible improvement but the magnitude and speed of responses to protection vary with the extent of fishing pressure nearby, types of habitats and species attributes. Predatory fish, such as groupers, jacks, small tuna and some seabreams, are likely to benefit the most from protection. Fisheries that target multi-species or sedentary species stocks, such as groupers and seabreams, will be favored over highly mobile single species such as large tuna and sharks (Hilborn et al., 2004). Molloy et al. (2002) concluded that although reserves may be effective after a short time, most reserves require more than a decade to yield significant results. Reserve stakeholders and fishermen need to have realistic expectations and management plans. Finally, MPAs are only likely to provide significant benefits when they are used in conjunction with direct catch or control efforts (Stefansson & Rosenberg, 2006).

3.5.3 Scientific management

A thorough research and scientific monitoring management plan will result in a better understanding of reserves' benefits and costs in ecological and socioeconomic terms. In addition, it will lead to increased knowledge regarding the complex marine habitats being protected and the dynamics that take place in a protected area versus another area. Species inventory, regular visual underwater scientific surveys and maps detailing habitat distribution and ecosystem diversity are needed. These are important for the development of modern marine management methods and will document the recovery of habitats and populations over time and make sure specific aims are being met.

3.6 Profits at all levels

A cost-benefit analysis from the northwestern Mediterranean clearly shows that several professional categories benefit from the positive returns of a marine protected area (Francour *et al.*, 2001). It is undeniable that professional fishermen make direct profits when spearfishing and recreational harvesting is prohibited in an area, as catches are generally higher in their vicinity. Fishermen and local residents profit from increased tourism to the MPA by selling fish to restaurants and

by taking tourists for sea tours. In addition, dive clubs promote and publicize their businesses using the image of an MPA situated nearby. Snorkelers, scuba divers and underwater photographers are especially attracted to protected areas in search of a rare encounter. Restaurants, hotels and small businesses make substantial profits from tourists frequenting remote areas because of the marine reserves. Finally, teachers and educators make direct use of snorkeling and on-shore activities by organizing student field trips, not to mention the necessary involvement of scientists (Francour *et al.*, 2001).

4 Conclusion

Establishing a Marine Reserve Network in Lebanon is difficult to achieve but not impossible. The proposed network is carefully designed to optimize recovery of the Lebanese marine ecosystem in terms of species diversity, habitats and resources. The information presented and conclusions reached are the result of knowledge acquired over more than two decades of observation, fieldwork, scientific research, and contact with fishermen and stakeholders complemented by an extensive literature review of the subject.

The general lack of detailed scientific information regarding the marine environment in Lebanon should not be an obstacle for designing a complex marine reserves network. Various studies from the western Mediterranean and around the world undoubtedly show that MPAs and Marine Reserves are important tools for conservation, fisheries management and other purposes such as education, research or tourism (Greenpeace, 2006). The author strongly believes that the proposed Marine Reserve Network, if applied as one entity with all of the recommended sites, will allow the basic and quick recovery of the Lebanese marine environment, fishery and tourism sectors currently under high threat. Monitoring this over time will verify whether conservation targets have been met.

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Greenpeace Mediterranean 2010
Beirut, Lebanon.
Tel: + 961 1 361 255
Fax: + 961 1 361 254