Funded by the European Union

The Marine Protected Area Strategy 2012

A baseline assessment of the five proposed estuarine sites as Marine Protected Areas

February 2024

This document was developed through the project "Conducting an evidence-based Non-State Actors Campaign on Marine Protected Areas Network" implemented by the Marine and Coastal Resources Program (MCR), Institute of the Environment (IOE), University of Balamand (UOB) in partnership with the Lebanese Environment Forum (LEF)

Authors:
Manal R. Nader, Ph.D.: Director, Institute of the Environment
Rawan Al Jamal, M.Sc.: Research Assistant, Marine and Coastal Resources Program
Andre Kammoun, M.Sc.: Research Assistant, Marine and Coastal Resources Program

To cite this report:

Nader, M., Kammoun, A. & Al Jamal, R. 2024. *The Marine Protected Area Strategy 2012. A baseline assessment of the five proposed estuarine sites as Marine Protected Areas.* Marine and Coastal Resources Program – Institute of the Environment – University of Balamand

Table of Contents

List of Figures

List of Tables

List of Abbreviations

MPA - Marine Protected Area

MoE - Ministry of Environment

PINR - Palm Islands Nature Reserve

TCNR - Tyre Coast Nature Reserve

ACNR - Abbasieh Coast Nature Reserve

MCR – Marine and Coastal Resources Program

IOE – Institute of the Environment

UOB – University of Balamand

LEF – Lebanese Environment Forum

FAO - Food and Agriculture Organization

LRB - Litani River Basin

ULRB – Upper Litani River Basin

LLRB – Lower Litani River Basin

ESCWA – Economic and Social Commission for Western Asia

ICZM – Integrated Coastal Zone Management of the Lebanese coastal zone

MoEW - Ministry of Energy and Water

RWEs – Regional Water Establishments

LRA - Litani River Authority

MoPH – Ministry of Public Health

MoA – Ministry of Agriculture

MoPWT – Ministry of Public Works and Transport

MoD - Ministry of the Displaced

MIM – Ministry of Interior and Municipalities

CDR – Council for Development and Reconstruction

CS – Council for the South

WWE – Regional Water and Waste Water Establishments

NWSS - National Water Sector Strategy

MoI - Ministry of Industry

EIA – Environmental Impact Assessment

ISQGs - Interim freshwater sediments quality guidelines

OCPs – Organochlorine Pesticides

DDD – Dichlorodiphenyldichloroethane

DDE – Dichlorodiphenyldichloroethylene

HCB – Hexachlorobenzene

POPs – Persistent Organic Pollutants

BOD – Biological Oxygen Demand

DO – Dissolved Oxygen

WHO – World Health Organization

EC - Electrical Conductivity

TDS – Total Dissolved Solids

SPNL - Society for the Protection of Nature in Lebanon

ARB – Awaly River Basin

LU – Land Use

LC - Land Cover

CNRS – National Center for Scientific Research

IUCN – International Union for Conservation of Nature

DRB – Damour River Basin

ERML - Environmental Resources Monitoring in Lebanon

BMLWWE – Beirut and Mount Lebanon Water and Wastewater Establishment

COD – Chemical Oxygen Demand

TP - Total Phosphorus

EPA – Environmental Protection Agency

List of Symbols

Ha – Hectare

MCM – Million Cubic Meters

BCM – Billion Cubic Meters

MW – Megawatts

Pb - Lead

Cd – Cadmium

Cr – Chrome

Fe – Iron

Cu – Copper

Zn – Zinc

Ca - Calcium

Mg - Magnesium

K - Potassium

Na - Sodium

NH4+ - Ammonium

$NO3^-$ - Nitrate

SO_4^{2-} - Sulfate

PO_4^{3-} - Phosphate

Cl^- - Chloride

CFU – Colony Forming Unit

TKN – Total Kjeldahl Nitrogen

CaO - Calcium Oxide

SiO_2 - Silica

Zr - Zirconium

I. Estuaries

Estuaries, also known as the point where rivers and oceans converge, are distinctive and dynamic ecosystems that are essential to the survival of species and the preservation of ecological equilibrium[1]. They are semi-enclosed coastal bodies of water where freshwater from rivers and streams enters coastal waters and mixes with saltwater from the ocean. This mixture is referred to as brackish water.

Estuaries are among the planet's most productive ecosystems because of the extraordinary diversity of flora and fauna that is supported by delicate salinity balance. This rich biodiversity found in estuaries is well known, frequently outpacing that of many non-estuarine habitats. Their distinct combination of freshwater and saltwater ecosystems results in a mosaic of habitats that sustain a wide variety of plant and animal species, such as marshes, mudflats, and open water areas. The transition zone they offer between freshwater rivers and the open sea, which is home to species adapted to different salt levels, further enhances this variety[2]. For their life cycles, fish, shellfish, birds, mammals, and a wide variety of invertebrates find the estuary habitat ideal[3]. Estuaries also serve as important pathways for a variety of aquatic species to migrate between freshwater and marine habitats and vice versa, which facilitates biodiversity enhancement in both estuarine and non-estuarine ecosystems[3,4]. In addition, they are known to be vital breeding and nursery sites for many marine species because of the nutrient-rich waters from river input and the profusion of flora that provide an abundance of food sources and shelter.

In addition to being hotspots for biodiversity, estuaries are essential to the Earth's biological system. They serve as natural filters removing contaminants and sediments from rivers before they enter coastal waters. By reducing erosion and serving as a buffer against storm surges, the vegetation in estuarine environments, where existent, aids in the stabilization of shorelines. Estuaries are also important for the cycling of nutrients because their ecosystems allow for the recycling and exchange of components that are vital to marine life[1,5]. These areas are also very valuable to humans as their significance goes well beyond ecological provisions. For example, their dynamic ecosystems offer a multitude of services that sustain fisheries, which are essential to the world's food security where they play crucial roles in the early phases of development and reproduction for a large number of commercially significant marine species. Furthermore, estuaries improve the

---

[1] Gao,D., Liu,C., Li,X., Zheng, Y., Dong, H., Liang, X., Niu, Y., Yin, G., Liu, M., Hou, L. (2022). High importance of coupled nitrification-denitrification for nitrogen removal in a large periodically low-oxygen estuary. https://doi.org/10.1016/j.scitotenv.2022.157516

[2] B. Barbier, E., D. Hacker, S., Kennedy, C., W. Koch, E., C. Stier, A., R. Silliman, B. (2011). The value of estuarine and coastal ecosystem services. https://doi.org/10.1890/10-1510.1

[3] A. Strydom, N., Kisten, Y., H. Montoya-Maya, P. (2023). Spatio-temporal relationships between larval fishes and zooplankton in cool-temperate estuaries of South Africa emphasizing the importance of mesohaline zone interactions. https://doi.org/10.1016/j.ecss.2023.108298.

[4] Pelage, L., Gonzalez, J., Le Loc'h, F., Ferreira, V., Munaron, J., Lucena-Frédou, F., Frédou, T. (2021). Importance of estuary morphology for ecological connectivity with their adjacent coast: A case study in Brazilian tropical estuaries. https://doi.org/10.1016/j.ecss.2021.107184.

[5] Eliani-Russak, E., Herut,B., Sivan, O., The role of highly stratified nutrient-rich small estuaries as a source of dissolved inorganic nitrogen to coastal seawater, the Qishon (SE Mediterranean) case. (2013). https://doi.org/10.1016/j.marpolbul.2013.02.001

quality of life of surrounding communities by supporting tourism and ecotourism activities like boating, fishing, and bird watching.

Recently, estuaries have been found to contribute significantly to climate change mitigation. In the first place, they serve as organic filters by capturing nutrients and sediments that rivers carry from upstream regions, which lessens nutrient pollution and sedimentation in coastal waters. The health of these ecosystems and the biodiversity they hold, depend on the maintenance of water quality and purity, which is aided by this filtering. Additionally, as they are essential for shoreline stabilization through sediment loading, they prevent coastal erosion and mitigate the impact of rising sea levels and hazards born at sea due stronger storms like storm surges[2,4]. By naturally trapping sediments delivered by rivers, these coastal ecosystems keep sediments from being transported farther offshore, leading to sediment buildup thus contributing to the upkeep or even construction of beaches and other coastal areas[2].

Given the ecological and socio-economic importance of estuaries, scientists and environmentalists alike are increasingly agreeing that estuaries should be designated as marine protected areas (MPAs defined as areas set aside for human activity regulation with the goals of preserving biodiversity, safeguarding ecosystems, and promoting sustainable resource use) due to their numerous ecological and human-related benefits[6]. By being designated as MPAs, estuaries can be protected against pollution, overexploitation, and habitat degradation with positive impacts on coastal waters. This will ensure that they can continue to support biodiversity and offer vital services to the local community and the environment through the increase of fish stocks, climate change mitigation by sequestering carbon, improving water quality, enhancing coastal resilience, and supporting healthier marine and freshwater ecosystems.

Therefore, the inclusion of these sites in MPA networks is imperative for the maximum output and effectiveness of coastal and marine conservation programs. More specifically, the Mediterranean has a range of estuarine environments throughout its shores, despite being a semi-enclosed sea. These estuaries are reported to support fisheries, which have long been essential to Mediterranean cultures, as well as contributing substantially to the biodiversity of the area[6,7].

Furthermore, several estuaries around the world and the Mediterranean have been declared as Ramsar sites as many qualify as wetlands. As of November 2023, there are 2,500 Ramsar sites (including estuaries that qualified as wetlands under RAMSAR) protecting 257,106,360 hectares involving 172 national governments worldwide. Of these sites, 428 are in the Mediterranean region[7].

Estuaries in the Eastern Mediterranean face particular challenges though due to limited, seasonal rainfall and anthropogenic stresses that highlight how urgently conservation activities must be undertaken. These delicate ecosystems, their resilience and health are under threat from rising industrialization, urbanization, population growth[8], pollution, climate change, habitat degradation,

---

[6] Osborn, Katherine & Mulligan, Tim & Buchheister, Andre. (2021). Seasonal Fish Communities in Three Northern California Estuaries. http://dx.doi.org/10.3398/064.081.0402

[7] RAMSAR SITES IN THE MEDITERRANEAN | MedWet

[8] Andricevic, R., Kekez, T., Vojkovic, M. (2021). Trophic status assessment of Central Eastern Adriatic Sea using water quality variables and loading capacity concept for estuaries. https://doi.org/10.1016/j.marpolbul.2021.113126

and overfishing amongst others. Given the significance of these estuaries for both ecological and socioeconomic reasons, governments and stakeholders must work to develop and implement efficient conservation policies that will guarantee their long-term viability and health.

II. Rivers of Lebanon

Lebanon has a total of 40 rivers, 16 of which are perennial (Annex 1: Some of the major rivers in Lebanon (Source: Updated NWSS 2020)), (Figure 1). The total length of rivers and streams in the country totals 730 km, and are characterized by small catchments and short length, each with its unique characteristics and importance[9]. The hydrographic system of Lebanon can be categorized into five main regions: Litani River Basin (LRB), El Assi Basin, Hasbani Basin, Coastal River Basins and the Minor and Isolated Sub-catchments (Annex 2: The hydrographic system in Lebanon (Source: Food and Agriculture Organization (FAO) in 201. The most important river in Lebanon is the Litani River, which is the longest in the country, running approximately 140 km in length. Other important rivers include Nahr al-Kabir, Nahr Ibrahim, Nahr el-Kalb, and Nahr el-Damour which all contribute significantly to Lebanon's fresh water resources.

The total annual discharge is estimated to be approximately 3452 Million Cubic Meter (MCM), with about 20% of this amount flowing into Transboundary Rivers (Annex 1: Some of the major rivers in Lebanon (Source: Updated NWSS 2020)). As a result, the net discharge from Lebanese rivers is roughly 2800 MCM/year, and varies depending on the season with the highest precipitation levels occurring during the winter and spring months (October or November to April or May), reaching their peak in February. These discharges are scarce during the months of June to August and are at their lowest in September. Rivers in Lebanon are mainly recharged by precipitation and snowmelt with 75% of water flow occurring between January and May [9].

These rivers are crucial for the country's economy and environment since they provide water resources for drinking, irrigation, hydropower generation, and industrial use. Moreover, they support freshwater aquatic ecosystems and are home for a wide range of biodiversity and wildlife, not to mention their importance on cultural and historical levels where some river basins have a mythological allure and countless archeological treasures left by different cultures. Furthermore, they are essential in nutrient upload into coastal waters driving coastal food chains, in sediment transport to replenish beaches that eroded during the winter season and in reducing salinity and temperature in shallow waters where such habitats represent spawning and nursery grounds. Thus, rivers have had, and still have, a vital role in supporting the livelihoods of communities and sustaining the country's natural resources and ecosystem services.

Rivers in the country are regulated by Law No. 192 dated 16/10/2020[10] that amended Law No. 77 dated 13/4/2018 "Water Law". It addresses through its chapters and articles all water resources including estuaries, dams, wetlands, groundwater reservoirs, hydrographic basins, surface water, groundwater, lakes, rivers, unconventional and conventional water resources.

[9] Lebanon – State of the Environment and Future Outlook: Turning the Crises into Opportunities" (SOER 2020), prepared by the United Nations Development Programme (UNDP) in Lebanon, with support from the UN Refugee Agency (UNHCR) and the United Nations Children's Fund (UNICEF), and in collaboration with the Ministry of Environment (MoE) and other national stakeholders.

[10] (ul.edu.lb) "قانون المياه"الجامعة اللبنانية | التشريعات | يرمي الى تعديل القانون رقم 77 تاريخ 2018/4/13

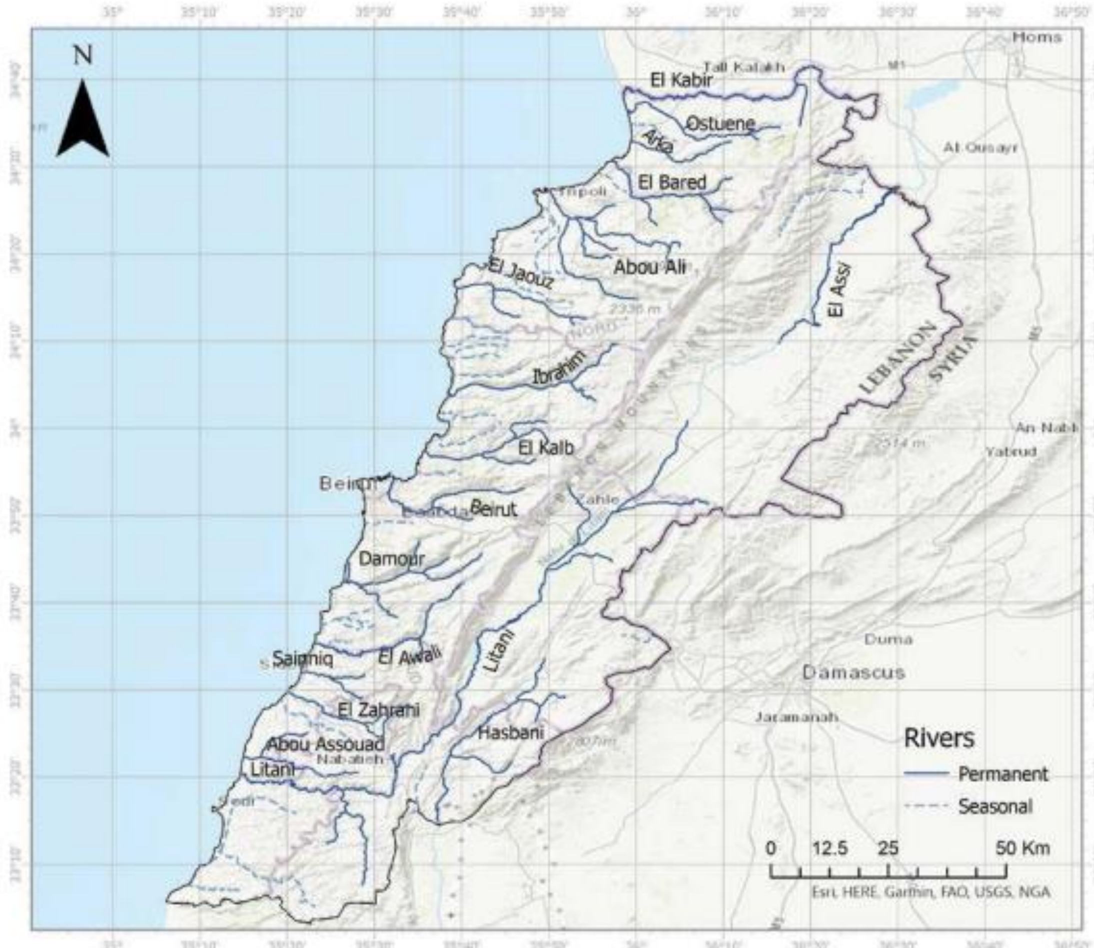

Figure 1: Permanent and Seasonal Rivers of Lebanon. (Source: FAO, 2016; MoEW/UNDP, 2014)

III. Threats to Lebanon's rivers

Despite their importance, over 50% of water resources in Lebanon are believed to be contaminated by physical, chemical, and biological pollutants, resulting in the rarity of clean water sources in the country[9]. The problem of deteriorating water quality has become a significant challenge on national level and is posing severe threats to human life and biodiversity. The most affected are surface water resources, followed by groundwater resources[11] where challenges faced are mostly associated with pollution, water scarcity, quarries, extraction of sand and habitat destruction. In addition to endangering the health of rivers, these threats, which can originate from both natural and anthropogenic sources, also have a negative domino effect on estuaries and MPAs. Pollution, a result of industrialization, urbanization, and poor waste management, is one of the main hazards to

[11] Baalbaki R, Ahmad SH, Kays W, Talhouk SN, Saliba NA, Al-Hindi M. (2019). Citizen science in Lebanon-a case study for groundwater quality monitoring. doi: 10.1098/rsos.181871.

Lebanese waterways. Pollutants consist of untreated or poorly treated domestic sewage discharged into rivers by communities contaminating the water with harmful bacteria and viruses[12], industrial discharges from manufacturing that can release chemicals and heavy metals into rivers, agricultural activities through the use of fertilizers and pesticides, solid waste improperly disposed which can lead to rivers becoming clogged with litter and debris, increased runoff and pollution from storm water carrying pollutants from roads, buildings, and other impervious surfaces due to the growth of urban areas[13]. All these pollutants carried by rivers that run into estuarine and coastal waters can have a detrimental effect on the biological balance and biodiversity of MPAs along the coast. This flux of pollutants can cause disturbances to reproductive cycles and population dynamics of marine animals, particularly those found in estuary environments.

Another major issue facing Lebanon's rivers is a lack of water and changing flow patterns. River flows have decreased as a result of climate change, deforestation, and unsustainable water extraction methods. This interferes with natural processes that support estuarine ecosystems and impacts the availability of freshwater supplies for human consumption. Estuaries are vital habitats for a variety of aquatic animals, and they rely on the constant flow of freshwater to provide the salinity and temperature gradients required for their survival. The growth and development of marine life can be impacted by seawater intrusion into estuaries due to changes in river flow and beach erosion. The main contributors to the uncontrolled extraction of water include farmers, municipalities, industries, tourist resorts and individuals. The main purpose of water extraction lies in irrigation, which accounts for 70% of total water consumption followed by industrial and domestic use[14].

The over- exploitation of water from rivers is mainly due to lack of effective environmental governance and enforcement of laws and regulations related to water management to control the behavior of people, as well as the lack of alternative water sources and efficient irrigation techniques. In addition, it is important to highlight that water abstraction occurring from the recharge zones of rivers, from where rivers receive their water, or from the recharge zones of springs and groundwater aquifers, which in turn replenish rivers, is a major contributor to competitiveness between people over water resources and a driver for chaotic extraction. Furthermore, quarries and uncontrolled extraction of sand and gravel increases the negative impacts on Lebanese rivers. This practice damages riverbanks, disturbs sediment flow patterns, and is frequently motivated by the need for urbanization. The physical structure of estuaries is impacted in a cascade of ways by these changes, which also have an impact on sediment deposition and the availability of suitable habitats for marine life. Furthermore, vulnerable and critical habitats within MPAs may be destroyed by the increased sedimentation brought on by anthropogenic activities, undermining the resilience and capacity of these areas to sustain a variety of marine species[15].

More importantly, management of estuaries falls under the jurisdiction of several public authorities: rivers fall under the MoEW, the marine public domain under and the Ministry of Public Works and Transport (MoPWT), fishing activities and the extraction of biological resources fall under the

---

[12] Dagher LA, Hassan J, Kharroubi S, Jaafar H, Kassem II. (2021). Nationwide Assessment of Water Quality in Rivers across Lebanon by Quantifying Fecal Indicators Densities and Profiling Antibiotic Resistance of Escherichia coli. Antibiotics (Basel). doi: 10.3390/antibiotics10070883.

[13] Shaban, Amin. (2019). Striking Challenges on Water Resources of Lebanon. 10.5772/intechopen.81878.

[14] Shaban, A. (2021). Rivers of Lebanon: Significant Water Resources under Threats. IntechOpen. doi: 10.5772/intechopen.94152

[15] Zema, D., Bombino, G., Denisi, P., Lucas-Borja, M., Zimbone, S. (2018). Evaluating the effects of check dams on channel geometry, bed sediment size and riparian vegetation in Mediterranean mountain torrents. https://doi.org/10.1016/j.scitotenv.2018.06.035.

Ministry of Agriculture (MoA), and biodiversity under the MOE. In addition, if an estuary is declared as an MPA, the MoE will also have jurisdiction on its management and conservation. Furthermore, no specific legislation regarding estuaries have been identified except Decision n°385/1997 that prohibits sea and river fishing on estuaries along the Lebanese coast[16]. Accordingly, the lack of specific laws and regulations that protect these sensitive sites may also form one of the major threats to their conservation.

IV. Impact of Dams

The ecological integrity of Lebanon's rivers is also threatened by the building of dams and other water infrastructure. Even while the main objectives of these constructions are frequently water management, they interfere with fish migration and change the natural water flow patterns (temperature, velocity, nutrient transport, etc…), which breaks the ecological connection between rivers and the sea. Since several marine species depend on upstream migration for their life cycle (i.e. feeding, mating and reproduction), dam obstruction can result in fish population losses and pose a detrimental effect on the overall biodiversity of estuarine and marine habitats.

Dams are large structures built across rivers or streams to control the flow of water. They are made for a variety of uses, such as hydropower production, flood control, irrigation, and recreational activities. Although dams come in a variety of sizes, shapes, and uses, they all aim to contain water and control its release. Nevertheless, despite these advantages, there are a large number of drawbacks to the building and maintenance of dams, which can have a significant and lasting effect on people and the natural environment. These detrimental effects, which range from social and economic hardships to ecological disturbances and extensive habitat loss, pose serious concerns about the viability of ambitious water infrastructure initiatives. The disruption of river ecosystems is one of the main environmental issues linked to dams[17]. As already stated, dams alter rivers' natural flow, which affects the cycling of nutrients, temperature regimes and the movement of silt. The temperature, silt, and nutritional properties of the reservoirs produced behind dams are frequently different from those of the free-flowing rivers they replace. Aquatic habitats and biodiversity usually suffer as a result of this modification where low temperature water flow reduces reproductive and survival abilities of species[18]. Dams are also barriers that many fish species encounter, especially those that migrate great distances for growth or spawning as part of their life cycle.

Another important environmental effect of dams is the disruption of sediment transport. They cause downstream erosion, the loss of fertile soil, and changes to the geomorphology of river channels by trapping sediments in their reservoirs[19]. The lack of sediments downstream negatively impacts aquatic habitats, plant life, and the resilience of river systems as a whole. In addition, dams play a role in the deterioration of water quality within their reservoirs[15]. In these man-made lakes, the standing water

[16] http://77.42.251.205/Law.aspx?lawId=200645

[17] Krztoń, W., Walusiak, E., Wilk-Woźniak. E. (2022). Possible consequences of climate change on global water resources stored in dam reservoirs. https://doi.org/10.1016/j.scitotenv.2022.154646.

[18] Avnaim-Katav, S., Almogi-Labin, A., Herut, B., Kanari, M., Guy-Haim, T. (2021). Benthic foraminifera from the Southeastern Mediterranean shelf: Dead assemblages and living-dead comparisons recording consequences of Nile River damming. https://doi.org/10.1016/j.marmicro.2021.101977.

[19] S.S. Ferreira, C., Seifollahi-Aghmiuni, S., Destouni, G., Ghajarnia, N., Kalantari, Z. (2022). Soil degradation in the European Mediterranean region: Processes, status and consequences. https://doi.org/10.1016/j.scitotenv.2021.150106.

can cause an accumulation of organic debris, nutrients and other pollutants, which can encourage the growth of hazardous algae. This eutrophication process can lead to fish deaths, a decrease in oxygen levels in the water, and the discharge of pollutants, which can have a damaging effect on aquatic ecosystems and the communities that depend on them for their livelihoods and water supply[20]. Building dams have an important and varied social repercussion as well. The relocation of local residents in the areas designated for reservoir construction is one of the most noticeable effects. Land is often needed for large dams, and villages, farms, and cultural heritage sites may have to be relocated due to reservoir flooding[21]. Communities that are uprooted may experience a decline in cultural identities, a disruption of social networks, and the loss of customary means of subsistence. Furthermore, dam-induced changes to river flows may have an effect on the availability of water for human and agricultural usage. Changes in water availability and quality can pose problems for communities that rely on rivers for residential water supply, fishing, and irrigation. Examining the economic feasibility of dams is an additional important consideration. Although dams are frequently marketed as long-term solutions for managing water resources and producing energy, they can be dangerous from an operational and financial standpoint. Projects that become economically unsustainable might be the result of construction delays, cost overruns, and changing knowledge of the effects on the environment and society. It can be expensive to decommission old dams and deal with the long-term environmental and socioeconomic repercussions. In Lebanon, dams are usually filled from surface water and these artificial lakes provide mostly contaminated water for irrigation to alleviate the pressure that irrigation is currently exerting on groundwater. The Lebanese government and local organizations are working to preserve the country's rivers and ensure their sustainable use, and even though there are debates concerning building dams due to Lebanon's topography and geology, in particular its seismic setting, there are several dams already built and operational as well as many others under construction (Table 1).

[20] Guo, F., Fry, B., Yan, K., Huang, J., Zhao, Q., O'Mara, K., Li, F., Gao, W., J. Kainz, M., T. Brett, M., E. Bunn, S., Zhang, Y. (2023). Assessment of the impact of dams on aquatic food webs using stable isotopes: Current progress and future challenges. https://doi.org/10.1016/j.scitotenv.2023.167097.

[21] Marchetti, N., Curci, A., Gatto, M., Nicolini, S., Mühl, S., Zaina, F. (2019). A multi-scalar approach for assessing the impact of dams on the cultural heritage in the Middle East and North Africa. https://doi.org/10.1016/j.culher.2018.10.007.

Table 1: Total dynamic capacity of existing dams in Lebanon (Source: Updated National Water Sector Strategy 2020-2035)

Dam	Static Storage (M m³)	Dynamic Storage (M m³/year)	Dam Height (m)	Status	Usage
BMLWE					
Chabrouh Dam	9	11	65	Operational	Potable / Irrigation
Ballout Lake	0.5	0.5	15	Operational	Potable / Irrigation
Qaysamani Lake	1	1	15	Operational	Potable
Janneh Dam	38	95	-60+100	Under Construction	Potable / irrigation / Hydropower
Bisri Dam	125	125	74	Under Construction	Potable / irrigation / Hydropower
Boqaata Dam	6	12	71.5	Under Construction	Potable
	179.5	**244.5**			
NLWE					
Kouachra Lake Rehab.	0.4	0.4	11	Operational	Irrigation
Brissa Dam	0.8	0.8	35	Needs repair	Irrigation
Mseilha Dam	6	12	35	Under Construction	Potable / Irrigation
Balaa Dam	1.2	2.2	35	Under Construction	Potable
	8.4	**15.4**			
BWE					
Yammouneh Lake	1.45	1.45	7	Operational	Irrigation
Assi Dam - Phase I		63	10	Under Construction	Irrigation
	1.45	**64.45**			
SLWE					
Qaraaoun Dam	**220**	**300**	62	Operational	Potable / irrigation / Hydropower
Total storage capacity at country scale	**409**	**624**			

Lebanon's 2012 surface water storage strategy was updated in 2020 and includes an update on the state of the dams (Annex 3: List of suggested dams in the NWSS for 2020-2035 (Source: NWSS 2020), Annex 4: List of dams in the 2012 NWSS (Sources: NWSS, 2012). A few of these dams have completion dates that extend beyond 2035. Furthermore, some of them were rejected after feasibility and/or design evaluations, as it was determined that they were not financially or geotechnically practical. In other instances, the growth of private development has rendered the sites chosen for the construction of the dam unavailable. As a result, a number of the possible dam locations identified in the 2012 plan have been discarded (National Water Sector Strategy (NWSS) 2020, http://faolex.fao.org/docs/pdf/leb211918EVolIV.pdf). From the five estuarine sites proposed in the MoE strategy, Litani River is associated with Qaraaoun Dam therefore affecting its estuary, Damour River associated with two dams, one upstream and one downstream, and Ibrahim River also associated with Chouane, Yahchouch, and Fitri dams. The El Kabir-Areeda River does not have any dams on the Lebanese side while three are constructed on the Syrian side of the watershed (Khalifah, Tell Hosh and Mzeineh), with an additional one (Idlin-Noura Al Tahta) in the planning phase. On the Awaly River course, there is the Bisri dam, however it was still in the planning and approval stages due to opposition and controversy over its construction.

V. Estuaries as MPA sites

River basins and their management play significant roles in influencing the health and ecosystem services of estuaries. Therefore, understanding the ecological state of river basins and their interactions with their estuaries is crucial for declaring these estuaries as MPAs since changes upstream have cascading effects on downstream estuarine environments.

The MPA Strategy of 2012 of the Ministry of Environment (MoE) proposed 18 sites for declaration as protected areas: nine coastal and marine sites, five estuary sites and four deep sea sites with the estuary sites being Litani, Awaly, Damour, Nahr Ibrahim and Arida[22] (Figure 2), in addition to the declared Palm Islands Nature Reserve (PINR) in 1992, Tyre Coast Nature Reserve (TCNR) in 1998, and most recently the Abbasieh Coast Nature Reserve (ACNR) in 2020[23].

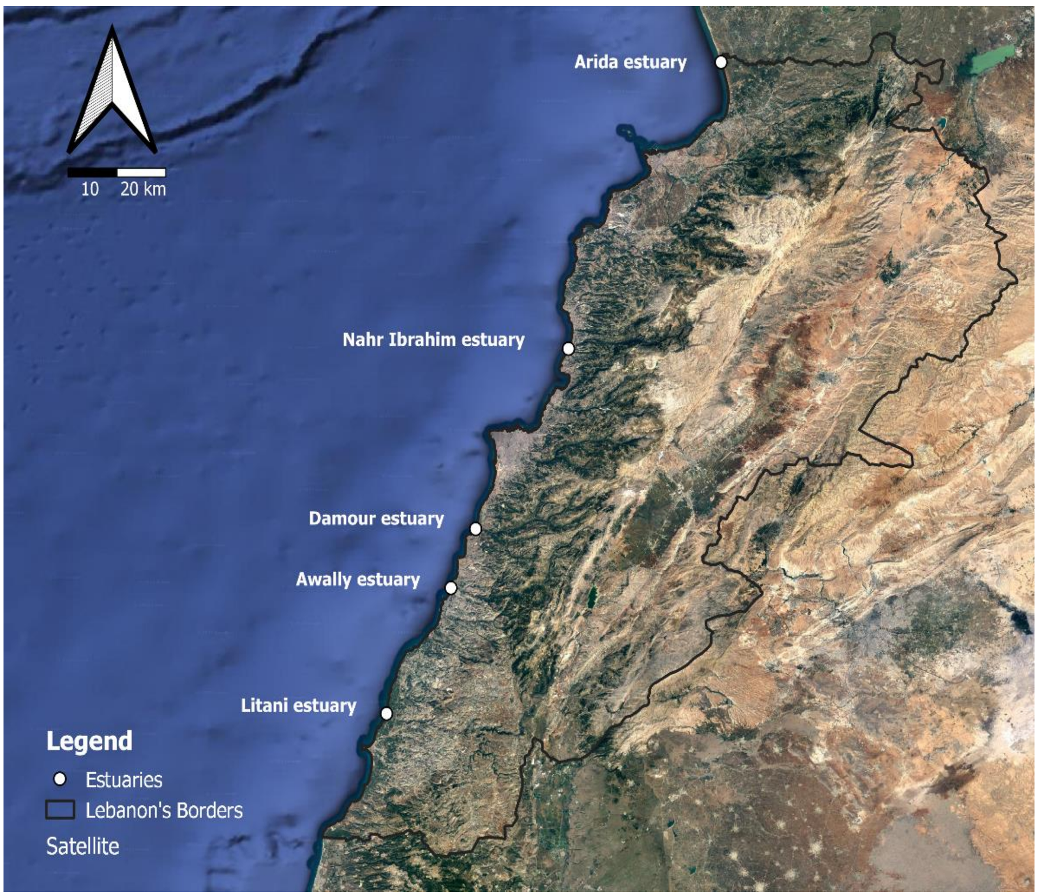

Figure 2: The five estuary sites proposed by Lebanon's MPA Strategy in 2012 (Source: MCR-IOE-UOB)

[22] El Shaer, H., Samaha, L., Jaradi, G., Lebanon's Marine Protected Area strategy. (2012).
[23] Nader, M.R., Al Jamal, R., Kammoun, A. & Tahhan, R. 2022. *Assessment of Lebanon's Marine Protected Areas against the creation of a "Marine Protected Area Network".* Marine and Coastal Resources Program - Institute of the Environment – University of Balamand.

Nine coastal sites have been scientifically assessed: Enfeh Peninsula, Ras Chekaa Cliffs, Raoucheh, Saida, Tyre and Nakoura in 2014[24], Batroun, Medfoun and Byblos in 2017[25] for declaration as MPAs, none were coastal estuaries. Even tough information describing these estuaries is included in the MPA Strategy 2012, it is limited and needs to be updated in order to support their declaration as protected areas. It is worthy to mention that within the project entitled "Marine and Coastal Biodiversity Conservation in Anfeh Hima", the Marine and Coastal Zones Resources Program at the Institute of the Environment at the University of Balamand (MCR- IOE- UOB) in partnership with IndyAct has conducted a biodiversity assessment for the Potential MPA of Anfeh in 2023, identifying marine motile and sessile species as well as assessing the physio-chemical parameters of the area[26].

1. Litani River Estuary

The Litani River is located in South Lebanon Governorate, being the longest gush and largest perennial river in Lebanon. It arises from the Beqaa Valley, west of Baalbek, and empties into the Mediterranean Sea north of Tyre in Qasmiyeh (33ᵒ20'19.28"; 35ᵒ14'42.05")[22] (Figure 3). It originates and flows entirely within the borders of Lebanon, covering eight administrative cazas (Bekaa West, Marjeyoun, Nabatiyyeh, Saida, Tyre, Jezzine, Hasbaya and Bent Jbail).

Figure 3: Litani River Basin. (Source: Amacha et.al, 2017)

[24] RAC/SPA - UNEP/MAP, 2014. Ecological characterization of sites of interest for conservation in Lebanon: Enfeh Peninsula, Ras Chekaa cliffs, Raoucheh, Saida, Tyre and Nakoura. By Ramos-Esplá A.A., Bitar G., Khalaf G., El Shaer H., Forcada A., Limam A., Ocaña O., Sghaier Y.R. & Valle C. Ed. RAC/SPA - MedMPAnet Project, Tunis: 146 p + annexes.

[25] SPA/RAC–UN Environment/MAP, 2017. Ecological characterization of potential new MPAs in Lebanon: Batroun, Medfoun and Byblos. By Ramos-Esplá, A.A., Bitar, G., Forcada, A., Valle, C., Ocaña, O., Sghaier, Y.R., Samaha, Z. & Limam A., Ed SPA/RAC. MedMPA Network Project, Tunis: 120 pages + annexes.

[26] Nader, M. & Al Jamal, R. 2022. *Marine Biodiversity Guide for the Potential Anfeh Marine Protected Area*. Marine and Coastal Resources Program – Institute of the Environment – University of Balamand

The Litani River watershed covers an area of 2180 km^2 and drains what accounts for nearly 20% of Lebanon's surface area with an estimated annual discharge rate of 770 MCM[27]. Rainfall, with an average of 875 mm/year, and snowmelt have a significant contribution to feeding the river, and as more tributaries join the river (a total of 19), the amount of water discharged from the basin gradually increases. The Qaraoun reservoir, the largest artificial lake in Lebanon with an area of around 12 km^2 and a storage capacity of around 220 MCM, was created in the 1960s when the Qaraoun Dam was built at an elevation of 850 to 800 m above sea level dividing the LRB into two sub basins, Upper Litani River Basin (ULRB) and Lower Litani River Basin (LLRB) (Figure 4). The upper basin being the largest, extends from the North Beqaa plain covering about 1500 km^2 of the Bekaa valley, and stretches from the river's source, at 1000 m elevation, to the Qaraoun Dam. Below the lake, the LLRB is characterized by an average altitude of about 600 m and a population of around 133000 capita living in 104 communities while the ULRB is home to half a million individuals. The shallow groundwater aquifer in the basin has an estimated water reserve of 105 MCM[28]. Due to its fertile soils and topographical features, this LRB is known for its agricultural practices, as well as its significant industrial hubs, mainly situated in the central Bekaa.

The LRB holds great importance due to its vital role in supporting urban development and the agricultural and industrial sectors: it is crucial for irrigation and contributes to the water needs of close to a million people, securing wetlands, a major reservoir, and a watershed ecosystem. The agricultural sector in the Bekaa mainly relies on the Litani water, with 31% of the income in the basin deriving from agriculture, and 6% of the inhabitants working in the sector. The river is also connected to three hydroelectric power plants that generate about 190 megawatts (MW) of

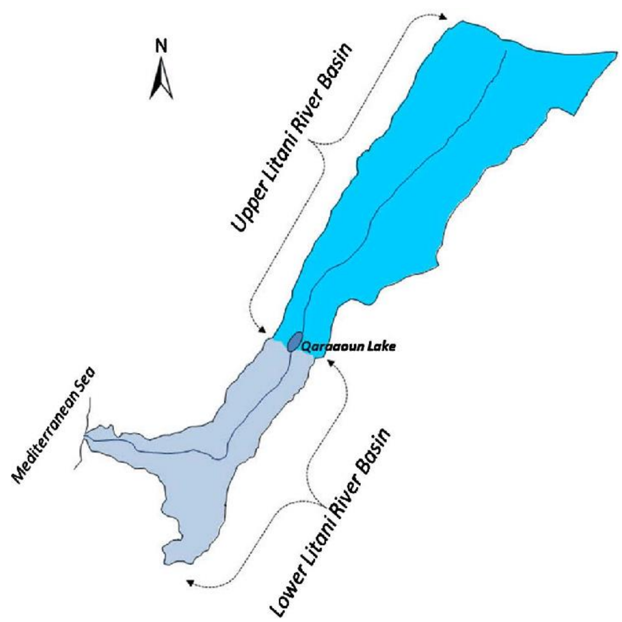

Figure 4: Upper and Lower Litani River Basin (Source: Haydar et.al, 2014)

[27] Shaban, Amin & Telesca, Luciano & Darwish, Talal & Amacha, Nabil. (2014). Analysis of Long-Term Fluctuations in Stream Flow Time Series: An Application to Litani River, Lebanon. http://dx.doi.org/10.2478/s11600-013-0175-4

[28] Fadel, A., Slim, K. (2018). Evaluation of the Physicochemical and Environmental Status of Qaraaoun Reservoir. In: Shaban, A., Hamzé, M. (eds) The Litani River, Lebanon: An Assessment and Current Challenges. Water Science and Technology Library, vol 85. Springer, Cham. https://doi.org/10.1007/978-3-319-76300-2_5

electricity, meeting 10-12% of Lebanon's needs[29]. Of the total rainfall received by the Lebanese territory, 24% is accounted for by the amount of water that is released from this basin. This amount makes up more than 40% of the total volume of water that flows via internal rivers. The LRB also features mountain crests covered in snow, the largest lake in Lebanon (artificial), and wetlands, including Ammiq and Kfar Zabad[30].

According to the MPA Strategy 2012[22], the Litani estuary, also referred to as the Qasmiyeh estuary, is significant for marine turtle populations, seagrass meadows, and fisheries. The habitat includes both living organisms and physical characteristics, serves as a fish and wildlife food source, nesting site, resting site, and feeding grounds. It is important to mention that this habitat has undergone major changes in its benthic community structure as a result of human activity. Habitat types include sandy beaches where the river converges with the sea and marine vegetation beds. In addition, it shows different criteria such as threatened species and habitats, fragile habitats and low recovery rates, all of which qualify this site as a potential protected area (Figure 5).

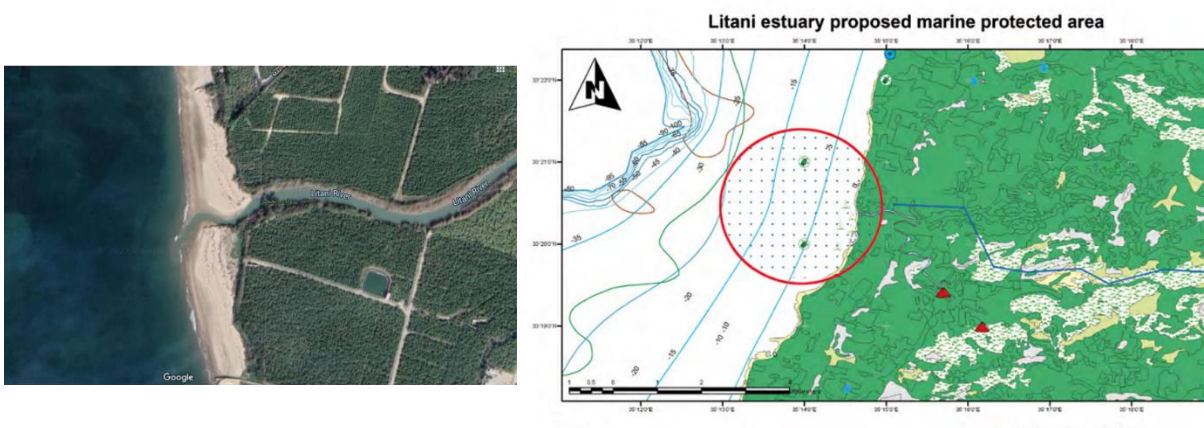

Figure 5: A) Satellite image of Litani Estuary (Source: Google Earth); B) Litani Estuary proposed MPA (Source: Lebanon's MPA Strategy, 2012)

In addition, within the project entitled "Environmental Resources Monitoring in Lebanon (ERML)" implemented by MoE under the management of UNEP in collaboration with UNDP and implemented by MCR-IOE-UOB in 2013, the Qasmiyeh River estuary is characterized as an Ecological High Priority Site[31] (Figure 6).

[29] CEDRO. Hydropower in Lebanon; History and Prospects. (2013).
[30] Amacha N, Karam F, Jerdi M, Frank P, Viala E, et al. (2017) Assessment of the Efficiency of a Pilot Constructed Wetland on the Remediation of Water Quality; Case Study of Litani River, Lebanon. Environ Pollut Climate Change 1: 119.
[31] MoE/UNEP/UNDP. (2013a). Environmental Resources Monitoring in Lebanon (ERML) project: 'Improved Understanding, Management and Monitoring in the Coastal Zone'. Available at: http://erml.moe.gov.lb/ViewPublications.aspx?menuId=6

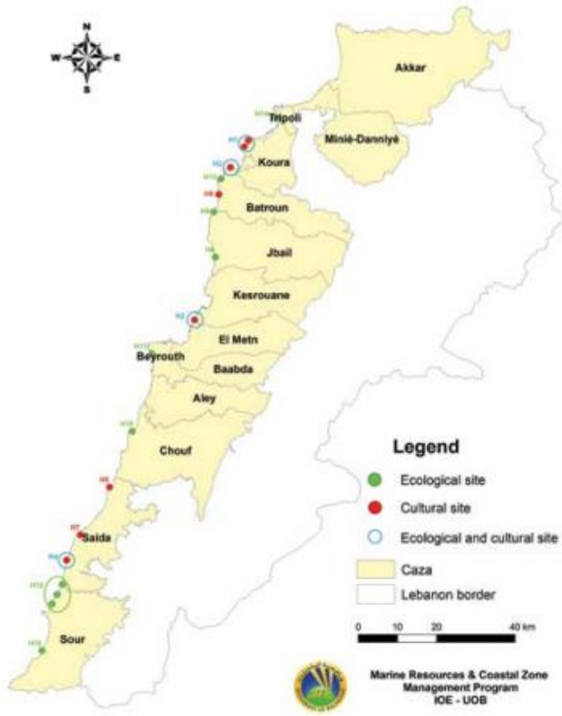

Figure 6: Ecological and Cultural high priority sites (Source: MoE/UNEP/UNDP, 2013a)

Given the importance of the LRB at national level, specific laws have been promulgated specifically for this basin (Table 2).

Table 2: Legislation specific for the Litani River Basin (Source:الجامعة اللبنانية / مركز المعلوماتية القانونية / عرض التشريعات (ul.edu.lb))

Legislation	Date	Subject
Decision No. 264	2020	Cancellation and withdrawal of the license of the agency of Litani Trading Company for Travel and Tourism «Letaco» - first category.
Decree No. 7085	2020	Conclusion of a loan agreement between the Republic of Lebanon and the Arab Fund for Economic and Social Development to contribute to the financing of the sewage facilities project in the northern and central Litani Basin.
Law No. 168	2020	Request for approval of a loan agreement between the Republic of Lebanon and the Arab Fund for Economic and Social Development to contribute to the financing of the sewage facilities project in the northern and central Litani Basin.
Decision No. 152	2020	Establishment of a national Hima «protected area» in the area of Kafr Zabad in the district of Zahle, Bekaa Governorate on the properties of the National Authority of the Litani River.
Decision No. 13	2020	Formation of a joint committee between the Ministry of Industry and the Litani River National Authority to survey and enforce the environmental commitment of industrial enterprises in the Litani River Basin.

Legislation	Date	Subject
Decree No. 4632	2019	Conclusion of a financing agreement for the "Local Development Program along the Litani River Basin" between the Government of Lebanon and the European Union.
Decision No. 45	2019	Amendment of Decision No. 12/1 of 20/2/2019 (to form a committee to follow up the file of pollution of the Litani River).
Decision No. 12	2019	Formation of a joint committee between the Ministry of Industry and the Litani River National Authority to survey and enforce the environmental commitment of industrial enterprises in the Litani River Basin.
Decision No. 796	2018	Prohibition of fishing in Lake Qaraoun and in the main course of the Litani River.
Decree No. 3373	2018	Raising the minimum salaries and wages and transferring the salary chains of employees in the Litani River National Authority.
Decree No. 2914	2018	The distribution of allocations for certain ministries under Law No. 63 dated 27/10/2016, which allocates funds for implementing projects and acquisition activities in the Litani River Basin from the source to the estuary, as amended in the Official Gazette No. 9 dated 23/2/2017 and No. 51 dated 2/11/2017.
Decree No. 2574	2018	Appointing Mr. Sami Hassan Alouieh as Chairman of the Board of Directors - General Manager of the National Authority for the Litani River.
Decree No. 1047	2017	Granting leave to the Council for Development and Reconstruction to resort to arbitration to resolve disputes that may arise with the FAO in the upcoming contract related to providing technical assistance to enhance good agricultural practices, including integrated pest management, to reduce chemical pollution in the upper basin of the Litani River.
Decree No. 977	2017	Authorizing the occupation of a portion of public river property (Litani River channel) in the Jazireh Al-Oqaira area - Sidon district - South Lebanon province for public benefit.
Law No. 63	2016	Allocating funds for the implementation of some projects and their acquisition works in the Litani River basin area from spring to mouth.
Decree No. 2659	2016	Accepting a grant from the Korean unit operating within the United Nations Interim Force in Lebanon for the benefit of the Ministry of National Defense - Army - South Litani Sector Command.
Law No. 49	2015	Approval of the conclusion of a second loan agreement No. (923) between the Republic of Lebanon and the Kuwait Fund for Arab Economic Development to finance the project of transporting Litani water to southern Lebanon for irrigation and drinking purposes (level 800 meters) and amending the loan agreement No. (634) held on 15/1/2002.
Law No. 50	2015	Approval of the conclusion of an additional loan agreement between the Government of the Republic of Lebanon and the Arab Fund for Economic and Social Development to contribute to the financing of the project of transporting Litani water to southern

Legislation	Date	Subject
		Lebanon for irrigation and drinking purposes (level 800 meters) signed on 16/6/2015.
Decree No. 2309	2015	Signing Loan Agreement No. 923 between the Lebanese Republic and the Kuwait Fund for Arab Economic Development to finance the project of transferring water from the Litani River to southern Lebanon for irrigation and drinking purposes (elevation 800 meters) and amending Loan Agreement No. 634 concluded on 15/1/2002.
Decree No. 2310	2015	Approving an additional loan agreement between the government of the Lebanese Republic and the Arab Fund for Economic and Social Development to contribute to financing the project of transferring water from the Litani River to southern Lebanon for irrigation and drinking purposes (elevation 800 meters).

1.1. Challenges

Currently, the Litani River is subject to severe challenges, primarily categorized into the following three groups:

- Physical challenges: include climatic variability and, in consequence, low infiltration rate and irregular water availability. In addition, increases in atmospheric temperature created an increased water demand, mainly for irrigation purposes. Furthermore, the geomorphology of the LRB lacks water-flow uniformity which often reduces the infiltration rate and enhances flooding[32]. The gentle slope also leads to slow stream-flow energy increasing the chances for faster evaporation and settlement of sediments and pollutants. Finally, loss of water due the existence of fault systems resulting in water seepage into undefined and very deep aquifers[33].
- Anthropogenic challenges: can be described through solid waste, organic and chemical pollution as well as the increasing rates of urbanization at the riverbanks. The primary source of organic material pollution is wastewater effluents, notably from household residues where surface water and wastewater mixture seeps into the rocks and soil before mixing with groundwater[34] seriously contaminating aquifers. Furthermore, untreated solid waste from a multitude of sources is discharged into the river. This is a common occurrence whereby these pollutants cover fractured rocks and subsequently contaminate the river basin's groundwater. They originate from food factories that produce dairy, soft drinks, alcoholic beverages, jams, molasses, and any other materials produced in these or similar factories. Factories also produce wastes from animal farms and slaughterhouses, hospital wastes, and wastes from agricultural fertilizers and food processing. The emergence of organic pollution in the Litani River is ascribed to the fact that the river and its streams serve as the closest open discharge points for liquid waste and wastewater from the communities situated along its banks, particularly with the absence of functional wastewater treatment facilities. In addition, industrial pollution results from factories such as the Berdaouni paper factory, the Ghzayel River

[32] F. Alcon, S. Tapsuwan, R. Brouwer, M. Yunes, O. Mounzer, M.D. de-Miguel. (2019). Modelling farmer choices for water security measures in the Litani river basin in Lebanon. https://doi.org/10.1016/j.scitotenv.2018.07.410

[33] Nemer, T., Meghraoui, M. (2006). Evidence of coseismic ruptures along the Roum fault (Lebanon): a possible source for the AD 1837 earthquake. doi:10.1016/j.jsg.2006.03.038

[34] Litani River Authority. https://www.litani.gov.lb/en-us/aboutlrb

sugar factory, and battery manufacturers situated in Zahle's industrial zone flood-plain regions. On the other hand, fuel stations that dump used fuel and oils into sewage canal systems are the source of chemical contamination. The primary sources of industrial wastewater are auto repair shops, tanning and battery companies. Chemical fertilizers and insecticides, which are employed in agriculture, are additional contaminants. Moreover, olive presses generate hazardous liquid waste in some areas. Dusts and clayey-fill rock cracks are produced by quarries, rock debris, and rock-cutting factories. These factors affect the infiltration and storage of water. This kind of contamination raises the concentration of river pollution and alters flow rates. Additionally, the recent increase in population in the ULRB—particularly in Houch El-Rafica—is a result of the Syrian refugee crisis[35]. A growing number of water consumers, including the urban, agricultural, and industrial sectors as well as higher living standards, need to be managed and included into the region's overall water management strategy taking into account that many wastewater treatment plants along the river are either not functional or barely operating. Several studies have also identified high levels of phosphorus and nitrogen, suspended solids, heavy metals, biochemical oxygen demand, and fecal pathogens, primarily indicating hypertrophic conditions[36].

- Management challenges: The Litani River Authority (LRA; https://www.litani.gov.lb/en-us) was established in 1954 and is the public institution responsible for operating and maintaining the water distribution network as well as for allocating water resources among farmers in the LRB. However, Lebanon is going through a major water scarcity problem due to the lack of an effective national water management plan and an unprecedented inefficiency in water conservation measures to balance water supply and demand. Even though there is an Updated NWSS for 2020-2035, the country still faces many challenges in its legal framework, human resource availability, supervision, monitoring and reporting, financial and commercial frameworks and operation and maintenance. In addition, there are no legal controls or enforcement of the law to control water related issues.

Over the years, several projects and studies have assessed the state of the Litani and Qaraaoun Reservoir starting as early as 1943. The funds provided by the Lebanese water sectors for these projects can be considered minimal when compared with those from international agencies targeting management plans that aim at improving water use and their quality. In 2019, a collaborative work plan was established between the MoE and the Ministry of Industry (MoI) to identify areas of cooperation. The aim of this joint effort was to address various issues including quarries and crushers, solid waste management, environmental impact assessments (EIA), pollution treatment of the Litani River and Qaraaoun Lake, measures to ensure environmental protection for rivers and basins, control of unplanned urban expansion, preservation of biological diversity, and the necessary steps for implementing the Air Quality Protection Law (Law No. 78/ 2018)[37].

In summary, the LRB is subject to several stressors like climatic variability, low infiltration rate, flood risk, fault system, organic, chemical and solid pollution, population growth, non-functional water treatment plants and absence of law enforcement amongst others. These are expected to also

[35] El Amine, Y. (2019). A broader view of the Litani’s pollution crisis: mounting conflicts and hidden pitfalls.
[36] T. Darwish, A. Shaban, I. Masih, H. Jaafar, I. Jomaa & J. P. Simaika (2023) Sustaining the ecological functions of the Litani River Basin, Lebanon, International Journal of River Basin Management, 21:1, 37-51, DOI: 10.1080/15715124.2021.1885421
[37] قانون حماية نوعية الهواء | التشريعات | الجامعة اللبنانية (ul.edu.lb)

affect the estuarine site, since no measures to bring these harmful practices and pressures to a halt are being seriously implemented.

1.2. Water quality

The LRB is facing considerable challenges in terms of surface and groundwater quality. Studies in 2014 have revealed elevated levels of heavy metals in the sediments of the LLRB, surpassing the permissible limits recommended in the Interim Freshwater Sediments Quality Guidelines (ISQGs), particularly during the dry seasons[38] (Annex 5: Heavy metals in bed sediments along the LLRB). Furthermore, significant pollution from sediments has been observed at the endpoint of the Litani River due to the accumulation of pollutants in that area. According to these studies, agricultural and industrial activities are identified as the primary sources of water and sediment contamination by heavy metals. Nine organochlorine pesticides (OCPs) have been detected in measurable quantities in the Litani River and Qaraaoun Lake. These OCPs include Dichlorodiphenyldichloroethane (DDD), Dichlorodiphenyldichloroethylene (DDE), endosulfan sulfate, b-endosulfan, Hexachlorobenzene (HCB), heptachlor, lindane, methoxychlor, and tetradifon. While concentrations of DDE in the Litani riverbed have been found to be within permissible levels, they exceeded the limit in the Qaraaoun Lake. This situation raises concerns about the potential accumulation of Persistent Organic Pollutants (POPs) in the lake. Concerning Biological Oxygen Demand (BOD) levels, the uncontrolled release of wastewater has resulted in elevated levels of BOD and reduced dissolved oxygen (DO) levels, especially during the dry season[39]. In addition, a microbiological analysis of groundwater in the LLRB in 2020 showed high contamination with salmonella and *Staphylococcus aureus* but not with *Clostridium perfringens*[40]. A recent study in 2022 characterized the ULRB (Annex 6: Additional information on the LRB) as eutrophied and mineralized, while the LLRB expressed better water quality highlighting the role of Qaraoun Dam in reducing eutrophication level in the LLRB[41]. It is important to highlight that these contaminants do make their way into the LLRB from the ULRB. However, the amounts and impacts of these contaminants are not currently measured or well understood. This lack of data hinders the ability to fully assess and mitigate the environmental risks posed by pollution in the river basin.

Contaminants are therefore carried by the river into the estuary, where they can accumulate and impact water quality, marine habitats, and associated biodiversity. Therefore, stressors affecting the river course will also be affecting the overall health and functioning of the estuarine ecosystem.

---

[38] Nehme, N., Haydar, C., Koubaissy, B., Fakih, M., Awad, S., Toufaily, J., Villieras, F., Hamieh, T., (2014). The distribution of heavy metals in the Lower River Basin, Lebanon. doi: 10.1016/j.phpro.2014.07.066

[39] Helou, K., Harmouche-Karaki, M., Karake, S., Narbonne, J. (2019). A review of organochlorine pesticides and polychlorinated biphenyls in Lebanon: Environmental and human contaminants. https://doi.org/10.1016/j.chemosphere.2019.05.109

[40] Nehme, Nada & Haidar, Chaden & Dib, Amani & Ajouz, Nawal & Tarawneh, Khalid. (2020). Quality Assessment of Groundwater in the Lower Litani Basin (LLRB), Lebanon. http://dx.doi.org/10.22606/gr.2020.51001

[41] Diab, M. and Soliman, M. (2022) "Investigating The Proper Use Of Litani River Basin Based On Water Quality," BAU Journal - Science and Technology: Vol. 3: Iss. 2, Article 10. DOI: https://doi.org/10.54729/FVAI6018

1.3. Macrophytes

A study in 2016 taking into account five sites distributed along both the upper and lower river basins identified a total of 35 taxa of both submersed (17 taxa: 5 algae; 2 bryophytes and 10 phanerogames) and emergent macrophytes (18 taxa of phanerogames)[42] forming different associations and communities across the different sites of the river (Annex 7: List of macrophytes in the upper and lower basins of the Litani River (Source: Baydoun et al, 2016).

1.4. Toxic algal blooms

The most recent studies in 2019 describe the Qaraoun reservoir as home for low phytoplankton biodiversity, dominated by toxic cyanobacterial blooms of *Mycrocystis aeruginosa* and *Aphanizomenon ovalisporum*[43]. However, no data concerning phytoplankton was found for the LLRB.

1.5. Diatoms

A study in 2016-2017 was conducted to reveal 39 diatoms species (Annex 8: Diatom species in Qasmiye River and estua) in the Qasmiyeh River in two stations: Station 1 in the river's estuary and Station 2 in the river[44] (Figure 7).

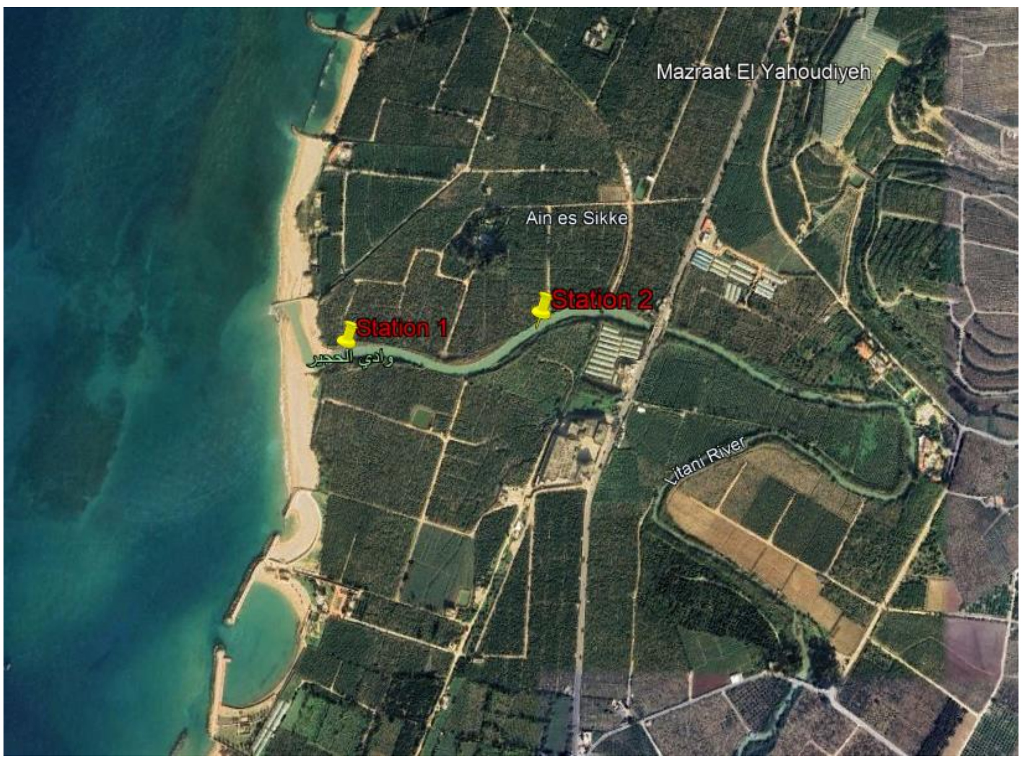

Figure 7: Diatom sampling stations (Source: Google Earth)

[42] Baydoun, Safaa & Ismail, Hanadi & Amacha, Nabil & Apostolides, Nelly & Kamar, Mahmoud & Abou-Hamdan, Hussein. (2016). Distribution Pattern of Aquatic Macrophytic Community and Water Quality Indicators in Upper and Lower Litani River Basins, Lebanon. DOI: 10.9734/JALSI/2016/25840 http://dx.doi.org/10.9734/JALSI/2016/25840

[43] Yazbek, Hamza & Fadel, Ali & Slim, Kamal. (2019). Facts about the Degradation of Lake Qaraoun, Lebanon, and Cyanobacterial Harmful Algal Blooms (HABS). Journal of Environmental Hydrology.

[44] Slim, K. Biodiversité des 3 stations du littoral libanais en se référant aux diatomées indicatrices de la qualité des eaux. (2017).

1.6. Fish species

Seven freshwater fish species are found in the Litani River (Annex 9: LRB Species IUCN Status). *Pseudophoxinus libani (*Figure 8*)*, the sole endemic freshwater fish found in Lebanon, was declared extinct in 1996[45]. However, subsequent observations have confirmed its presence in Yammouneh Lake, Litani River, and Qaraoun Lake, raising hopes that it may also exist in other locations. Unfortunately, the areas where it has reappeared face significant anthropogenic threats. Yammouneh Lake has undergone development, while the Litani River and Qaraoun Lake suffer from severe pollution as previously mentioned. It is widely acknowledged that overfishing has contributed to the eradication of certain fish species from specific rivers. A field survey in 2021 done by the LRA and Society for the Protection of Nature in Lebanon (SPNL), after a mass mortality of fish in the Quaraoun Lake, identified five fish species, one of them being the Vulnerable Mirror Carp (*Cyprinus carpio*) [46] as assessed by The International Union for Conservation of Nature (IUCN) Red List (Annex 9: LRB Species IUCN Status). Additional species include the Lebanese Loach (*Oxynoemacheilus leontinae*), which is limited to the Litani and northern Jordan drainages.

Figure 8: Pseudophoxinus libani (Source : Bariche et al, 2016)

1.7. Molluscs

A survey in 2006 identified multiple freshwater molluscs in the ULRB as well as the Qaraoun lake. Eight other species were found in Ammiq, one of them being the Vulnerable *Gyraulus bekaensis* (Figure 9) in addition to the endangered mussel *Potomida littoralis*, which is rapidly declining throughout its fragmented range. Other land gastropods of urban habitats and land gastropods of open and half-shaded rocky habitats were identified in this study (Annex 10: List of molluscs found in Lebanon in 2006). Five years later a survey conducted in Abou Ali, Orontes and Litani Rivers (Figure 1) confirmed the presence of five *Pseudobithynia* species[47] where one is Critically Endangered *(P. kathrinae)* and one is Endangered *(P. levantica)* (Figure 9, Annex 9: LRB Species IUCN Status). All these species are susceptible to be found in the Litani estuary where the river converges with the sea.

---

[45] M. Doumani, F. (2013). Background Paper and Selected Annotated Bibliography On Hill Lake Ecosystem Services and Climate Change in Lebanon. World Bank Sustainable Agricultural Livelihoods in Marginal Areas (Salma) Project.

[46] https://www.spnl.org/a-probable-disease-epidemic-in-mirror-carp-fish-of-litani-river/

[47] Ulrich Bößneck (2011) New records of freshwater and land molluscs from Lebanon, Zoology in the Middle East, 54:1, 35-52, DOI: 10.1080/09397140.2011.10648879 https://doi.org/10.1080/09397140.2011.10648879

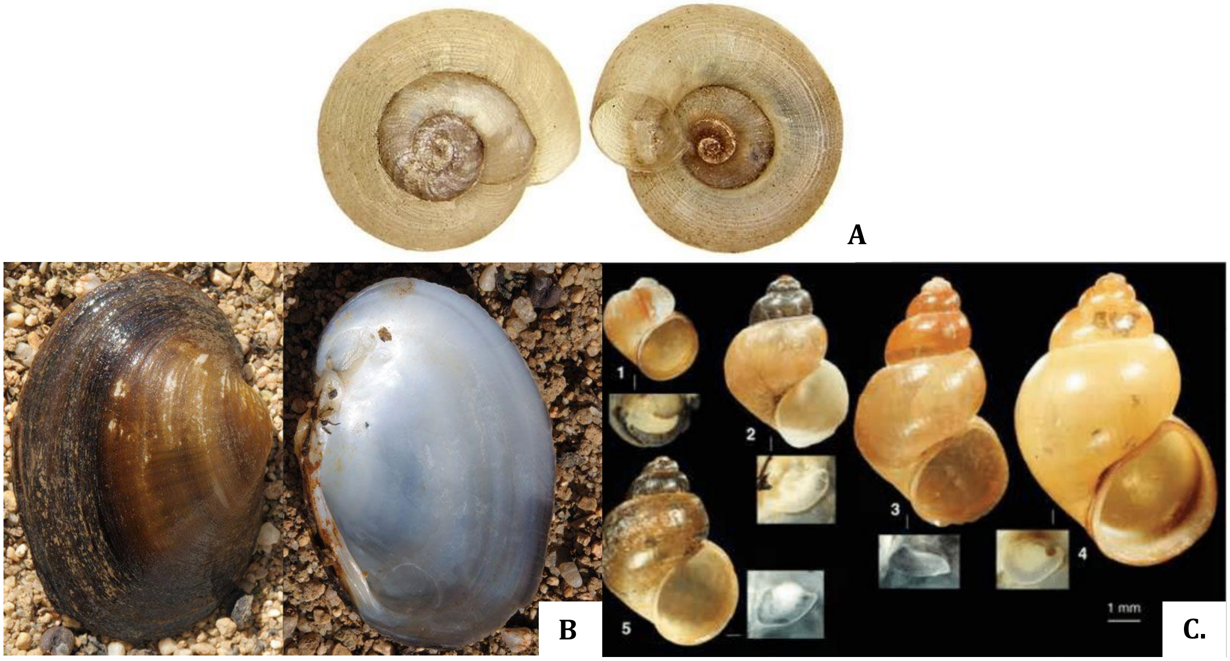

Figure 9: A) Gyraulus bekaensis ; B) Potomida littoralis ; and C) 1: Pseudobithynia badiella, 2: P. saulcyi, 3: P. kathrin, 4: P. hamicensis, 5: P. levantica

2. Awaly River Estuary

Awaly River Basin (ARB) is located in Southern Lebanon covering an area of 301 Km^2. The Awaly River is a perennial coastal river, 48 km long, originating from the Barouk Mountain at an altitude of 1,492 m and the Niha Mountain[48]. Two tributaries, the Barouk River and Aaray River, contribute to the Awaly River's water supply. The convergence of these two tributaries takes place at Bisri, where their flows merge to form a single stream known as the Awaly River and locally as the Bisri River. From there, the Awaly River flows westward until it discharges in the Mediterranean Sea,

[48] J. Al Sayaha, M., Abdallaha, C., Khourib, M., Nedjaic, R., Darwich, T. (2019). Application of the LDN concept for quantification of the impact of land use and land cover changes on Mediterranean watersheds - Al Awaly basin - Lebanon as a case study. https://doi.org/10.1016/j.catena.2019.01.023

north of the city of Saida (33°35'18.90"; 35°23'8.58")[22] (Figure 10). Nahr El Awaly Valley is considered one of the 26 Key Biodiversity Areas (KBAs) for plants in Lebanon[9].

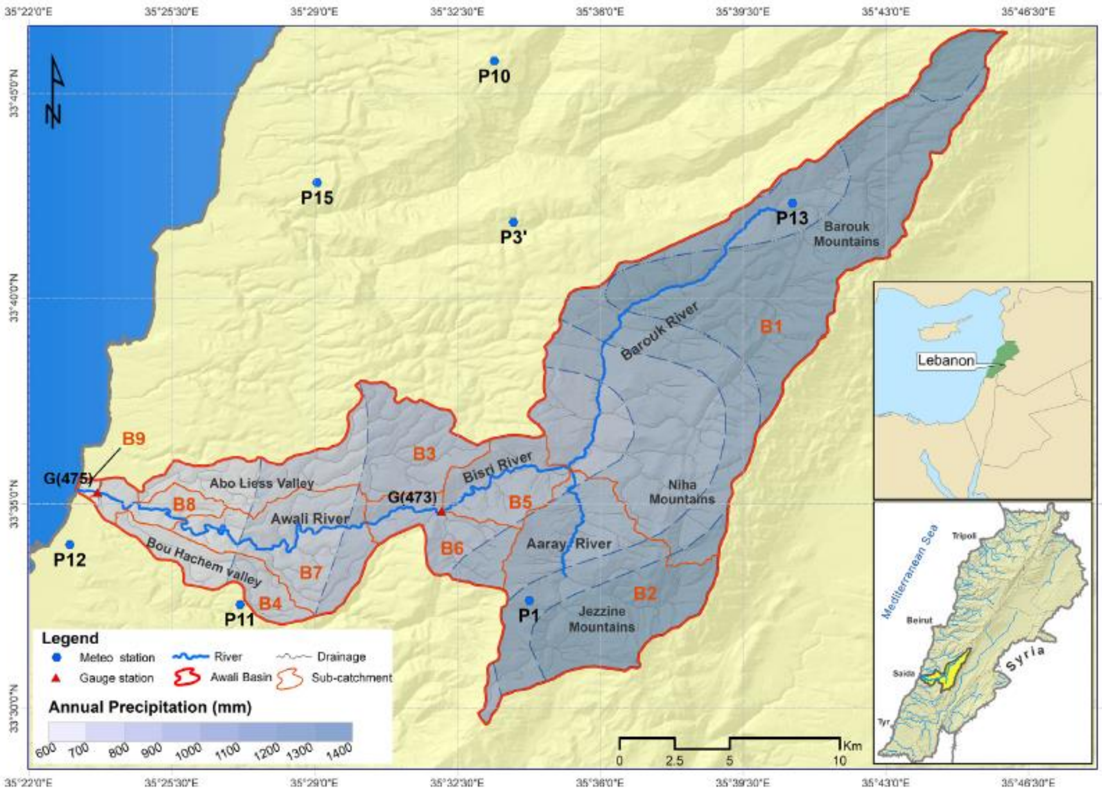

Figure 10: Awaly River Basin. (Source: Hdeib et al., 2018)

The catchment exhibits diverse topography, with varying elevations throughout. The elevated regions of Mount Lebanon (1950 m above sea level) stretch alongside the coast and experience consistent snowfall during winter. In contrast, the low coastal area consists of flat plains primarily used for agriculture. The catchment is distinguished by its steep slopes that converge towards a valley, where the Awaly River meanders. The average annual rainfall in the basin is approximately 1255 mm, with variations between 600 mm inland and 1300-1400 mm in the mountainous areas. The discharge of the catchment is monitored through two permanent limnigraphic gauge stations operated by the LRA. These stations (Figure 10), namely the Marj Bisri gauge station G(473) and the Saida gauge G(475), provide continuous measurements of surface water levels at hourly intervals (or every 15 minutes). G(473) tracks the upstream flow along the Bisri River, while G(475) monitors the flow approximately 800 m upstream from the catchment's outlet into the Mediterranean Sea. At G(475), the average annual yield for the basin is approximately 347 MCM, with 85% of this occurring during the winter. On average, the daily flow at G(475) is around 11 m^3/s[49].

Many faults pass through the Awaly Basin and play a major role in directing surface and groundwater such as the Roum Fault, which is an active seismogenic fault associated with significant earthquakes in the past. Its extent has been a subject of controversy within the Lebanese Restraining Bend (Figure 11)[33].

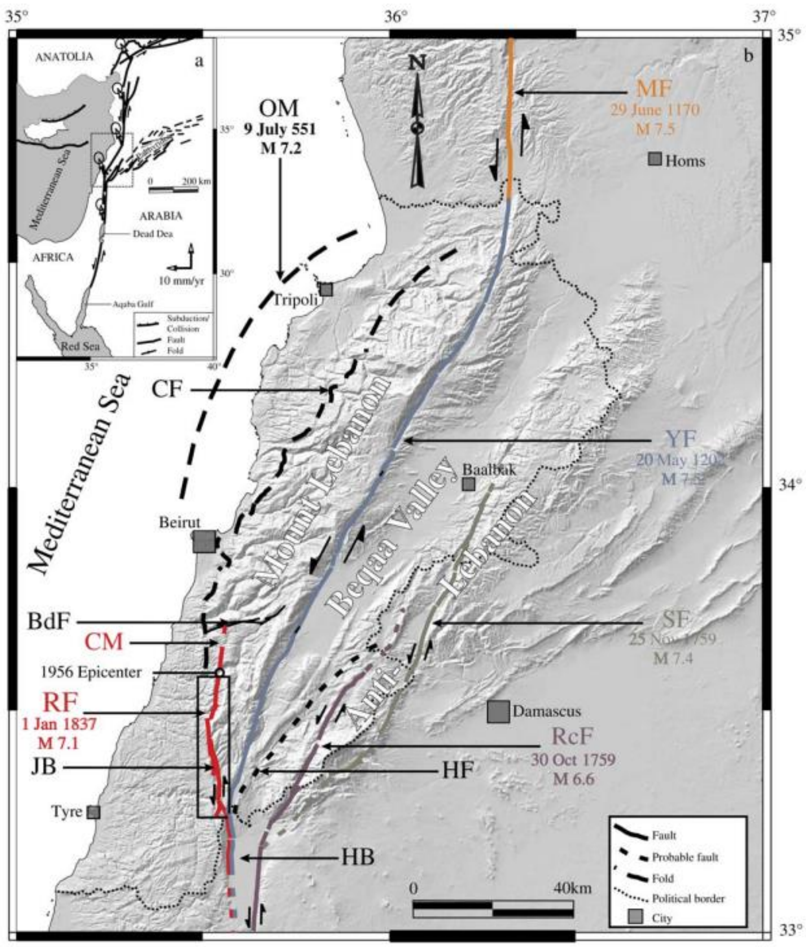

Figure 11: Lebanese Restraining Bend (Top left, Source: Nemer, T. & Meghraoui, M. (2006))

The Environmental and Social Impact Assessment of the Greater Beirut Water Supply Augmentation Project in 2014 recommended the construction of the Bisri Dam in order to provide potable water to the Greater Beirut Area on the medium and long terms. This planned dam is situated in a critical location within the fault's path, specifically the Bisri valley, which experienced a significant earthquake in 1956. It is emphasized that the future reservoir behind the Bisri dam will be situated above an active fault, posing risks of fault movement, liquefaction, mass

[49]Hdeiba, R., Abdallaha, C., François Colin, F., Broccac, L., Moussad, R. (2018). Constraining coupled hydrological-hydraulic flood model by past storm events and post-event measurements in data-sparse regions. https://doi.org/10.1016/j.jhydrol.2018.08.008

movements, and potentially inducing seismicity[50]. Considering the delicate fault system and the potential for a major earthquake, the proposed Bisri dam site is deemed unfavorable and necessitates careful attention and thorough evaluation of reservoir-induced/triggered seismicity[51]. On the Litani/Awaly River Streams, there are three hydropower plants: Markabi, Awaly, and Joun installed in 1961, 1964 and 1967 respectively, all managed by the LRA, with seven units and a total of around 190 MW installed capacity[34].

In the ARB, there are natural and cultural sites (two protected areas and 20 protected historical sites) protected by laws/decrees that can play some role in the management of the area because of their touristic value and cultural importance[52] (Figure 12).

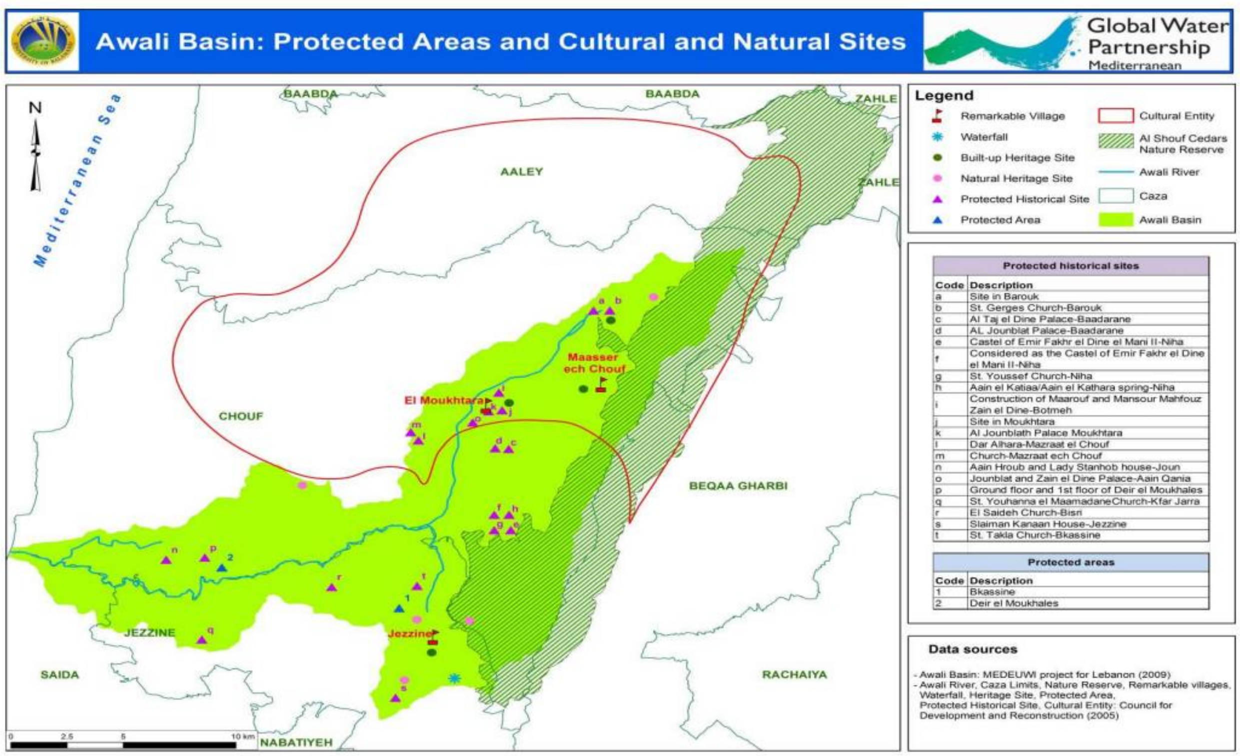

Figure 12: Protected Areas and Cultural and Natural Sites in the ARB (Source: GWP-Towards an Integrated Management of the Water Resources and the Coastal Area of the Awaly River Basin)

Law 131 in 1998[53] states that the MOE holds responsibility for declaring, classifying and/or safeguarding all natural sites along the course of the Awali River and its tributaries, stretching from

[50]Council of Development and Reconstruction. (2014). Environmental and Social Impact Assessment of the Greater Beirut Water Supply Augmentation Project

[51] J. Basbous, T.S. Nemer, A. Yehya, E. Maalouf. (2022). Assessing the potential for reservoir induced seismicity from the Bisri dam project in Lebanon. https://doi.org/10.1016/j.enggeo.2022.106679

[52] Global Water Partnership – Mediterranean (GWP-Med). Towards an Integrated Management of the Water Resources and the Coastal Area of the Awaly River Basin.

[53] http://77.42.251.205/Law.aspx?lawId=200296

the Barouk area through the Bisri Valley to its mouth in the Awali area (Figure 10). Nevertheless, several institutions are related to water management in the ARB:

- CDR
- MoEW
- BMLWE
- MoE
- MoPH
- MoA
- LRA
- The Council for the South
- The Central Fund for the Displaced
- Concerned Municipalities

According to the MPA Strategy 2012[22], seagrass meadows and fisheries are two significant aspects of the Awaly River Estuary. Habitat types include sandy beaches where the river converges with the sea and marine vegetation beds (Figure 13). The dominant feature of the marine area facing the Awaly River estuary is made of soft and sandy bottoms, which is colonized by seagrass meadows, as observed by the

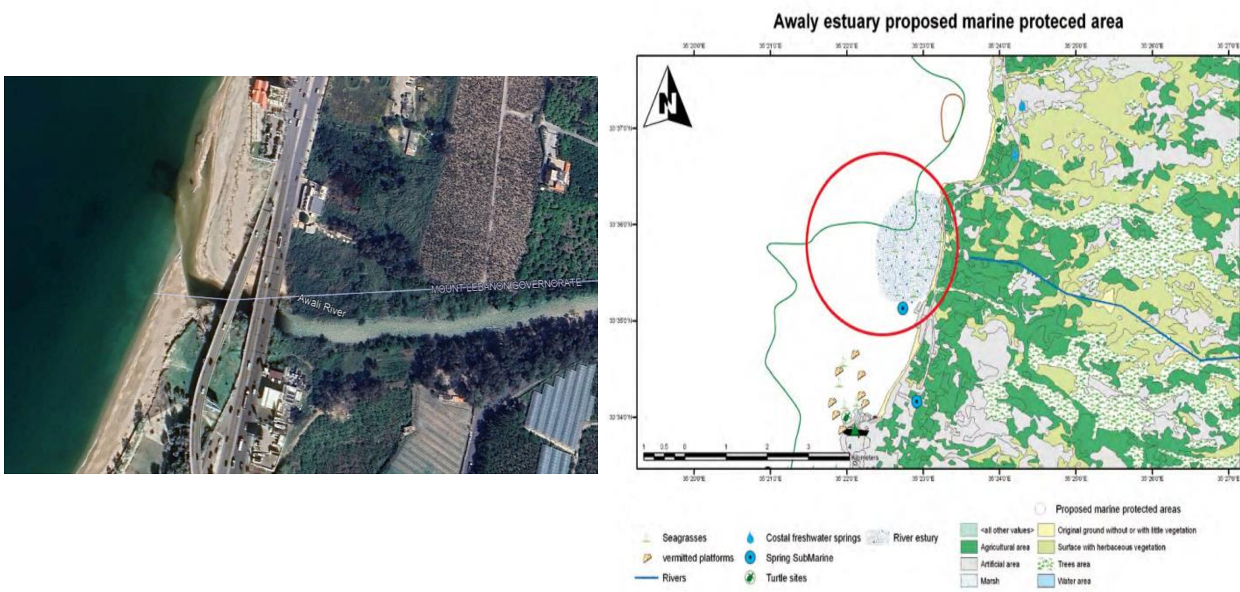

Figure 13: A) Satellite image of Awaly Estuary (Source: Google Earth); B) Proposed Awaly Estuary MPA (Source: Lebanon's MPA Strategy, 2012)

IUCN project team in 2012, while hard bottoms and vermetid platforms characterize the south of the estuary[52]. The freshwater inflow from the Awaly River has a significant impact on this ecosystem, playing a crucial role in the productivity of the surrounding marine habitat. The nutrients carried by the river contribute significantly to the proliferation of phytoplankton, thereby affecting the entire food chain. Nevertheless, no specific studies targeting marine biodiversity were conducted.

2.1. Challenges

The Awaly River is under various threats that can be grouped into four main categories:

- Population growth: The rapid and uncontrolled urban sprawl, elevated pollution levels resulting from traffic and other combustion sources, various human activities, deforestation, soil erosion, and the alarming decline in biodiversity are putting massive pressure on the natural ecosystem of the ARB. The basin, which has a population of 161,000 people experiences significant anthropogenic pressures intensified by the Syrian refugee crisis[9]. Water requirements in the basin are met by direct access to the river and the utilization of municipal wells, artificial wells, and agricultural rainfall collection ponds. The extraction of water from the Awaly River is also necessary to support the operation of the three hydro-electrical power plants.
- Pollution: Severe pollution is observed in specific parts of the ARB due to uncontrolled point and non-point pollution sources, particularly near human settlements and roads. The pollution originates from various combustion processes and the improper disposal of solid waste, including intentional or accidental fires in dump sites. The release of untreated domestic and industrial wastewater, agricultural runoff, and unregulated disposal of solid waste also contribute to environmental, health, and socioeconomic challenges in the region. Inadequate infrastructure and ineffective management of various effluents contribute to the transportation of land-based pollution into waterways, eventually reaching the estuary and coastal waters (Figure 13). Furthermore, sea-based sources of pollution, particularly from shipping activities, pose a significant threat to the Awaly estuary. The proximity of the Saida port, located just a few kilometers south of the estuary, intensifies the pressure on the area due to the presence of nearby marine navigation routes[51]. This leads to the degradation of the quality of brackish waters as well as harm the biodiversity within the estuary.
- Climate change: As the temperature continues to rise, one side effect will be sea level rise causing drastic destruction to river estuaries and coastal wetlands. In addition, the increase in salinity might alter the biodiversity of such ecosystems. Extreme events such as floods and droughts will be more likely to occur, resulting in devastating damage if no plans were put into action. It is also important to mention that due to higher temperatures, evapotranspiration rates will increase, and with the increasing anthropogenic pressures, this will lead to a significant drop of the surface and groundwater in the ARB, consequently affecting the amount of discharge reaching the estuary and therefore the biodiversity and its health in this ecosystem.

In summary, the ARB is subject to several stressors (Annex 11: Additional information on the Awaly River Basin) such as climatic variability, climate change, presence of a fault system, pollution, population growth, planned dams and absence of law enforcement amongst others. These are expected to also affect the estuarine site, since no measures to bring these harmful practices and pressures to a halt are being implemented.

2.2. Water quality

It is significant to remember that the Awaly River is primarily the discharge of power plants that divert water from Qaraaoun Lake. As a result, it is expected that water quality of the Awaly's River is similar to that of the Qaraaoun Lake (Chapter V, Section 1, Sub-Section 1.2.). Water quality assessments were carried out irregularly and show biological, physical and chemical properties of the river but not the estuarine area (Annex 11: Additional information on the Awaly River Basin When it comes to temperature, Awaly water is considered cool (average of 21.68 °C)[54].

2.3. Freshwater species

There were four freshwater fish species identified in the vicinity of the planned location for the Bisri dam (Annex 12: Awaly Species IUCN Status), amongst them the Critically Endangered common eel (*Anguilla anguilla*) (Figure 14) and the endemic Levantine minnow (*P. libani*) (Figure 8), as well as the vulnerable freshwater crab (*Potamon bileki*) [52]. Two small populations of *Salariopsis fluviatilis* (Figure 14) seem to be confined in the lower parts of Nahr Awaly and Nahr Damour, living only in the last few hundred meters of freshwater close to the estuary (Annex 12: Awaly Species IUCN Status. The Awaly River does not harbor any exotic fish or macro invertebrates, likely due to human disturbances affecting the flow and quality of the river water, such as pollution. Additionally, freshwater fisheries in Lebanese rivers do not hold significant commercial value, and therefore do not pose a threat to freshwater species. However, certain recreational fishermen employ destructive methods, such as dynamite, poison, or electricity, which jeopardize the existence of various species. Conversely, artisanal fisheries are practiced in the marine area adjacent to the Awaly River, primarily due to the presence of the Saida port, a major fishing port along the Lebanese coastline. Fishing boats used in this area are generally smaller than 12 m, and the common fishing gears include entangling nets, longlines, and pots. Some fishermen also employ industrial gears like purse seines and lampara, which have the capacity to catch significant amounts of fish.

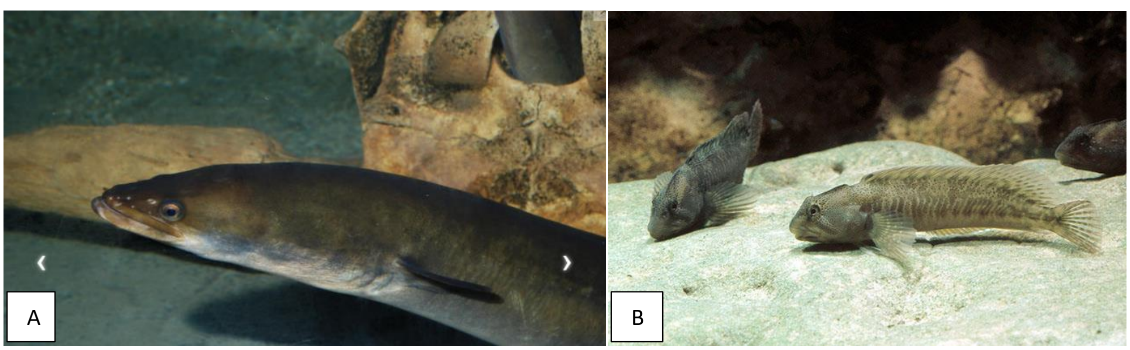

Figure 14: Anguilla anguilla (Source: IUCN Red List) ; B) Salariopsis fluviatilis (Source: FishBase)

2.4. Amphibians and reptiles

Various species of reptiles were found in the Bisri basin (eight species in total)[52], with a Least Concerned status according to the IUCN Red List (Annex 12: Awaly Species IUCN Status). There is potential that these species are found in the estuarine area, in the brackish water.

[54] Houri, A., W. El Jeblawi, S. (2007). Water quality assessment of Lebanese coastal rivers during dry season and pollution load into the Mediterranean Sea. doi: 10.2166/wh.2007.047

2.5. Mammals

The swift field survey conducted at the Bisri Dam site identified the existence of 21 mammal species, amongst them only one expected to be found in the estuarine area: the Near Threatened common otter (*Lutra lutra)*[52] (Figure 15) (Annex 12: Awaly Species IUCN Status.

Figure 15: Lutra lutra (Source: VCG)

3. Damour River Estuary

The Damour River, located 20 km south of Beirut, is a perennial river that spans 40 km in length and drains in the Damour village (33º42'20.82"; 35º26'23.15")[22] (Figure 16).

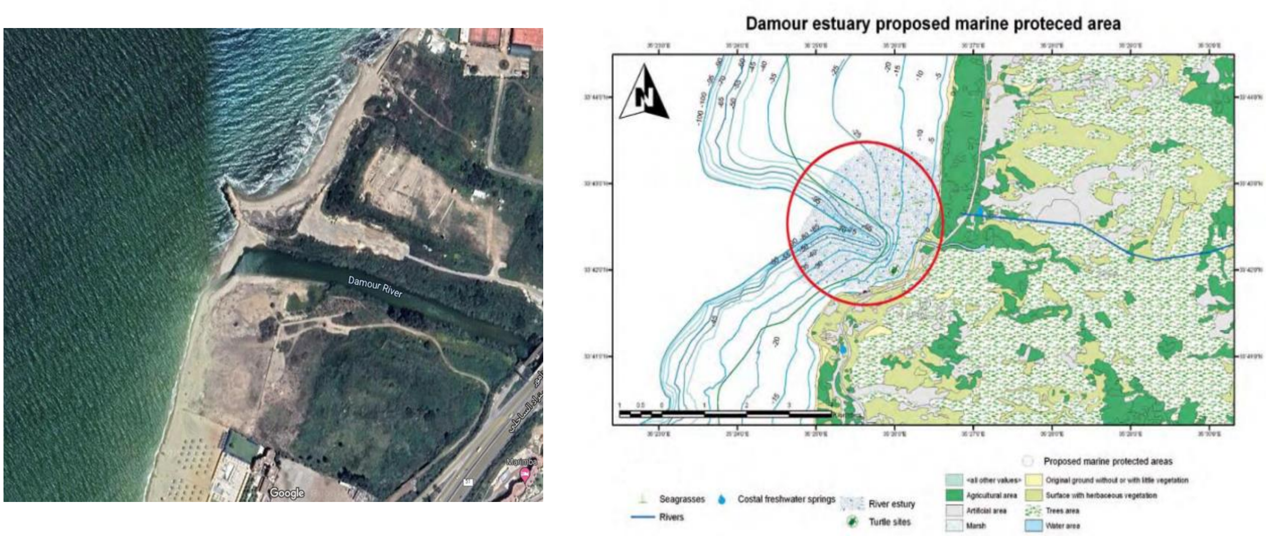

Figure 16: A) Satellite image of Damour Estuary (Source: Google Earth); B) Damour estuary proposed MPA (Source: Lebanon's MPA Strategy, 2012)

The Damour River Basin (DRB) covers an area of 333 km^2 and originates from the highest hill of the Barouk Mountain, which reaches an elevation of 1948 m. Contribution to the river's discharge is two major springs, Es Safa and Barouk, as well as the convergence of three minor rivers: Es Safa, Zeble, and El Hamam. The tributaries of the Damour River have carved deep valleys and canyons, with steep slopes and cliffs along the river sides. The valley depth in many places can exceed 700 m, and the relief is highly pronounced. The average annual discharge of the Damour River, recorded between 1992 and 2001, was approximately 100 million m^3/yr, with an average flow rate of 8.2 m^3/s[55]. On average, the Damour is the warmest river in the country (28.28°C). This might be explained by the warm, slow flowing waters which are exposed to the sun[54]. Groundwater resources primarily exist in the Sannine Aquifer, which is protected from direct contact with the sea by the Chekka formation. In the Saadiyat area, the aquifer is replenished through precipitation infiltration and runoff from the Damour River. The main land use categories in the region consist of arable lands, forests, agricultural areas, settlements, and recreational spaces. Small-scale industrial facilities, such as car repair workshops, food-processing establishments, and various shops, are scattered throughout the area. However, the agricultural landscape dominates the DRB, with bananas and vegetables being the main crops cultivated.

As a result, the Damour River holds socioeconomic significance as it provides irrigation for the agricultural coastal plains. It is also recognized as the 17th out of the 26 KBAs for plants in Lebanon[9]. To facilitate irrigation, two dams have been constructed on the Damour River, one upstream and one downstream. The lower dam diverts around 1,100 m^3/h, while the upper dam diverts about 650 m^3/h[56]. The average annual flow rate of the river is approximately 3.21 m^3/s. Precipitation rates increase with altitude, ranging from around 900 mm/yr at the mouth area to over 1500 mm/yr in the higher parts of the basin along the Barouk Mountain ridge. The entire basin experiences an average precipitation rate of about 1230 mm/yr, as estimated from the pluviometric map of Lebanon[55]. The area relies heavily on groundwater as the primary source of drinking water supply. In the village of Damour alone, there are 64 public and private wells, with 16 public wells (14 belonging to the Beirut Water Authority and two municipal wells) serving domestic water needs. More than 44 private wells are also used for domestic and irrigation purposes. An additional 42 private wells in the Saadiyat Area are also used to meet domestic water demand[56]. According to the MPA Strategy 2012[22], the estuary has a sandy bottom and patches of seagrass meadow, which define the site. Many different species use the estuary as a feeding, spawning, and nursery area. Here, reports of the green turtle (*Chelonia mydas*) (Figure 17) have been made. Habitat types include coastal wetlands (estuaries), sandy beaches and marine vegetation beds.

[55]Khair, K., Kassem, F., Amacha, N. (2016). Factors Affecting the Discharge Rate of the Streams – Case Study; Damour River Basin, Lebanon. DOI: 10.9734/JGEESI/2016/28027

[56]Conseil et Développement s.a.l.- INECO ("Institutional and Economic Instruments for Sustainable Water Management in the Mediterranean Basin"). (2009). Institutional framework and decision-making practices for water management in the Damour River Basin, Lebanon-Towards the development of a strategy for water stress mitigation.

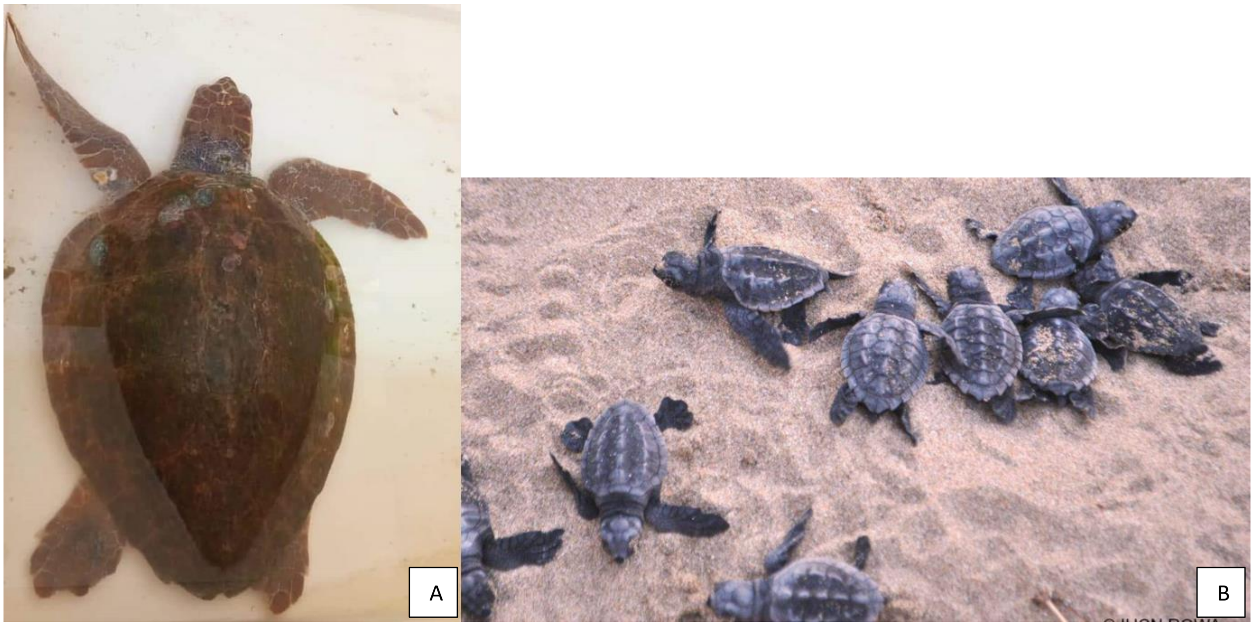

Figure 17: A) Chelonia mydas (Source: Ali Badreddine-Facebook); B) Chelonia mydas hatchlings (Source: Lebanon news)

From a legal point of view, Decision 129 in 1998[57] states that the site of Wadi Damour (starting from the Safa spring with all tributaries passing through Kafr Niss - Salfaya - Ramhala - Wadi Ain Bal - Maaser Beiteddine - Baakline - Deir El Qamar - Beiteddine - Nahr Al-Hamam - the confluence of the two rivers and even its mouth in Damour) is considered one of the natural sites that the MoE can classify and take decisions on its protection (Annex 9). In addition, within the ERML, the Damour river estuary is characterized as an Ecological High Priority Site[31] (Figure 6).

3.1. Challenges

One of the major challenges is the increasing rate of urban sprawl towards the riverbed. There are water shortages downstream, especially in the summer as a result of upstream excessive use of river water. Furthermore, the lack of appropriate legislation for water allocation exacerbates conflicts between the Damour Municipality and upstream users and negatively impacts agricultural activity downstream[54]. Pesticide and fertilizer use are just two of the many agricultural pressures that the Damour River encounters as it runs through the agricultural flatlands. Environmental infractions are common, including the illegal dumping of untreated sewage and effluents from restaurants and other such facilities consequently affecting the estuarine ecosystem. Water quality in the estuary is also impacted by pollution caused by farm waste, used oil from gas stations, and industrial effluent[55]. These pollution problems are aggravated by the estuary's restricted ability to dilute contaminants during dry seasons. According to available literature, the estuary catchment area does not yet have any wastewater treatment plant, and many settlements do not have sewage networks. However, because of more dilution and stronger flows during the wet season, the assimilative capacity of the estuary is enhanced and overall water quality increased. The absence of law enforcement is often cited by local officials as the main barrier to managing the estuarine basin and resolving persistent

[57] http://77.42.251.205/Law.aspx?lawId=199737

infractions. Additionally, local governments lack the manpower and funding required to introduce essential actions and interventions for the protection and management of the estuary. In addition, the principal aquifers in the country are affected or threatened by overexploitation of groundwater where seawater intrusion from the Mediterranean Sea is greatly impacting the Damour aquifer. Also, the over-drafting of groundwater on the coast for irrigation is mainly located in the Akkar and Damour Agricultural Plains. Finally, it is important to mention that the Damour coastal waters are affected by harmful fishing practices, sand extraction and the narrowing of the sandy beaches that pose threats to coastal infrastructure from storm surges and coastal flooding[58].

In summary, the Damour River is subject to several stressors such as climatic variability, climate change, pollution, population growth, seawater intrusion, non/barely functional waste water treatment plants and absence of law enforcement amongst others. These are expected to also affect the estuarine site, since no measures to bring these harmful practices and pressures to a halt are being implemented.

3.2. Physio-chemical analysis

The rapid biodiversity assessment conducted between June 2021 and May 2022[59], also undertook a physio-chemical analysis. However, it only included the Damour River and not its estuary (Annex 13: Additional information on the Damour Estuary).

3.3. Biodiversity

As mentioned previously in the Awaly River, one small population of the freshwater blenny, *S. fluviatilis* (Figure 14) seem to be confined in the lower parts of Awaly and another in Damour River, living only in the last few hundred meters of freshwater close to the estuary. The Riparian Forest Quality Index (QBR; commonly utilized to evaluate the quality of riparian habitats and the overall health of the river) of different locations along the river varied from mildly disturbed with good quality to extremely degraded with bad quality. A rapid biodiversity assessment was carried out during a field visit (June 2021-May 2022)[59], resulting in the identification of 110 flora species, along with several unidentified species. Among the 110 identified species, two are listed under the IUCN Red List of threatened species (Figure 18).

[58]Nader, M., Jazi, M., Abou Dagher, M., Indary, S. (2012). UNEP – ERML: Improved Understanding, Management and Monitoring in the Coastal Zone.
[59] Small Grants-Critical Ecosystem Partnership Fund-Difaf. (2022). Develop an Integrated Management Plan for Damour River Basin – Lebanon, Final completion and impact report.

Figure 18: A) *Arum hygrophilum* (Near Threatened) (Source: worldoffloweringplants.com); *B) Platanus orientalis* (Vulnerable) (Source: it.yougardener.com)

In terms of endemism, six flora species were found to be endemic to Lebanon (*Papaver umbonatum*, *Allium zebdanense*, *P. subpiriforme*, *Trifolium plebeium, Erysimum gonyocaulon* and *Euphorbia berythea*). Advanced studies utilizing environmental DNA (eDNA) revealed the detection of 27 vertebrate taxa, with 44.4% (12 taxa) having at least 99% similarity to species in global reference databases. The identified vertebrates included four unique fish species, six amphibians, one reptile, 13 bird species, and three mammals one of them is the Near Threatened common otter (*L. lutra)* (Figure 15). These taxa belonged to nine orders, 19 families, and 21 genera. Notable species included the Critically Endangered European eel (*A. anguilla*) (Figure 14) and the Vulnerable Mediterranean spur-thighed tortoise (*Testudo graeca*). Among the commonly detected species were the marsh frog (*Pelophylax ridibundus*) and the Mesopotamian barb (*C. damascina*) (Figure 19), both of which are endemic to Lebanon (Annex 14: Damour Species IUCN Status). Additionally, a total of 332 macroinvertebrate taxa were detected, with 3.9% (13 taxa) showing at least 99% similarity to species in global reference databases. Regarding micro and macrophytes, the Damour River exhibits a high diversity of benthic diatom taxa, with 48 taxa being the most common group among microalgae. Furthermore, physical and chemical analyses indicated oligotrophic conditions across all locations and a high ecological status. Certain areas experience a decrease or absence of specific species (such as the European Eel, barb fish, and frogs) due to the release of wastewater from industries, restaurants, and slaughterhouses. It suggests that the discharge of wastewater upstream may have a greater impact on the fauna in nearby areas compared to downstream locations where water quality improves, leading to a higher abundance of these species[59 **Error! Bookmark not defined.**].

Figure 19: Capotea damascina (Source: https://biotopfish.com/species/capoeta-damascina-mesopotamskaya-hramulya)

3.4. Diatoms

A study in 2016-2017 was conducted to reveal 36 diatoms species (Annex 15: Diatom species in the two stations on the Damour River) in the Damour River in two stations: Station 1 Moulta' el Nahrain (confluence of the two rivers) (Conductivity= 560 microS/cm, T° =16°C, O_2 =8.70 mg/l and pH= 8.7), and Station 2 next to the estuary (Conductivity =1860 micro S/m, T°= 24°C, O_2 = 7.8 mg/l and pH = 8)[44]. Results concerning water quality indicated low pollution in stations one and two.

4. Nahr Ibrahim Estuary

The Nahr Ibrahim River valley is located in the western-central region of Lebanon. It stretches from an altitude of 2700 m in Mount Lebanon with a catchment area of 326 km^2. The river flows westward for 30 km until it reaches the Mediterranean Sea, 25 km north of Beirut (34°03'49.95"; 35°38'33.67")[22] (Figure 20). According to the MPA Strategy 2012[22], the estuary has a sandy bottom and patches of seagrass meadow, which define the site. Many different species use the estuary as a feeding, spawning, and nursery area. In addition, the green turtle (*C. mydas*) (Figure 17) has been reported in this coastal area. Habitat types include coastal wetlands (estuaries), sandy beaches and marine vegetation beds.

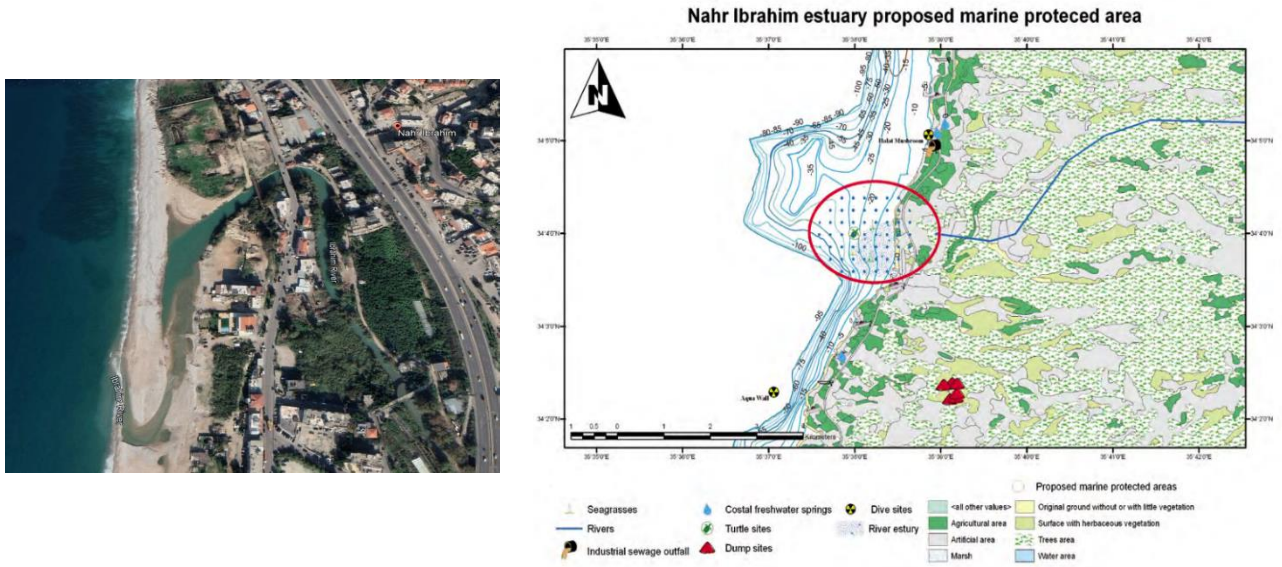

Figure 20: A) Satellite image of Nahr Ibrahim Estuary (Source: Google Earth); B) Nahr Ibrahim estuary proposed MPA (Source: Lebanon's MPA Strategy, 2012)

Furthermore, the basin is fed by two main sources, Afqa and Roueiss, situated at altitudes of 1200 and 1300 m, respectively[60] (Figure 21).

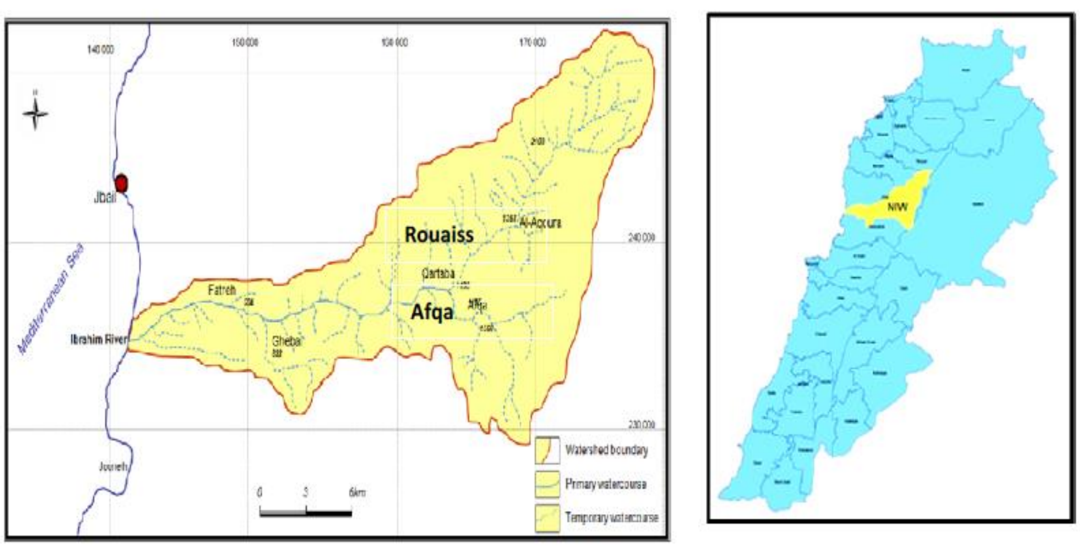

Figure 21: Nahr Ibrahim watershed (Source: Darwish, T. et al, 2015)

[60] Hanna, N., Lartiges, B., Kazpard, V. *et al.* Hydrogeochemical Processes in a Small Eastern Mediterranean Karst Watershed (Nahr Ibrahim, Lebanon). *Aquat Geochem* **24**, 325–344 (2018). https://doi.org/10.1007/s10498-018-9346-x

These sources have average annual discharge rates of 2.8 and 1.7 m^3/s respectively. Additionally, numerous smaller tributaries and springs contribute to the flow of the Ibrahim River, with references made to around 30 smaller springs bringing the average annual flow to 500 million m^3. In the mountainous areas of the basin, precipitation mostly occurs as snowfall between November and March, lasting until late summer. The snowmelt plays a crucial role in the river's flow, accounting for 30-80% (with an average of 58%) of the total yearly discharge[61]. The river basin encompasses 64 villages, ranging in elevation from 50 m in Halat to 2200 m in the upper reaches. The population density in the Nahr Ibrahim watershed is approximately 1700 inhabitants per km^2. Three dams exist along its watercourse feeding three small hydroelectric plants, namely Chouane, Yahchouch, and Fitri that were established in 1961, 1955, and 1951, respectively. As of 2018, these plants have an installed capacity of 32 MW and an effective capacity of 17 MW[61,63].

It is important to highlight that the path of Nahr Ibrahim holds significant historical value, stretching from Jbeil fortress to Afqa cave, which was once a site for religious rituals. It also possesses biological and ecological importance, characterized by its valleys, mountain peaks, and river channels. However, despite its remarkable attributes, Nahr Ibrahim is not officially designated as a World Heritage site. Additionally, it lacks the status of a Protected Area according to Lebanese law despite long-standing recommendations for its protection.

4.1. Challenges

Unfortunately, rapid urbanization, growing agribusiness and industrialization, recent forest fires, soil erosion, flooding, and heightened risks of mass movement and rockfalls are all contributing to the degradation of the estuarine ecosystem in this area[62]. The impact of human activity on this river basin is most evident in the modification of river channels, growth of urban areas and the encroachment of road networks upon its 5% forested areas. The estuary area itself is highly industrialized. Sewage and industrial runoffs originate from food establishments, repair workshops, woodworking facilities, and marble factories, among other factories that produce plastic, paint, galvanize, electroplate, and ferrous materials. Because of the torrential and strong character of precipitation, bare soils are exposed to the full influence of climatic conditions, making this area extremely prone to landslides and soil erosion[63,64].

In summary, the Ibrahim River is subject to several stressors such as climatic variability, climate change, flooding risk, pollution, population growth, landslides and soil erosion, modification of river channels and absence of law enforcement amongst others. These are expected to also affect the estuarine site, since no measures to bring these harmful practices and pressures to a halt are being implemented.

---

[61] T. Darwish, A. Shaban, I. Portoghese, M. Vurro, R. Khadra, et al. Inducing Water Productivity from Snow Cover for Sustainable Water Management in Ibrahim River Basin, Lebanon. British Journal of Applied Science & Technology, 2015, 519, 10.9734/BJAST/2015/13777.hal-01218753

[62] Abdallah, C., Faour, G. Landslide hazard mapping of Ibrahim River Basin, Lebanon. Nat Hazards 85, 237–266 (2017). https://doi.org/10.1007/s11069-016-2560-1

[63] Ghsoub, M., Fakhri, M., Courp, T., Khalaf, G., Buscail, R., Ludwig, W. (2020). River signature over coastal area (Eastern Mediterranean): Grain size and geochemical analyses of sediments. https://doi.org/10.1016/j.rsma.2020.101169

[64] Najjar, P.E., Chidiac, S., Probst, JL. et al. Geochemical signature of the bed sediments at the outlet of the Ibrahim River (Lebanon): temporal variation. Environ Monit Assess 195, 509 (2023). https://doi.org/10.1007/s10661-023-11103-1

4.2. Water quality

A study in 2020 in the marine ecosystem directly facing the Ibrahim River mouth revealed two depositional environments linked to two distinct sources of organic matter, respectively, characterizing the examined area. The sediments in the high energy nearshore shallow marine area (≤30 m) are primarily composed of fine sand and have low levels of Total Nitrogen (TN) and Organic Carbon (OC). The majority of the organic matter at these sampling locations is fresh and comes from a marine autochthonous source. Sediments with high OC and TN values, predominantly composed of fine fractions interpreted as fluvial deposits carried by the Ibrahim River flow, are found in the deep, windless, low energy marine environment (≥60 m). Furthermore, the benthic environment is revealed to be meso-oligotrophic to oligotrophic. Seasonal variations of granulometric, geochemical and biochemical parameters were also recorded[63].

Another follow up study in 2021 was conducted and the results showed that two sets of sample stations could be distinguished: (1) nearshore shallow stations with low OC concentration in sediments and more diversified populations of marine organisms, and (2) deep stations with high OC levels and a fine proportion of grain size where polychaetes predominated. The fine fraction and Organic Matter (OM) concentration at the deep stations were likewise connected to the Pb and Cu content of the sediment. However, every station under investigation was determined to be either completely uncontaminated or only marginally contaminated by trace elements. It also demonstrated that the macroinvertebrate population was mostly impacted by sediment grain size and OM content, both of which reflect the hydrodynamic regime, since biological effects of trace elements on biota were uncommon. The ratio of amphipods and the ecological status of the studied stations was considered good and unaffected by seasonal variation[65]. Other sporadic studies were conducted, however none targeted the estuarine ecosystem (Annex 16: Additional information on the Ibrahim River Estuary.

4.3. Diatoms

A study in 2016-2017 was conducted to identify diatoms species in the Ibrahim River in two stations: Station 1 facing a hydroelectric plant (Conductivity= 376 microS/cm, T° =18°C, O_2 =9 mg/l and pH= 9), and Station 2 next to the estuary (Conductivity =478 micro S/m, T°= 19.5°C, O_2 = 8.8 mg/l and pH = 8.7). A totalof 31 species were identified spread over 13 Families (Annex 17: Diatom species in the two stations on the Ibrahim River). Results concerning water quality indicated low pollution in station one, and medium pollution in station 2.

4.4. Biodiversity

In the Ibrahim River Estuary, there are only assessments concerning the flora in the basin (Annex 16: Additional information on the Ibrahim River Estuary). However, fauna assessments could not be found.

[65] Ghsoub, M., Fakhri, M., Courp, T., Lteif, M., Khalaf, G., Ludwig, W. (2021). Combining chemical and biological parameters to assess the ecological quality of a coastal ecosystem in the Levantine Basin. https://doi.org/10.1071/MF21222

5. El Kabir-Areeda River Estuary

The Nahr al-Kabir, referred to as al-Nahr al-Kabir al-Janoubi in Syria and simply as the Kabir in Lebanon, is a transboundary river that flows through both countries and empties into the Mediterranean Sea at Arida (34⁰ 37’59.70”; 35⁰ 58’34.20”)[22] (Figure 22).

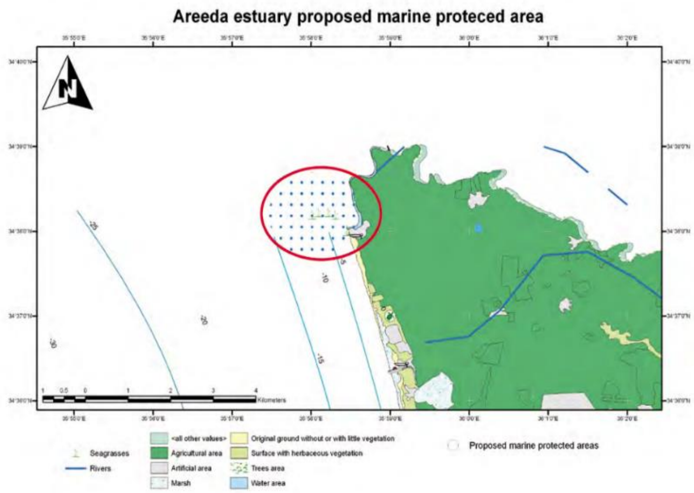

Figure 22: A) Satellite image of Areeda Estuary (Source: Google Earth); B) Areeda estuary proposed MPA (Source: Lebanon's MPA Strategy, 2012)

It forms the international border between the Akkar region in Lebanon and the Syrian governorate of Tartous for a significant portion of its course. The river spans a length of 77.8 km and covers a watershed area of 954 km2, with 26% located in Lebanon and 74% in Syria[66]). Numerous tributaries contribute to the Nahr el Kabir's flow on both sides of its course. In Syria, these include the Wadi al Atchane, the Nassiriya (formed by the confluence of the Raweel and the Mzeineh), and the Arous. On the Lebanese side, the main tributaries are the Wadi Khaled, Es-Safa, and Chadra. The highest point within the catchment is the Lebanese mountain Qarnat Araba, reaching an altitude of 2,215 m. The basin can be divided into four geomorphological zones: the mountain region in the upper catchment shared between Lebanon and Syria, the cross-border Bqaiaa Plain within the mountains, the central plateau/gorge area along the border, and the cross-border Akkar/Hamidiye Plain along the coast. The estimated population within the basin is approximately 530,000 residing in settlements ranging from 200 to 5,500 inhabitants. These communities consist of a mix of urban and rural areas with around 19% of the basin population in Lebanon and about 81% in Syria. The river experiences a distinct flow regime, characterized by a high-flow season from November to May and a low-flow season from June to October, with minimum flow typically occurring in August or September. While the river's flow regime is not entirely natural, as flow regulation is limited on the main stem and in the runoff generation area (with only three smaller dams operational), it largely maintains its natural seasonal characteristics. Increased discharge during the high-flow period is primarily due to rainfall during the Mediterranean winter season and snow-melt from the mountains

[66]UN-ESCWA and BGR (United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe). 2013. Inventory of Shared Water Resources in Western Asia. Beirut.

in spring. During the dry summer months, the river's flow is solely sustained by groundwater discharge, as demonstrated by the groundwater flow regime of the Ain Es-Safa Spring. Peak spring discharge, caused by maximum groundwater recharge rates, occurs in March, while peak river discharge from surface runoff occurs in February. The Nahr el Kabir's annual flow volume has been measured since 1955. The mean annual flow volume at the outlet monitoring station near Hekr al Dahri is estimated at approximately 377 MCM (1969-2011), while upstream at the Arida monitoring station in the Bqaiaa Plain, it is 180 MCM (1955-2011) (Figure 23). According to the Syrian-Lebanese agreement (Annex 18: Additional information on the Areeda River Estuary, the mean annual flow volume at Noura al Tahta, where a dam is planned, is estimated to be 150 MCM. Mean annual precipitation in the entire basin ranges from 600 to 1,000 mm, with an estimated loss of 40%-50% to evapotranspiration and 30% contributing to river runoff[67]. However, observed data indicates a complex spatial pattern of precipitation throughout the basin, likely influenced by the intricate micro-climate induced by the Homs Gap. Groundwater plays a significant role in contributing to the river runoff of the Nahr el Kabir. Approximately 70 perennial springs ensure a continuous flow within the river's main channel, even during the dry summer months.

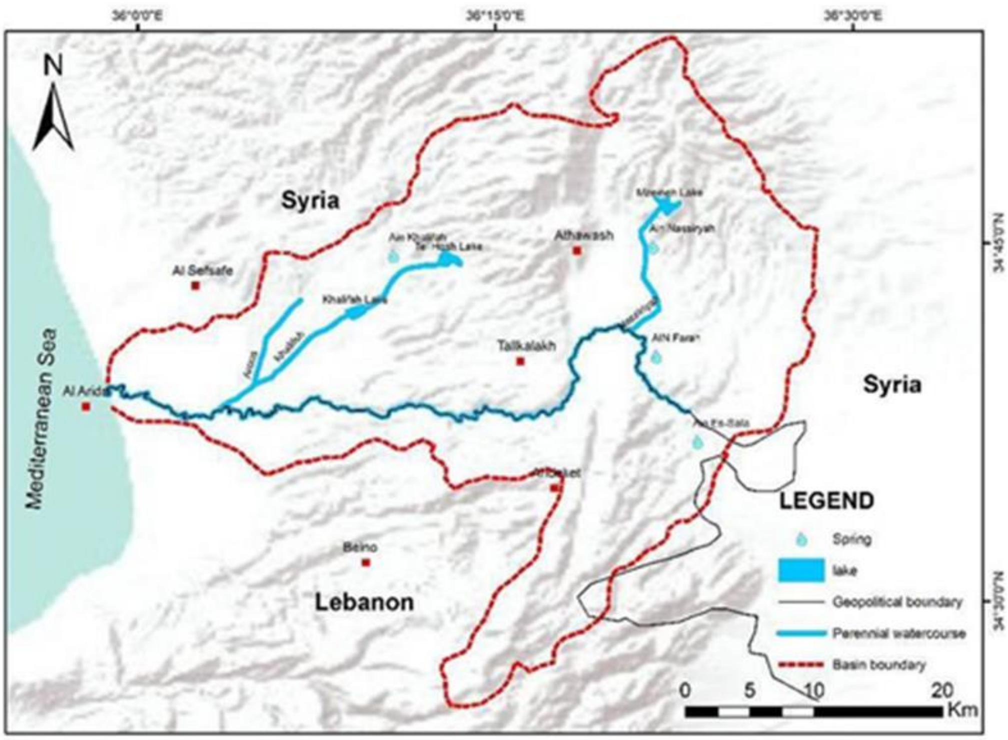

Figure 23: El Kabir watershed (Source: Shaban,A. 2017)

According to the MPA Strategy 2012[22], the estuary has a sandy bottom and patches of seagrass meadow, which define the site. Many different species use the estuary as a feeding, spawning, and nursery area. Here, reports of the green turtle (*C. mydas*) (Figure 17) have been made. Habitat types include coastal wetlands (estuaries), sandy beaches and marine vegetation beds.

5.1. Challenges

The river basin's threats have resulted in environmental deterioration which pose a serious risk to human health. The river is severely contaminated as a result of improper agricultural practices, random solid waste management, and the uncontrolled release of untreated sewage. There has been a discernible decrease in the overall river discharge due to climate change and increased water extraction brought on by population growth and altered land use. Other challenges include the growth of the water hyacinth (*Eichhornia crassipes*) along the river's course in addition to recurrent floods[67]. The estuary is directly impacted by these problems in the river basin. The region's fragility is highlighted by the regular floods which have traditionally cost farmers their livelihoods and caused devastation along the Nahr al Kabir on both sides of the border. The seriousness of the problem is highlighted by previous flood occurrences, such as the 2003 flooding that destroyed houses, damaged towns, and resulted in losses of crops and cattle as well as the 1979 destruction of the iron bridge in the village of Arida. To address these issues, Lebanon built a flood wall in the Bqaiaa Plain that is 2 m high and 4.5 km long, beginning near the Ain Farash Spring. Although Syria has built three dams, with an additional one planned to reduce the risk of flooding, flash floods continue to devastate the Lebanese portion of the basin (Annex 18: Additional information on the Areeda River Estuary, seriously damaging the agricultural sector, especially in the impoverished Akkar region[67]. As a result, the health and resilience of the estuary ecosystem are significantly impacted by the environmental issues in the river basin.

In summary, the Areeda River is subject to several stressors such as climatic variability, climate change, flooding risk, pollution, population growth, growth of invasive organisms and absence of law enforcement amongst others. These are expected to also affect the estuarine site, since no measures to bring these harmful practices and pressures to a halt are being implemented.

5.2. Water quality

Sporadic targeted studies were conducted; however, they are outdated and do not target the estuary but rather the river as a whole (Annex 18: Additional information on the Areeda River Estuary). These studies concluded that the watershed is highly polluted, mainly from sewage, solid waste, agricultural fertilizers, and industrial activities. Coliform bacteria counts exceeded guidelines for various uses and sediment analysis revealed the banned insecticide DDT's continued use, along with elevated levels of Cr and Ni from industries, and traces of oil products.

[67] Shaban, A., Khawlie, M., Abdallah, C., Awad, M. (2005). Hydrological and watershed characteristics of the El-Kabir River, North Lebanon. Lakes & Reservoirs: Research & Management. 10. 93 - 101. 10.1111/j.1440-1770.2005.00262.x.

5.3. Biodiversity

The proliferation of the invasive water hyacinth (*E. crassipes*) (Figure 24), known as "Zahret el Nil" in Arabic, has emerged as an environmental concern[67]. Its presence in the basin was first observed in 2006, causing blockages in the irrigation canals of the Arous River in Syria. Subsequently, it quickly spread throughout the Nahr el Kabir, obstructing waterways along a 13 km stretch of the river. The exact introduction of this non-native aquatic weed into Syria remains unknown. The water hyacinth has a significant impact on the ecosystem. It has a rapid growth rate, doubling its population within two weeks, and can reach a height of one meter above the water surface. This growth pattern blocks sunlight and reduces oxygen levels for aquatic organisms, disrupts the natural flow of the river, and creates a conducive habitat for mosquitoes, which can act as disease carriers in the basin. Both

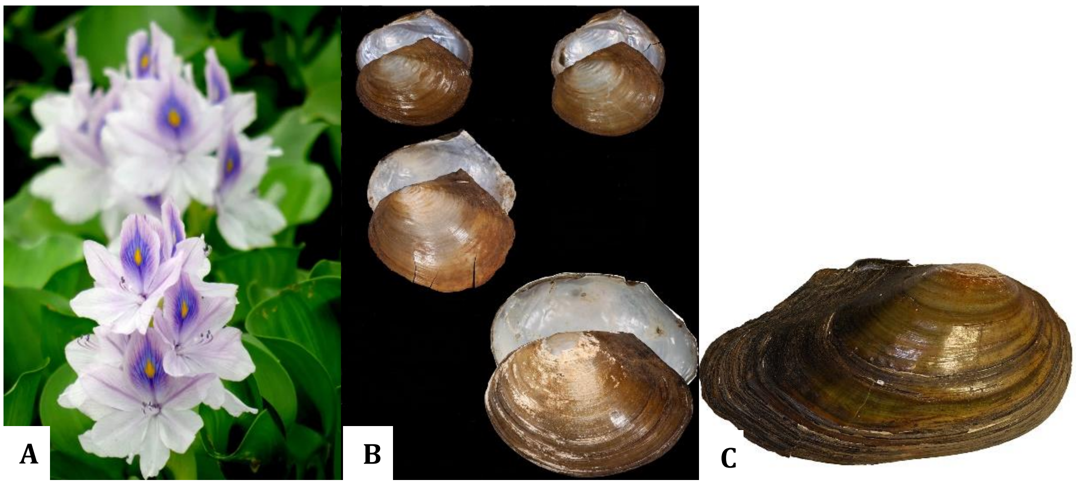

Figure 24: A) Invasive Water Hyacinth (Eichhornia crassipes); B) Mussel (Anodonta anatina); and C) Endemic mussel (Pseudunio homsensis).

riparian countries have been making continuous joint efforts to remove the water hyacinth from the river using excavators in an attempt to control its spread. However, the survival of this invasive plant is favored by the nutrient-rich discharge from agricultural runoff and sewage waste into the Nahr el Kabir, undermining these control efforts. In addition to the water hyacinth issue, it is worth noting that the mussel species *Anodonta anatina* (Figure 24) has been found in the El Kabir River in the Latakia Governorate of Syria. Moreover, the endemic mussel species *Pseudunio homsensis* (Figure 24) has also been identified in this river[68]. These species are susceptible to be found in the estuary.

[68] A. Tomilovaa, A., A. Lyubasa, A., V. Kondakova, A., S. Konoplevaa, E., V. Vikhreva, I., Yu. Gofarova, M., Ozcanc, T., Altunc, A., Ozcanc, G., E. Gürlekd, M., Şereflişanc, H., Kebapçie, U., Froufef, E., Lopes-Limaf, M., N. Bolotova, I. (2020). An endemic freshwater mussel species from the Orontes River basin in Turkey and Syria represents duck mussel's intraspecific lineage: Implications for conservation. https://doi.org/10.1016/j.limno.2020.125811

VI. Main gaps for declaring estuaries as MPAs

All estuaries in Lebanon, including the estuaries proposed in the MPA Strategy 2012[22] for protection suffer the same main gaps that may be summarized as follows (Table 3).

Table 3: Main gaps facing the estuaries proposed in the MPA Strategy 2012

Gaps	Litani	Awaly	Damour	Ibrahim	Areeda
Lack of recent studies and monitoring programs covering the physical, chemical and biological parameters in the estuarine ecosystem in particular	✓	✓	✓	✓	✓
Notable gaps in research and understanding					
Outdated laws concerning the management of the whole watershed	✓	✓	✓	✓	✓
Lack of understanding of the effects of anthropogenic activities on the estuarine ecosystem	✓	✓	✓	✓	✓
Validation of the presence of species in the field	✓	✓	✓	✓	✓
Mapping of habitats	✓	✓	✓	✓	✓
Marine biodiversity is not studied	✓	✓		✓	✓
No fauna assessments				✓	✓

In addition, river basins discharging onto the Lebanese coast, including their estuaries are subject to many anthropogenic threats that lead to degradation of estuarine ecosystems (Table 4).

Table 4: Threats to the estuaries proposed in the MPA Strategy 2012

Threats	Litani	Awaly	Damour	Ibrahim	Areeda
Climatic variability	✓	✓	✓	✓	✓
Climate change	✓	✓	✓	✓	✓
Low infiltration rate	✓				
Flooding risk	✓			✓	✓
Fault system	✓	✓			
Pollution	✓	✓	✓	✓	✓
Population growth (increased water demand)	✓	✓	✓	✓	✓
Dam	✓	✓	✓	✓	
Non/barely functional water treatment plants	✓		✓		

Threats	Litani	Awaly	Damour	Ibrahim	Areeda
Absence of law enforcement	✓	✓	✓	✓	✓
Lack of funding	✓	✓	✓	✓	✓
Seawater intrusion			✓		
Growing agribusiness and industrialization				✓	
Landslides and soil erosion				✓	
Modification of river channels				✓	
Growth of invasive organisms					✓

VII. Main requirements for environmental assessments of estuaries

For all estuaries proposed in the MPA Strategy 2012[22] data is limited and monitoring programs are absent. An environmental assessment of an estuary must include, but is not limited to, the following:

1. Physical Parameters:
    - Salinity: Measuring the salt content of water helps understand salinity regimes in estuaries and the extent of their influence on marine ecosystems.
    - Temperature: Monitoring temperature variations helps evaluate the influence on the life cycle of and ecosystem dynamics.
    - Turbidity: Examining water clarity provides insights into suspended sediment levels, light penetration, and habitat suitability for various organisms.
    - Currents: Understanding water flow patterns and tidal currents aids in determining sediment transport, nutrient distribution, and larval dispersal.
    - River flow regime: Involves monitoring parameters such as discharge (volume of water passing a point per unit of time), water level, and flow velocity. This data helps assess the quantity and timing of freshwater inputs into the estuary.

2. Chemical Parameters:
    - DO: Assessing dissolved oxygen levels indicates the availability of oxygen for aquatic organisms and can reflect the degree of water pollution and/or eutrophication.
    - Nutrient Levels: Measuring concentrations of nitrogen, phosphorus, and other essential nutrients helps evaluate nutrient enrichment, eutrophication events and potential impacts on primary productivity.
    - pH: Monitoring acidity or alkalinity levels provides insights into water chemistry and its influence on aquatic organisms.
    - Heavy metals and pollutants: Analyzing the presence and concentrations of pollutants, such as heavy metals, pesticides, or hydrocarbons, helps assess water quality and potential ecological risks.

3. Biological Parameters:
    - Species Composition: Identifying and documenting the diversity of plants, animals, and microorganisms present in estuaries helps assess overall biodiversity and potential impacts of environmental changes.
    - Species Abundance: Quantifying the population sizes or densities of different species indicates their relative importance and ecological roles within the estuarine ecosystem.
    - Species environmental status: identifying environmental status of species helps guide management and conservation efforts for species at risk
    - Invasive species: Monitoring invasive or alien species and developing mitigation measures for their proliferation.
    - Habitat types.
    - Riparian biodiversity.
    - Nesting and breeding grounds.

These main parameters collectively contribute to a comprehensive understanding of estuaries, their ecological dynamics, and the biodiversity they support thus helping in declaring these sites as protected areas, focusing protection efforts and building effective management plans for their sustainability.

VIII. Main recommendations to declare estuaries in the MPA Strategy 2012 as protected areas

Estuaries require baseline assessments to improve their conservation status through promoting sustainable practices and sustainable management of natural resources, policy development and law enforcement and finally spreading awareness and education. More specifically, extensive assessments at all levels is required to declare the estuaries listed in the MPA Strategy 2012 as protected. This can be achieved through the following steps:

- Develop a methodology to assess the scientific viability for declaring the five estuaries as MPAs.
- Declare the five estuaries as MPAs according to applicable regulations.
- Delineate the area of influence of river flow into marine estuarine waters to be included in the MPA.
- Analyze the institutional and legal frameworks related to the protection, conservation, management and monitoring of estuaries.
- Conduct baseline scientific assessments for all five estuaries (environmental, social and economic) with emphasis on area of influence on coastal waters.
- Review the policy of dam construction to take into consideration the MPA Strategy of 2012.
- Develop and secure resources for the management and protection of the whole watershed of the five estuaries proposed in the MPA Strategy 2012[22] (Application of the Source to Sea management approach[69]).

[69] https://siwi.org/publications/implementing-the-source-to-sea-approach-a-guide-for-practitioners/

- Empower municipalities to adopt policies and enact laws by strengthening their capacity as local administrative authorities.
- Build the capacity of local community groups, including youth and women, to actively participate in conservation efforts along the basins in general and the estuaries in particular.

These recommendations if implemented will contribute to achieving the following:

- Implementation of regulations to prevent or restrict habitat destruction along riverbanks and in riverbeds.
- Prohibiting the discharge of untreated wastewater into the river by improving the capacity and performance of already existing wastewater treatment plants and monitoring their effectiveness.
- Reducing water diversion from the riverbed into channels.
- Reducing pollution from both point and non-point sources.
- Establishing and executing a comprehensive solid waste management plans.
- Adopting the Source to Sea management approach allowing sustainable management of the whole watershed of the river leading to the estuary.
- Encouraging sustainable agricultural practices among farmers and regulate the use of river water for irrigation, and fertilizer and pesticide use.

Funded by the European Union

Annex 1: Some of the major rivers in Lebanon (Source: Updated NWSS 2020)

Name	Length (km)	Average Annual Volume (1990 – 2013) (Mm^3)	Mohafaza	Kaza	Transboundary	Perennial/Seasonal
El Kabir	77.8	432	Akkar	Akkar	Yes	Perennial
Ostuene	44	71	Akkar	Akkar	No	Perennial
Arka	25	49	Akkar	Akkar	No	Seasonal
El Bared	24	127	Akkar	Akkar	No	Perennial
Abou Ali	45	218	North	Bcharre	No	Perennial
El Jaouz	38	57	North	Batroun	No	Perennial
Ibrahim	30	335	Kesrouan	Jbeil	No	Perennial
El Kalb	31	190	Kesrouan	Kesrouan	No	Perennial
Beirut	42	78	Beirut	Beirut	No	Perennial
Damour	38	183	Mount-Lebanon	Chouf	No	Perennial
El Awaly	48	433	South	Saida	No	Perennial
Sainiq	22	11	South	Sidon	No	Seasonal
El Zahrani	25	18	South	Sidon	No	Perennial
Litani (upper)	140	223	Beqaa	Baalbek	No	Perennial
Litani (lower)	170	215	Beqaa	Baalbek	No	Perennial
Hasbani	25	151	Beqaa	Hasbaya	Yes	Perennial
El Assi	46	390	Baalbek-Hermel	Baalbek-Hermel	Yes	Perennial

Annex 2: The hydrographic system in Lebanon (Source: Food and Agriculture Organization (FAO) in 2016

The hydrographic system of Lebanon		
Region nb	**Region name**	**Region description**
1	Litani River Basin (LRB)	Largest catchment in the country, covering around 2,180 km^2 and draining 20% of Lebanon's total area. The Litani River flows through the eastern and southern parts of the country. Its average annual water flow is estimated to be 475 MCM, but it is subject to significant inter-annual variations due to the Eastern Mediterranean weather regime (cold, rainy winters and hot, dry summers).
2	El Assi Basin	Located in the northeast of Lebanon and comprises the watershed of the Orontes River known as the El Assi River, which is the only perennial river in Western Asia that flows north from Lebanon to Syria and Turkey and discharges into the Mediterranean Sea in Turkey with a mean annual flow volume of 1.2 Billion Cubic Meter (BCM).
3	Hasbani Basin	Located in the southeast of Lebanon and includes the Hasbani River, which is one of the tributaries that form the Jordan River and eventually flows into the Dead Sea.
4	Coastal river basins	Include the most important coastal rivers of Lebanon, such as El Kabir, Ostuene, El Bared, Abou Ali, El Jaouz, Ibrahim, El Kalb, Beirut, Damour, El Awaly, El Zahrani, and Abou Assouad rivers.
5	Minor and isolated sub-catchments	Flow between major river systems.

Annex 3: List of suggested dams in the NWSS for 2020-2035 (Source: NWSS 2020)

Priority	Description
NLWE	
1	El Bared dam: Construction of Water Supply dam (37-90 MCM) and associated water treatment plant and transmission network
3	Atolbe Dam: Construction of Water Supply hill lake (0.70 MCM) to supply Qobayyat
3	Qarqaf Dam: Construction of Irrigation DAM (20-25 MCM) for Akkar coastal region
3	Noura el Tahta Dam: Construction of dam (35-50MCM) for Nour el Tahta and surrounding villages
2	Dar Baachtar Dam: Construction of Water and Irrigation Dam (7 MCM) for Koura and Batroun
BWE	
1	Assi Phase I Dam: Completion of execution works for Assi Phase 1 Water and Irrigation Dam (63 MCM), and supervision works.
2	Assi Phase 2 Dam: Construction of Assi Phase 2 Water and Irrigation Dam (15 MCM).
3	Younine Dam: Providing additional storage capacity of 5.8 MCM for the irrigation of 1200 ha
3	Massa Dam: Providing additional storage capacity of 8 MCM for the irrigation of 1600 ha
SLWE	
2	Ibl es Saqi Dam: Construction of Irrigation and Water supply dam (50 MCM) on the Hasbani river next to Ibl es Saqi, with related transmission lines and reservoirs
3	Choumariye Dam: Construction of Water supply and Irrigation DAM (28 MCM) on Litani River with related transmission lines and reservoirs
3	Khardali Dam: Construction of Irrigation and Water supply dam (128 MCM) on Litani river (Khardali segment) including downstream works (transmission lines and reservoirs)
BMLWE	
1	Azounieh Dam: Construction of Water Supply dam (4-5 MCM)
2	Damour Dam: Construction of Water and Irrigation DAM (42-106 MCM) for Beirut and Damour region.
3	Maaser Chouf Dam: Construction of Water Supply hill lake (2.2 MCM)

Annex 4: List of dams in the 2012 NWSS (Sources: NWSS, 2012)

WE	ID	DAMS & LAKES	CAZA	PROJECT STATUS	SCORE / 100	PRIORITY	FINANCING SOURCE
B M L W E							
	14	Janneh Dam	Jbeil	UC	75	1	BMLWE
	15	Chabrouh Dam	Kesrouane	E	74	2	MEW
	34	Ballout Lake	Metn	E	69	3	LRA
	7*	Bisri Dam	Jezzine	PD	67	4	CDR + WB + IsDB
	16	Boqaata Dam	Kesrouane	UC	65	5	MEW
	17	Qaysamani Lake	Baabda	E	63	6	CDR + KFAED
	18	Aazounieh Dam	Aley	RC	62	7	MEW
	6*	Damour Dam	Chouf	FS	60	8	CDR
	19	Maaser El Chouf Dam	Chouf	RC	57	9	MEW-N.A.
	11	Laklouk Lake	Jbeil	DD	54	10	MEW-N.A.
	5*	El Manzoul Dam	Metn	RC	43	11	CDR + KFAED
	13	Mokhada Lake	Jbeil	IS	-	12	MEW-N.A.
	12	Ratiba Lake	Jbeil	DD	-	12	MEW-N.A.
N L W E							
	2	Kouachra Lake Rehab.	Akkar	E	72	1	MEW
	5	Bared Dam	Akkar	RC	71	2	MEW-N.A.
	1	Adline Noura Tahta	Akkar	IS	64	3	MEW+SYRIA-N.A.
	9	Mseilha Dam	Batroun	UC	64	4	MEW
	10	Balaa Dam	Batroun	UC	63	5	MEW
	33	Rahwe Lake	Batroun	DD	62	6	MEW-N.A.
	4	Qarkaf Dam	Akkar	RC	61	7	MEW-N.A.
	3*	Dar Boochtar Dam	Koura	IS	57	8	CDR
	6	Iaal Dam	Zghorta	DD	55	9	MEW-N.A.
	2*	Brissa Dam	Danniye	UC	46	10	CDR + SB
	7	Ouadi Chich-El Arz	Bcharre	RC	44	11	MEW-N.A.
	3	Atolbe Lake	Akkar	DD	43	12	MEW-N.A.
	8	Hadath El Jebbeh	Bcharre	RC	38	13	MEW-N.A.
	1*	Kammoua Lake	Akkar	IS	-	14	MEW-N.A.
B W E							
	29	Aassi Dam Phase II	Hermel	RC	81	1	MEW-N.A.
	30	Assi Dam - Phase I	Hermel	UC	75	2	MEW-N.A.
	32	Ouadi Sbat Dam	Hermel	DD	69	3	MEW-N.A.
	26	Barhacha Lake	Zahle	RC	54	4	MEW-N.A.
	28	Yammouneh Lake	Baalbeck	UC	50	5	MEW
	27	Younine Dam	Baalbeck	RC	49	6	MEW-N.A.
	4*	Massa Dam	Zahle	PD	48	7	LRA-N.A.
	20	Rachaya-Ain Arab Lake	Rachaya	IS	-	8	MEW-N.A.
S L W E							
	31	Qaraaoun Dam	West Bekaa	E	88	1	LRA
	24	Ibl Es Saki Dam	Marjayoun	RC	57	2	MEW-N.A.
	11*	Kfarsir Dam	Nabatiye	IS	55	3	LRA + CDR - N.A.
	36	Ansar Dam	Saida	DD	51	4	MEW-N.A.
	10*	Khardaly Dam	Nabatiye	PD	50	5	LRA + CDR - N.A.
	43	Ain Baal Dam	Sour	IS	45	6	MEW-N.A.
	38	Khiam Dam	Marjayoun	IS	43	7	MEW-N.A.
	25	Chohour Dam	Sour	IS	43	7	MEW-N.A.
	39	Barich Dam	Sour	IS	43	7	MEW-N.A.
	23	Nabaa el Tasse - JarJou	Nabatiye	IS	42	8	MEW-N.A.
	8*	Lebaa Lake	Jezzine	IS	41	9	MEW-N.A.
	44	Kounine Dam	Bint Jbeil	IS	40	10	MEW-N.A.
	35	Jinsnaya Dam	Jezzine	IS	40	10	CDR-N.A.
	42	Aita El Chaab Dam	Bint Jbeil	IS	39	11	MEW-N.A.
	37	Balatat El Jamajim Dam	Saida	IS	38	12	MEW-N.A.
	40	Kfarwa Lake	Nabatiye	IS	38	12	MEW-N.A.
	9*	Aazbieh Lake	Jezzine	IS	35	13	CDR-N.A.
	41	Jbaa Lake	Nabatiye	IS	30	14	MEW-N.A.
	21	Salaa Lake	Hasbaya	IS	-	15	MEW-N.A.
	22	Kfarhouna Lake	Jezzine	IS	-	15	MEW-N.A.

Annex 5: Heavy metals in bed sediments along the LLRB (Source: Nehme et al, 2014)

Heavy metal	Period	S1	S2	S3	S4	S5	S6	ISQG mg.Kg^{-1}
Fe	RS	980	1636	1200	7000	12000	4800	20000
	DS	980	15118	22398	10920	20040	30954	
Cd	RS	2	10	10	10	10	10	0.6
	DS	2	14	32	22	34	36	
Zn	RS	80	224	200	60	60	40	123
	DS	80	54	2	26	12	68	
Pb	RS	14	88	100	20	100	100	35
	DR	14	0	22	0	40	136	
Ni	RS	4	4	4	4	4	4	23
	DR	4	4	4	10	6	24	
Cr	RS	2	10	10	10	20	40	37.3
	DR	2	10	10	28	20	60	

RS: Rainy season, DS: dry season

Annex 6: Additional information on the LRB

Water quality:

In 2018, *Vertcillium dahliae*, a fungal plant pathogen causing leaves to curl and discolor and even cause death in some plants, was detected in six rivers, amongst them the Litani River, as well as in the Litani irrigation channel due to the rivers being surrounding by commercial fields intensively planted with *V. dahliae* susceptible hosts[70].

The assessment of physiochemical parameters showed contaminations with certain heavy metals and cations as well exceeding the standards set by the World Health Organization (WHO) (Table 1). The contamination can be attributed to the use of agricultural fertilizers mixed with sewage, resulting in a decline in water quality at these specific sites[38]. Other physicochemical parameters were assessed such as the temperature, the electrical conductivity (EC), pH and Total Dissolved Solids (TDS) (Table 2).

Table 1: WHO acceptable limits of heavy metals, cations and anions (Source: Nehme et al, 2020).

Heavy Metal	**Symbol**	**WHO acceptable limit (mg/L)**	**Exceeded WHO limit (Yes/No)**
Lead	Pb	0.01	Yes
Iron	Fe	0.3	In conformity
Cadmium	Cd	5	No
Chrome	Cr	0.05	No
Copper	Cu	1	No
Zinc	Zn	5 mg/L	No
Cations	**Symbol**	**WHO acceptable limit (mg/L)**	**Exceeded WHO limit (Yes/No)**
Calcium	Ca^{2+}	250	Yes
Magnesium	Mg^{2+}	50	No
Potassium	K^+	12	No
Sodium	Na^+	150	No
Ammonium	NH_4^+	0.2	No
Anions	**Symbol**	**WHO acceptable limit (mg/L)**	**Exceeded WHO limit (Yes/No)**
Nitrate	NO_3^-	50	Yes
Sulfate	SO_4^{2-}	250	Yes
Phosphate	PO_4^{3-}	-	No
Chloride	Cl^-	250	No

Table 2: Physiochemical parameters (Source: Nehme et al, 2020)

Parameter	**Symbol**	**WHO acceptable limit**	**Result**	**Exceeded WHO limit (Yes/No)**

[70]Baroudy, F., Habib, W., Tanos, G., Gerges, E., Saab, C.,Choueiri, E., Franco Nigro, F. (2018). Long-Distance Spread of Verticillium dahliae Through Rivers and Irrigation Systems. https://doi.org/10.1094/PDIS-08-17-1189-RE

Temperature	T(°C)	-	30C°- 35C°	Normal for sampling months
pH	-	6.5-8.5	6.80-7.55	No
Electrical conductivity	EC	320-550µs/cm	380-666 µs/cm	Yes (Accentuated mineralization)
Total Dissolved Solids	TDS	-	110 and 280 ppm	-

Annex 7: List of macrophytes in the upper and lower basins of the Litani River (Source: Baydoun et al, 2016)

Macrophytes	Species code	Rayak	El Marj	Jeb Janine	Dellafi	Khardali
Submersed species						
Alg. *Chara* sp.	Char				1	1
Alg. *Cladophora* sp.	Clad	1	1	1	1	1
Alg. *Rhizoclonium* sp.	Rhiz				1	1
Alg. *Spirogyra* sp.	Spir			R	1	R
Alg. *Vaucheria* sp.	Vauc	1	1	1		
Bry. *Amblystegium* sp.	Ambl				1	
Bry. *Cinclitods* sp.	Cinc				1	
Phy. *Ceratophyllum demersum* L.	CerD			+		
Phy. *Lemna gibba* L.	LemG			R		
Phy. *Lemna minor* L.	LemM			1		
Phy. *Myriophyllum spicatum* L.	MyrS			1	1	
Phy. *Potamogeton crispus* L.	PotC			1	4	
Phy. *Potamogeton pectinatus* L.	PotP			1		
Phy. *Potamogeton trichoides* Cham. & Schltdl.	PotT			2		
Phy. *Ranunculus fluitans* Lam.	RanF			1		
Phy. *Ranunculus aquatilis* L.	RanA			1		
Phy. *Ranunculus trichophyllus* Chaix ex Vill.	RanT			1		
Emergent species						
Phy. *Apium nodiflorum* (L.) Lag.	ApiN			1	1	
Phy. *Butomus umbellatus* L.	ButU	1	1	3		2
Phy. *Carex divisa* Huds.	CarD				+	1
Phy. *Cyperus longus* L.	CypL					2
Phy. *Epilobium hirsutum* L..	EpiH				1	
Phy. *Eupatorium cannabinum* L.	EupC				1	1
Phy. *Glyceria plicata* (Fr.) Fr.	GlyP					+
Phy. *Lycopus europaeus* L.	LycE			1	1	2
Phy. *Nasturtium officinale* R. Br.	NasO				1	
Phy. *Mentha aquatica* L.	MenA	1		1	1	
Phy. *Phalaris arundinacea* L.	PhaA	1		3	2	2
Phy. *Phragmites australis* (Cav.) Trin. Ex Steud.	PhrA	2	1	3	2	2
Phy. *Polygonum persicaria* L.	PolP	R		1	1	1
Phy. *Sparganium emersum* Rhemann	SpaE					+
Phy. *Sparganium neglectum* Beeby	SpaN			+	+	
Phy. *Sparganium angustifolium* Michx.	SpaA			1	1	1
Phy. *Typha angustifolia* L.	TypA					2
Phy. *Veronica anagallis-aquatica* L.	VeAa				1	
Total species		**7**	**4**	**22**	**21**	**16**

Annex 8: Diatom species in Qasmiye River and estuary

	05/10/2016		20/05/2017	
	St1	**St2**	**St1**	**St2**
Achnanthes delicatula	abs	5	Abs	3
Achnanthes minutissima	64	3	36	abs
Achnanthes minutissima var. saprophila	abs	>200	Abs	abs
Amphora commutata	3	abs	24	4
Amphora lybica	2	abs	11	abs
Amphora oligotraphenta	3	abs	Abs	abs
Amphora veneta	3	abs	10	abs
Aulacoseira granulata	abs	abs	2	abs
Brachysira neoexilis	35	4	>200	abs
Cocconeis disculus	1	abs	Abs	abs
Cocconeis placentula	abs	1	Abs	abs
Cyclotella sp.	1	abs	Abs	abs
Cymbella affinis	1	abs	Abs	abs
Cymbella microcephala	24	2	10	abs
Cymbella minuta	abs	1	Abs	abs
Diploneis oblongella	abs	1	Abs	1
Diploneis ovalis	2	abs	2	abs
Fragilaria capucina	abs	abs	7	abs
Fragilaria nanana	2	abs	1	abs
Gomphonema angustum	abs	abs	1	abs
Gomphonema minutum	1	abs	abs	abs
Gomphonema parvulum	1	abs	12	abs
Gomphonema parvulum var. exilissimum	abs	abs	5	abs
Gomphonema pumilum	5	2	abs	abs
Mastogloia elliptica	abs	Abs	1	abs
Melosira varians	abs	Abs	6	abs
Navicula cryptocephala	8	Abs	abs	abs
Navicula minima	3	Abs	abs	abs
Navicula phyllepta	38	Abs	2	abs
Navicula salinarum	abs	Abs	5	abs
Navicula saprophila	abs	Abs	21	abs
Navicula trivialis	abs	Abs	25	abs
Nitzschia compressa	abs	Abs	3	abs
Nitzschia denticula	abs	Abs	7	abs
Nitzschia inconspicua	1	Abs	abs	abs
Nitzschia palea	abs	Abs	4	abs
Nitzschia recta	abs	Abs	3	abs
Nitzschia sigma	abs	Abs	6	abs
Pleurosigma aestuarii	abs	Abs	1	abs
Nombre total d'espèce	**19**	**09**	**25**	**03**

Annex 9: LRB Species IUCN Status

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
Fish												
Pseudophoxinus libani				✓							2013	Pseudophoxinus libani (Levantine Minnow) (iucnredlist.org)
Cyprinus carpio						✓					2008	Cyprinus carpio (Eurasian Carp) (iucnredlist.org)
Squalius lepidus				✓							2013	Squalius lepidus (Mesopotamian pike chub) (iucnredlist.org)
Oxynoemacheilus angorae				✓							2013	Oxynoemacheilus angorae (Angora loach)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
												(iucnredlist.org)
Aphanius mento				✓							2013	Aphanius mento (Iridescent Killifish) (iucnredlist.org)
Gambusia holbrooki				✓							2012	Gambusia holbrooki (Eastern Mosquitofish) (iucnredlist.org)
Oxynoemacheilus leontinae				✓							2013	Oxynoemacheilus leontinae (Tiberias loach) (iucnredlist.org)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
Molluscs												
Potamopyrgus antipodarum		✓									2011	Potamopyrgus antipodarum (New Zealand Mudsnail) (iucnredlist.org)
Pseudobithynia hamicensis				✓							2013	Pseudobithynia hamicensis (iucnredlist.org)
Valvata saulcyi				✓							2013	Valvata saulcyi (iucnredlist.org)
Gyraulus piscinarum				✓							2009	Gyraulus piscinarum (iucnredlist.org)
Lymnaea stagnalis				✓							2015	Lymnaea stagnalis (Great Pond Snail)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
												(iucnredlist.org)
Radix auricularia				✓							2014	Radix auricularia (iucnredlist.org)
Stagnicola cf. berlani	Not found											
Planorbis carinatus				✓							2009	Planorbis carinatus (iucnredlist.org)
Gyraulus bekaensis						✓					2013	Gyraulus bekaensis (iucnredlist.org)
Musculium lacustre				✓							2015	Musculium lacustre (iucnredlist.org)
Potomida littoralis							✓				2013	Potomida littoralis (iucnredlist.org)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
Pseudobithynia kathriae								✓			2009	Pseudobithynia kathrinae (iucnredlist.org)
Pseudobithynia levantica							✓				2013	Pseudobithynia levantica (iucnredlist.org)
Pseudobithynia badiella	Not found											
Pseudobithynia saulcyi	Not found											

Annex 10: List of molluscs found in Lebanon in 2006

Neritidae
01. *Theodoxus jordani* (Sowerby, 1832)

Melanopsidae
02. *Melanopsis buccinoidea* (Olivier, 1801)

Hydrobiidae
03. *Radomaniola gaillardotii* (Bourguignat, 1856)
04. *Potamopyrgus antipodarum* (J. E. Gray, 1843)

Bithyniidae
05. *Pseudobithynia amiqensis* Glöer & Bößneck, 2007 (Fig. 2a)
06. *Pseudobithynia levantica* Glöer & Bößneck, 2007 (Fig. 2b)
07. *Pseudobithynia kathrini* Glöer & Bößneck, 2007 (Fig. 2c)

Valvatidae
08. *Valvata saulcyi* (Bourguignat, 1853)

Lymnaeidae
09. *Lymnaea stagnalis* (Linnaeus, 1758)
10. *Radix auricularia* (Linnaeus, 1758)
11. *Stagnicola* cf. *berlani* (Bourguignat, 1870) sensu Kruglov, 2005 (Fig. 3c, 6a)
12. *Galba truncatula* (O. F. Müller, 1774)

Physidae
13. *Physella acuta* (Draparnaud, 1805)

Planorbidae
14. *Planorbis carinatus* O. F. Müller, 1774 (Fig. 3a)
15. *Gyraulus piscinarum* (Bourguignat, 1852)
16. *Gyraulus bekaensis* Glöer & Bößneck, 2007 (Fig. 3b)
17. *Ancylus fluviatilis* (O. F. Müller, 1774) s.l.

Lauriidae
18. *Lauria cylindracea* (Da Costa, 1778)

Orculidae
19. *Orculella sirianocoriensis libanotica* (Tristram, 1865)
20. *Orculella mesopotamica riedeli* Hausdorf, 1996 (Fig. 4d)

Buliminidae
21. *Turanena benjamitica* (Benson, 1859)
22. *Pene syriacus syriacus* (L. Pfeiffer, 1864)
23. *Buliminus damascensis* (Pallary, 1929) (Fig. 4a)
24. *Euchondrus septemdentatus* (Roth, 1839)
25. *Euchondrus* cf. *ledereri* (L. Pfeiffer, 1868) (Fig. 4b)
26. *Euchondrus* spec. (Fig. 4c)

Pleurodiscidae
27. *Pleurodiscus erdelii* (Roth, 1839)

Clausiliidae
28. *Cristataria dutaillyana* (Bourguignat, 1868)
29. *Cristataria* cf. *zelebori* (Rossmässler, 1856)
30. *Elia moesta* (Rossmässler, 1839)
31. *Albinaria hedenborgi* (L. Pfeiffer, 1849)

Succineidae
32. *Oxyloma* cf. *elegans* (Risso, 1826) (Fig. 6b)

Zonitidae
33. *Eopolita protensa jebusitica* (Roth, 1855)
34. *Oxychilus syriacus* (Kobelt, 1879)
35. *Oxychilus renanianus* (Pallary, 1939)

Limacidae
36. *Limacus flavus* (Linnaeus, 1758)

Agriolimacidae
37. *Deroceras berytensis* (Bourguignat, 1852)

Sphincterochilidae
38. *Sphincterochila fimbriata* (Bourguignat, 1852) (Fig. 4e)

Hygromiidae
39. *Monacha syriaca* (Ehrenberg, 1831)
40. *Monacha obstructa* (L. Pfeiffer, 1842)
41. *Monacha* cf. *compingtae* (Pallary, 1929) (Fig. 5a)
42. *Monacha* spec. (Fig. 5b)
43. *Platytheba nummus* (Ehrenberg, 1831)
44. *Metafruticicola fourousi* (Bourguignat, 1863)
45. *Metafruticicola berytensis* (L. Pfeiffer, 1841)

Helicidae
46. *Cochlicella acuta* (O. F. Müller, 1774)
47. *Xeropicta krynickii* (Krynicki, 1833)
48. *Eobania vermiculata* (O. F. Müller, 1774)
49. *Cornu aspersum* (O. F. Müller, 1774)
50. *Helix engaddensis* (Bourguignat, 1852)

Sphaeriidae
51. *Musculium lacustre* (O. F. Müller, 1774) (Fig. 2d)
52. *Pisidium amnicum* (O. F. Müller, 1774) (Fig. 2e)
53. *Pisidium casertanum* (Poli, 1791) (Fig. 2f)
54. *Pisidium subtruncatum* Malm, 1855 (Fig. 2g)
55. *Pisidium tenuilineatum* Stelfox, 1918 (Fig. 2h)
56. *Pisidium personatum* Malm, 1855 (Fig. 2i)

Annex 11: Additional information on the Awaly River Basin

- Challenges include land degradation: Forest systems in the basin are equally vulnerable, with a significant risk of fires in the central to upper area where forests are primarily located. The erosion risk is also high, driven by deforestation, unsustainable land use practices, and the steep slopes of the region. The expansion of urban areas has led to the loss of various land use and land cover (LU/LC) classes, with forests being the most severely impacted. The dense forests, which originally covered 53.59 km^2 (17.8%) of the basin, have progressively diminished[43]. This transformation of forests into cleared areas can be attributed to both natural factors like fires and human-related factors such as urban expansion, deliberate fires, and changes in land use practices (e.g., cultivation of crops or orchards, resulting in a 4.29 km^2 increase in olive groves). Furthermore, changes in grasslands and shrub lands have also contributed to the conversion of forested areas into cleared land, particularly in regions with limited pressure on their utilization. The increasing conversion and exploitation of shrub lands and grasslands have further contributed to the decline of forests. The expansion of urban and managed areas has occurred at the expense of natural classes (forests, grasslands, and shrub lands), highlighting a lack of proper land planning and emphasizing the urgent need for intervention in the study area to address this land degradation.

- An assessment in 2007[71] showed that pH values in the ARB lie within WHO (2004) limits for drinking water (6.5–8.5). pH values obtained in Awaly were higher than the reported 7.43 for Qaraaoun, while DO values were close to the reported average of 6.52 mg/l with the water movement through the turbines expected to increase the DO level (Table 1, Table 2).

Table 1: River temperature, pH values, dissolved oxygen and saturation for Awaly River during dry season (2007*)*

July				August				September			
pH	T (°C)	DO (mg/l)	% sat	pH	T (°C)	DO (mg/l)	% sat	pH	T (°C)	DO (mg/l)	% sat
8.18	20.7	6	66	8.17	21.5	7.24	80	8.15	22.5	7.4	82

Table 2: Bacteriological results in the Awaly River during the dry season (2007)

July		August		September	
Total coliform	E. coli	Total coliform	E. coli	Total coliform	E. coli
140	0	710	1	40	1

As for the TDS, the Awaly river did not exceed the WHO acceptable limits for drinking water (<600 mg/l), neither the 40 mg/l sulfate level. For nitrates, Awaly showed the lowest level in comparison to the other rivers assessed. Fluctuations were seen where nitrate levels were highest in August for most rivers and then it drops again in September. This could be attributed to increasing agricultural fertilizing activities between July and August, which then decrease towards the end of the summer, resulting in a lower nitrate loading of river basins. Phospohate levels were also very low in the Awaly river.
In 2018, *V. dahliae,* a fungal plant pathogen causing leaves to curl and discolor and may even cause death in some plants, was detected in six rivers, amongst them the Awaly River**Error! Bookmark not defined.**.
The most recent assessment of the National Council for Scientific Research (CNRS) in 2023 demonstrated the presence of 180 CFU/100ml of Fecal Streptococci and 108 CFU/100ml of Fecal coliforms in the public beach/North of Awaly River (Sandy/Pebbles) rendering it good/safe for swimming[72].

- Flora in the Bisri area

No vegetation assessment was conducted in the Awaly estuary, however in the Bisri area, three types of vegetation were identified in the Environmental and Social Impact Assessment in the Water Supply Augmentation Project in 2014[49]:

- Type 1. Vegetation formations along the river course consist of *Platanus orientalis* L., *Salix libani* Bornm, *Alnus orientalis* Decne trees, along with accompanying shrubs and herbaceous plants.
- Type 2. The hillside in the North/Northeast region is primarily characterized by plant associations including *Pinus brutia*, *P. pinea*, *Quercus calliprinos*, *Q. infectoria*, *Laurus nobilis*, and *Pistacia paleastina*.

---

[71]Houri, A., W. El Jeblawi, S. (2007). Water quality assessment of Lebanese coastal rivers during dry season and pollution load into the Mediterranean Sea. doi: 10.2166/wh.2007.047
[72]National Council for Scientific Research (CNRS). (2023). Status of the marine environment in Lebanon.

- Type 3. The South/Southeast region exhibits similar characteristics to the previous type, but with denser bush-like formations.

Furthemore, around 50 plant species were identified with one being endemic (*Ricotia lunaria)*. In addition to the abundance of wild plants, Marj Bisri boasts a variety of fruit trees, predominantly citrus trees, as well as greenhouses cultivating roses and strawberries, along with commercial plots of lawn grass.

- Birds

A total of 32 species were documented in the surveys conducted (Table 3)[52]. Some are known to depend on forest habitats and may be found in the riparian areas both upstream and downstream of the Bisri site. These forest-dependent species include the Winter Wren (*Troglodytes troglodytes)*, Eurasian Jay *(Garrulus glandarius)*, Chaffinch *(Fringilla coelebs)*, and Blackbird (*Turdus merula).*

Table 3: Bird species in the riparian areas both upstream and downstream of Bisri (GWP-Med)

	Species	Scientific name	Status	T	E	R	C
1	Bulbul	*Pycnonotus xanthopygos*	R				+
2	Graceful Warbler	*Prinia gracilis*	R				+
3	Common Chiffchaff	*Phylloscopus collybita*	SB, PM, WV				+
4	Chaffinch	*Fringilla coelebs*	R, PM, WV				+
5	Winter Wren	*Troglodytes troglodytes*	R				+
6	Blackbird	*Turdus merula*	R				+
7	Eurasian Jay	*Garrulus glandarius*	R				+
8	Great Tit	*Parus major*	R				+
9	European Greenfinch	*Carduelis chloris*	R				+
10	Blackcap	*Sylvia atricapilla*	SB, PM, WV				+
11	Sardinian Warbler	*Sylvia melanocephala*	R, PM, WV				+
12	Lesser Whitethroat	*Sylvia curruca*	SB, PM, ?wv				+
13	White Storks	*Ciconia ciconia*	PM	+			+
14	Pelican	*Pelecanus onocrotalus*	PM	+			+
15	Short-toed Snake Eagle	*Circaetus gallicus*	SB, PM	+		+	
16	Long-legged Buzzard	*Buteo rufinus*	R, PM, WV				+
17	Hooded Crow	*Corvus cornix*	R				+
18	Palestine Sunbird	*Cinnyris osea*	R, wv			+	
19	European Goldfinch	*Carduelis carduelis*	R, WV, pm				+
20	House Sparrow	*Passer domesticus*	R				+
21	Swift	*Apus apus*	SB, PM				+
22	Lesser Spotted Eagle	*Aquila pomarina*	PM				+
23	Black headed Bunting	*Emberiza melanocephala*	SB				+
24	Corncrake	*Crex crex*	pm	+		+	
25	Black Kite	*Milvus milvus*	PM				+
26	Steppe Buzzard	*Buteo vulpinus*	PM				+
27	Hoopoe	*Upupa epops*	R, SB			+	
28	White Wagtail	*Motacilla alba*	PM, WV				+
29	Steppe Buzzard	*Aquila nipalensis*	pm			+	
30	Levant Sparrowhawk	*Accipiter brevipes*	PM				+
31	European Sparrowhawk	*Accipiter niseus*	PM			+	
32	Marsh Harrier	*Circus aeroginosus*	PM			+	

Annex 12: Awaly Species IUCN Status

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
Freshwater species												
Anguilla anguilla								✓			2018	Anguilla anguilla (European Eel) (iucnredlist.org)
Capoeta damascina				✓							2013	Capoeta damascina (Levantine Scraper) (iucnredlist.org)
Oxynoemacheilus leontinae				✓							2013	Oxynoemacheilus leontinae (Tiberias loach) (iucnredlist.org)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
Pseudophoxinus libani				✓							2018	Pseudophoxinus libani (Levantine Minnow) (iucnredlist.org)
Salariopsis fluviatilis				✓							2006	Salariopsis fluviatilis (Freshwater Blenny) (iucnredlist.org)
Potamon bileki						✓					2008	Potamon bileki (iucnredlist.org)
Amphibians and reptiles												
Natrix tessellata				✓							2020	Natrix tessellata (Dice Snake) (iucnredlist.org)
Pelophylax bedriagae				✓							2021	Pelophylax bedriagae (Bedriaga's Frog)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
												(iucnredlist.org)
Pelobates syriacus				✓							2020	Pelobates syriacus (Syrian Spadefoot) (iucnredlist.org)
Bufotes viridis				✓							2020	Bufotes viridis (Green Toad) (iucnredlist.org)
Bufo bufo				✓							2021	Bufo bufo (Common Toad) (iucnredlist.org)
Hyla savignyi				✓							2021	Hyla savignyi (Lemon-Yellow Tree Frog) (iucnredlist.org)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
Salamandra infraimmaculata				✓							2022	Salamandra infraimmaculata (Near-Eastern Fire Salamander) (iucnredlist.org)
Ommatotriton vittatus				✓							2022	Ommatotriton vittatus (Southern Banded Newt) (iucnredlist.org)
Mammals												
Lutra lutra					✓						2008	Lutra lutra (Eurasian Otter) (iucnredlist.org)

Annex 13: Additional information on the Damour Estuary

- Water quality

A key issue of conflict between downstream and upstream users is related to the deterioration of river water quality, due to the discharge of waste from domestic and industrial sources. Pollution from sewage disposal from restaurants and residences, due to the lack of wastewater treatment plants is confirmed by the presence of high bacterial contamination of fecal and total coliform, while pollution of industrial origin from neighboring villages, such as olive presses, stone cutters, and concrete and asphalt production is confirmed by the detected Chemical Oxygen Demand (COD). Moreover, the concentrations of phosphates are attributed to agricultural activities along the river and in the coastal plains.

The concentration of DO is higher in the upstream of the Damour river since the waters are turbulent because of the steep slope and organic matter originates from natural sources and is dominated by humus matter (humic and fulvic acids). Total Phosphorus (TP) was found less than 0.3 mg/L and Nitrogen yielded less than 1 (Total Kjeldahl Nitrogen (TKN) < 1)[73].

Additionally, groundwater exploitation pattern has led to the degradation of the quality of water resources in the area. Water quality measurements have revealed an increasing trend in the levels of chlorides over the years (1990-2003) in the water samples taken from public wells, which confirm seawater intrusion. Water samples analyzed from municipal and private wells in the area further confirmed seawater intrusion, as chloride and TDS levels were found to be high, exceeding the Guidance Value and the Maximum Admissible Value of the MoE, and ranging between 20 to 1240 mg/l and 239 to 1850 mg/l, respectively. The highest chloride and TDS levels were detected in Saadiyat due to the existence of numerous wells and the direct contact of the Sannine Aquifer with the sea[56]. The most recent assessment of the CNRS in 2023 demonstrated the presence of 138 CFU/100ml of Fecal Streptococci and 166 CFU/100ml of Fecal coliforms in the Damour/ Sandy beach (sandy pebbles) rendering it good/safe for swimming[54].

- Physio-Chemical Analysis
  - The temperature of the river varies along its course, with an increase observed downstream towards the sink, such as the sea or open water surfaces.
  - pH plays a crucial role in chemical and biological processes within water, and it is an important factor influencing species distribution in aquatic habitats. According to the Environmental Protection Agency (EPA) water quality criteria for pH in freshwater, the recommended range is 6.5 to 9. In the case of the Damour River, pH levels fall within this range, ranging from 8.3 to 8.6, which is considered normal for pH in surface waters.
  - The level of DO ranges from 87% to 97%, with the lowest values observed at the source due to groundwater inflow. As we move downstream, DO increases as it reacts with the atmosphere and absorbs oxygen.

---

[73] Small Grants-Critical Ecosystem Partnership Fund-Difaf. (2022). Develop an Integrated Management Plan for Damour River Basin – Lebanon, Final completion and impact report.

- The redox potential (ORP) is a measure of a river or lake's ability to self-clean and decompose waste products. In a healthy environment, a high ORP value exceeding 300mV is expected. However, along the Damour River, the ORP ranges from 83mV to a maximum of 132mV, indicating that the river does not possess the complete self-cleaning capacity.
- Conductivity in the mid-range (200 to 1000 µS/cm) is typically the background level for most major rivers. Conductivity levels outside of this range may indicate unsuitability for certain species of fish or aquatic insects. High conductivity levels (1000 to 10,000 µS/cm) serve as an indicator of saline conditions. In the Damour River, the highest conductivity level recorded is 666 µS/cm, placing the river within the mid-range and suitable for supporting various species.

Annex 14: Damour Species IUCN Status

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
Flora												
Arum hygrophilum					✓						2017	Arum hygrophilum (Water Arum) (iucnredlist.org)
Platanus orientalis						✓					2016	Platanus orientalis (Oriental Plane-tree) (iucnredlist.org)
Mammals												
Lutra lutra					✓						2008	Lutra lutra (Eurasian Otter) (iucnredlist.org)
Freshwater species												
Anguilla anguilla								✓			2018	Anguilla anguilla (European Eel)

Species name	IUCN Status										Data assessed	Link
	Not evaluated (NE)	Not Applicable (NA)	Data Deficient (DD)	Least Concern (LC)	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)	Extinct in the wild (EW)	Exctinct (EX)		
												(iucnredlist.org)
Capoeta damascina				✓							2013	Capoeta damascina (Levantine Scraper) (iucnredlist.org)
Reptiles												
Testudo graeca						✓					1996	Testudo graeca (Common Tortoise) (iucnredlist.org)
Amphibians												
Pelophylax ridibundus				✓							2021	Pelophylax ridibundus (Marsh Frog) (iucnredlist.org)

Annex 15: Diatom species in the two stations on the Damour River

	9/11/2016		27/2/2017
	D1	D2	D1
Achnanthes minutissima	32	22	42
Amphora ovalis	12	8	8
Amphora veneta	abs	abs	16
Cocconeis placentula	8	10	12
Cyclotella kutzingiana	12	abs	abs
Cyclotella meneghiniana	8	12	8
Cymatopleura elliptica	4	6	10
Cymatopleura solea	5	6	8
Cymbella affinis	16	18	11
Cymbella cistula	abs	abs	6
Cymbella naviculiformis	8	6	6
Cymbella tumida	14	10	abs
Cymbella turgida	abs	8	abs
Diatoma vulgara	8	abs	abs
Fragilaria ulna	12	18	19
Gomphonema acuminatum Var. coronata	6	abs	abs
Gomphonema constrictum Var. capitata	22	22	abs
Gomphonema constrictum Var.curta	12	abs	abs
Gomphonema lanceolatum	8	10	abs
Gomphonema olivaceum	abs	abs	8
Gomphonema parvulum	18	122	22
Gyrosigma spencerii	8	7	8
Melosira granulata	8	8	abs

	9/11/2016		27/2/2017
	D1	D2	D1
Melosira varians	8	14	28
Navicula cryptocephala	23	28	23
Navicula nivalis	4	abs	abs
Navicula rynchocephala	abs	abs	12
Navicula tripunctata	24	22	abs
Nitzschia apiculata	12	18	8
Nitzschia intermedia	8	22	6
Nitzschia obtusa	abs	abs	4
Nitzschia palea	abs	22	abs
Rhoicosphania curvata	200	180	68
Surirella angusta	abs	abs	12
Surirella linearis	abs	abs	8
Surirella ovata	4	22	abs
Total number of species	**26**	**25**	**23**

Annex 16: Additional information on the Ibrahim River Estuary

- Water quality:

  The Ibrahim River is facing pollution issues arising from mineral discharge originating from nearby marble industries, as well as anthropogenic pollutants from surrounding villages. The Afqa Source exhibits elevated levels of certain mineral components (Mn, Co, Ni, Fe, and Mo), likely of natural origin. Some areas are primarily affected by mineral components (Cd, Ca, Al, SO_4, etc.) due to the common discharges from marble factories located along the river's edge. Other sites experience mineral and bacteriological contamination, primarily resulting from high anthropogenic discharges from the nearby villages and cities[74]. Fecal coliform levels at the Ibrahim River outlet were found to range between 0.6×10^3 and 2.4×10^3 CFU/100 ml. Phosphate levels were reported as 0.048 mg/L, while mean nitrate levels were relatively low at 0.82 mg/L. Recent studies in Lebanon on OCPs indicated that average concentrations of DDE in the surface water of the Ibrahim River (23.16 ng/L) exceeded the maximum admissible level set by the EPA for surface water (8.3 ng/L) by 2.8 times. DO levels exhibit a decreasing trend downstream. Higher DO concentrations are observed upstream due to turbulent waters caused by steep slopes and minimal anthropogenic inputs, favoring natural oxygen dissolution. In contrast, downstream regions experience significant anthropogenic inputs and the rivers flow in a flatter manner. The average DO level in the Ibrahim River was reported as 7.6 mg/L. Anthropogenic contribution has led to significant enrichment in arsenic, while Zn displays moderate enrichment. Zn, in particular, has no natural origin in the Ibrahim River and predominantly stems from anthropogenic discharges related to pharmaceutical industries located at the river outlet where the sampling was conducted.

  The most recent assessment of the CNRS in 2023 demonstrated the presence of 65 CFU/100ml of Fecal Streptococci and 153 CFU/100ml of Fecal coliforms in the Okaibeh/Nahr Ibrahim beach (sandy) rendering it good/safe for swimming[54].

- Flora:

  Nahr Ibrahim is known for its remarkable biodiversity, as evidenced by a vegetation survey conducted in 2012, which documented 367 plant specimens belonging to various species[75]. The most abundant plant families observed were *Asteraceae, Poaceae, Fabaceae, Lamiaceae, and Apiaceae,* accounting for 38% of the recorded flora. The remaining species were categorized into 25 different families. The identified species were classified as endemic, riparian, weed, or invasive, revealing the presence of two endemic species (*Origanum ehrenbengii* and *Papaver umbonatum*), 13 riparian-specific species, two riparian generalists, 39 weed species, and three reported Mediterranean invasive species. Additionally, 15 species were recognized for their medicinal value. Several species fell into multiple

---

[74] Daou, C., Salloum, M., Legube, B. et al. Characterization of spatial and temporal patterns in surface water quality: a case study of four major Lebanese rivers. Environ Monit Assess 190, 485 (2018). https://doi.org/10.1007/s10661-018-6843-8

[75] Abboud M, Makhzoumi J, Clubbe C, Zurayk R, Jury S, Talhouk SN (2012) Riparian habitat assessment tool for Lebanese rivers (RiHAT): case study Ibrahim River. BioRisk 7: 99–116. doi: 10.3897/biorisk.7.1331

categories, such as 11 species with medicinal and weed properties, four species with medicinal and riparian generalist properties, four species with medicinal and riparian-specific properties, two species with riparian-specific and weed characteristics, one species with riparian generalist and Mediterranean invasive traits, and one species with both medicinal and Mediterranean invasive attributes. Recent studies further affirm that the area stretching from the river outlet to its summit encompasses approximately 70% of Lebanon's flora, along with unique plant associations and their transitions across different altitudinal zones. This makes the Nahr Ibrahim valley the 13th KBA site out of 26 in Lebanon[11]. The natural vegetation cover dominates the majority of the basin, with 30% comprised of dense and open coniferous trees (such as *Pinus* species, *Cedrus* species, *Juniperus* species, *Cupressus* species) and broadleaved trees (mainly *Quercus* species), as well as various types of shrubs. Agricultural lands cover a smaller portion, approximately 8.41%, and include field crops like fruit trees, bananas, olives, vineyards, and protected agriculture such as greenhouses. Bare lands make up 21.5% of the area and are characterized as unutilized terrains. Notably, one rare species reported in the Nahr Ibrahim region is *E. europaeus concolor*, also known as the European hedgehog.

Annex 17: Diatom species in the two stations on the Ibrahim River

	9/11/2016		27/2/2017	
	Ibr 1	Ibr2	Ibr 1	Ibr2
Achnanthes minutissima	38	42	12	Abs
Achnanthes minutissima Var. cryptocephala	42	22	23	8
Amphora ovalis	8	5	12	Abs
Amphora veneta	Abs	Abs	6	Abs
Cocconeis placentula	8	6	12	Abs
Cymatopleura ovata	5	9	Abs	Abs
Cyclotella meneghiniana	Abs	12	8	18
Cymbella affinis	200	92	200	28
Cymbella amphicephala	48	12	88	12
Cymbella cistula	8	8	Abs	Abs
Cymbella microcephala	8	12	12	2
Cymbella ventricosa	Abs	Abs	16	7
Diatoma elongatum	23	44	Abs	Abs
Diatoma vulgare	12	14	Abs	Abs
Fragilaria capucina	15	19	Abs	Abs
Fragilaria ulna	7	Abs	12	14
Gomphonema constrictum Var.capucina	36	28	Abs	Abs

	9/11/2016		27/2/2017	
	Ibr 1	Ibr2	Ibr 1	Ibr2
Melosira varians	8	6	12	Abs
Melosira granulata	Abs	6	Abs	Abs
Navicula cryptocephala	Abs	12	12	8
Navicula cryptonella	18	68	8	Abs
Navicula cuspidata	Abs	4	Abs	Abs
Navicula pupula	Abs	12	8	6
Navicula tripunctata	6	Abs	6	14
Nitzschia apiculata	4	18	6	8
Nitzschia dissipata	Abs	Abs	8	18
Nitzschia intermedia	4	16	12	12
Nitzschia frustulum	Abs	22	Abs	Abs
Nitzschia palea	Abs	12	Abs	27
Surirella angustata	Abs	12	Abs	Abs
Surirella ovata	Abs	Abs	5	22
Total number of species	**20**	**25**	**20**	**15**

Annex 18: Additional information on the Areeda River Estuary

- Agreements and water resource management

The Fraternity, Cooperation and Coordination Treaty, signed and ratified by Lebanon and Syria in 1991, serves as the formal foundation for collaboration in various sectors, including water resources. To oversee the treaty's implementation, several joint entities were established in the same year. One such entity is the Lebanese-Syrian Joint Committee for Shared Water, which includes representation from the Lebanese Ministry of Energy and Water and the Syrian Ministry of Irrigation. After eight years of negotiations, in April 2002, both countries reached an agreement to share the water of the Nahr el Kabir. This agreement draws upon the principles outlined in the United Nations Convention on the Law of Non-Navigational Uses of International Watercourses, of which both countries are signatories. The agreement focuses on the joint construction of a multi-purpose dam near Noura al Tahta, with a planned storage capacity of 70 MCM. The primary purpose of the dam is to provide water for irrigation and domestic use. According to the agreement, the allocation of water is based on each riparian country's share in the catchment area that drains into the dam location, with Lebanon receiving 40% and Syria receiving 60% of the river's total annual yield. It is worth noting that the agreement does not consider the origin of the water, i.e., the contribution of each riparian to the river's flow. Furthermore, the amount of water utilized upstream of the dam, within the respective allocation proportions, is subtracted from each country's share of stored water. The costs associated with the dam's construction and engineering studies are to be equally divided between both countries. The Lebanese-Syrian Joint Committee for Shared Water serves as the central entity for cooperation between the two countries regarding shared water resources. This committee consists of members from both Lebanon and Syria and operates through two subcommittees. The first subcommittee, established in 2009, is the Sub-Committee for the Control of Water Hyacinth, which focuses on assessing and managing the spread of this invasive plant. The second subcommittee, called the Sub-Committee for River Protection and Environmental Preservation, is responsible for coordinating and supervising matters related to river hydrology, pollution, and infringements (Figure 1). Regular monthly meetings used to be held by the subcommittees in either Lebanon or Syria to facilitate data exchange, discussion of basin-related issues, and the development of joint measures to address problems such as illegal activities, river pollution, and violations along the river course. The quality of both surface water and groundwater in the Nahr el Kabir watershed is rapidly declining due to unregulated disposal of untreated domestic sewage, animal waste, solid waste, and unsustainable agricultural practices. Although joint efforts by the governments have provided temporary solutions to recurring issues of water pollution, floods, and illegal activities, an overarching plan for the integrated and sustainable management of the basin's natural resources is still lacking. Preparations were underway for the construction of new wastewater treatment plants in the watershed, specifically in the Al Bireh/Mounjez region in Lebanon and Tartous Governorate in Syria. Both countries have sought assistance from international donors for water supply management and hydrological monitoring, and several projects have been initiated. However, these projects are currently on hold due to the crisis in Syria since March 2011.

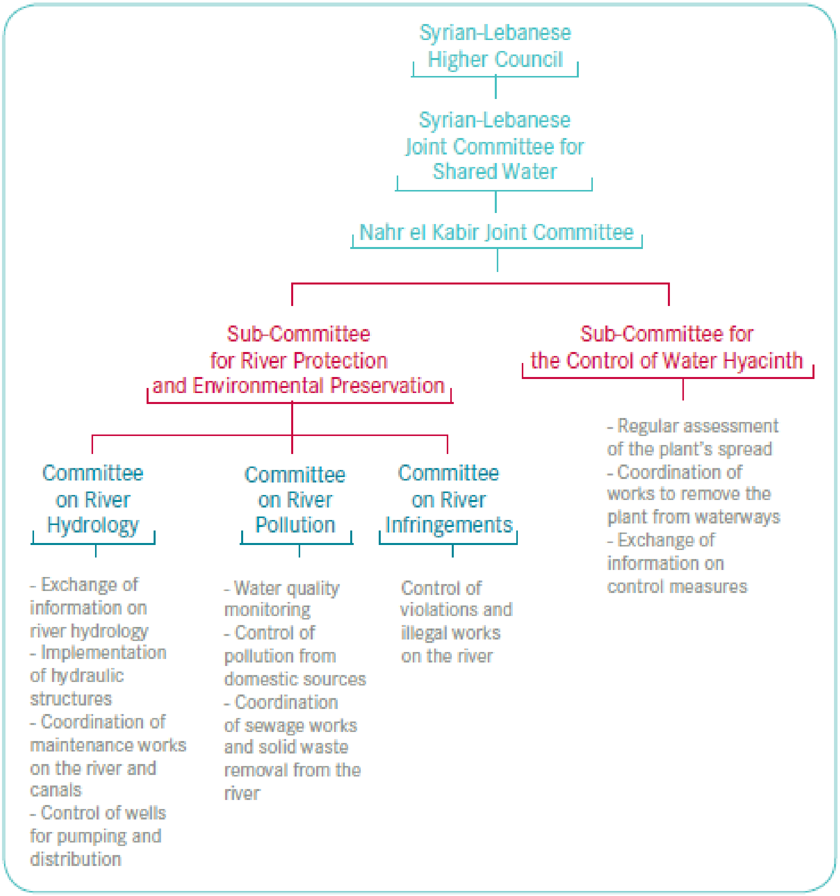

Figure 1: Organizational structure and roles of the Nahr el Kabir joint sub-committees (Source: UN-ESCWA and BGR, 2013)

- Use

Despite the growing socio-economic activity along the main service road connecting Lebanon and Syria, the Akkar region in the Nahr el Kabir Basin remains one of the poorest districts in Lebanon. This has led to increased pressure on the basin's natural resources. The primary source of income in the area is traditional agricultural production, which relies on summer irrigation in the lowland areas. Consequently, an extensive network of irrigation and drainage canals has been developed in the coastal and inner plains. In Lebanon, water usage in the basin is primarily for domestic purposes and irrigation. Currently, there are no dams in the Lebanese part of the basin. The region features two main irrigation schemes: the Bqaiaa Plain covering 990 Ha and the Machta Hassan/Machta Hammoud/Chadra lands covering 730 Ha[67]. If the planned Noura al Tahta Dam is constructed, it would support irrigation for an additional 4,959 Ha in the Akkar Plain in Lebanon and surrounding higher zones, with 3,500 Ha allocated for agricultural reclamation. Syria initiated dam construction in the Nahr el Kabir Basin in the 1980s. Currently, three main dams with a total capacity of 75 MCM have been constructed (Table 1). These dams provide irrigation water for the Bqaiaa Plain and the coastal region through three main irrigation schemes. The Tell Hosh and Khalifah Dams supply water for 6,820 Ha and 700 Ha of farmland, respectively, while the Mzeineh Dam irrigates 4,000 Ha. A pumping station planned at the Ain Farash Spring was thought to deliver 0.25 m^3/s of water for irrigation of 319 Ha in the Bqaiaa Plain. Since 2000, a groundwater irrigation scheme has been in place, utilizing 92 wells with a total yield of 20 MCM per year to irrigate 2,138 Ha. The total irrigated area in the Syrian part of the Nahr el Kabir Basin is estimated to be approximately 13,660 Ha.

Table 1: Constructed and planned dams in the Nahr el Kabir Basin in Syria (Source: UN-ESCWA and BGR, 2013)

Name	Completion year	Capacity (MCM)	Purpose	Background information
Khalifah	1985	3.5	Irrigation	Irrigation of 700 ha.
Tell Hosh	1999	52	Irrigation	Irrigation of 6,820 ha. Water originates from the Farash Spring and the Raweel and Khalifah Rivers.
Mzeineh	2003	19.2	Irrigation	Located on the Mzeineh River. Irrigation of 4,000 ha. The dam was to be supplied with 14 MCM from the Raweel River through a water diversion canal.
Idlin-Noura Al Tahta	Planned	70	Irrigation and flood control	Joint Lebanese-Syrian project. Irrigation of 10,000 ha on both sides of the border. It was also planned to be used for flood management and for domestic and industrial water supply.

- Water quality

In the years 2001-2002, water and sediment samples taken from the watershed indicated significant levels of pollution. High concentrations of nitrate-nitrogen (NO_3-N), phosphates (PO_4-P), and nitrite (NO_2-N) were observed, with particularly extreme levels of phosphates. The pollution originates from settlements within the basin that directly release sewage and solid waste into the river or dispose of it in close proximity[67,76.] Agricultural fertilizers also contribute to nutrient pollution. Moreover, counts of coliform bacteria from sewage waste exceed international guidelines for drinking, irrigation, or bathing purposes. While salinity is not a major concern, the EC values of the river water increase from the upstream area towards the coastal plain due to intensive irrigation practices. Analysis of river sediments revealed higher levels of the DDT parent compound compared to its residual compound DDE, indicating the continued use of this banned substance as an insecticide in agricultural areas within the watershed during the 2001-2002 period. Sediment samples also showed elevated levels of Cr and Ni, suggesting human activities such as small-scale leather tanning and metal plating industries in the watershed contribute to the anthropogenic enrichment. Other pollutants from point sources were identified, including seasonal residues and waste from olive presses in Syria, as well as traces of oil products from fuel tanks in Lebanon[77]. The wide-ranging pollution in the basin poses a risk to groundwater, particularly the shallow aquifers in the Bqaiaa and Akkar/Hamidiye Plains, which are currently being tapped by wells. Certain springs were found to contain nutrients and coliform bacteria, indicating that contamination resulting from localized land use practices upstream may have already reached the aquifer[78]. In the coastal plains, the aquifer lies 15-20 m below the surface in the border area (Table 2).

---

[76] Hassan, S., Thomas, R.L., Shaban, A., Kawass, I. and Khawlie, M. (2005), Phosphorus and nitrogen in the waters of the El-Kabir River watershed in Syria and Lebanon. Lakes & Reservoirs: Research & Management, 10: 109-116. https://doi.org/10.1111/j.1440-1770.2005.00263.x

[77] Thomas, R.L., Shaban, A., Khawlie, M., Kawass, I. and Nsouli, B. (2005), Geochemistry of the sediments of the El-Kabir River and Akkar watershed in Syria and Lebanon. Lakes & Reservoirs: Research & Management, 10: 127-134. https://doi.org/10.1111/j.1440-1770.2005.00267.x

[78] Hamze, M., Hassan, S., Thomas, R.L., Khawlie, M. and Kawass, I. (2005), Bacterial indicators of faecal pollution in the waters of the El-Kabir River and Akkar watershed in Syria and Lebanon. Lakes & Reservoirs: Research & Management, 10: 117-125. https://doi.org/10.1111/j.1440-1770.2005.00265.x

Table 2: Mean salinity, nutrients bacteria and heavy metals in El Kabir river (Source: ESCWA-BGR, 2013, based on Hassan et al., 2005; IDRC, 2003; Thomas et al., 2005)

		SALINITY (µS/cm)	NUTRIENTS (mg/L)			COLIFORM BACTERIA (cfu/100 ml)		HEAVY METALS (ppm)	
		EC	PO_4-P	NO_3-N	NO_2-N	Total coliform	Faecal coliform	Cr	Ni
Region	Upper Kabir	470	8.02	0.58	0.03	173,609	18,684	1,150	375
	Bqaiaa Plain	520	15.82	0.04	0.05	64,056	29,489	702	459
	Chadra	510	15.05	0.03	0.02	39,756	18,177	513	562
	Coastal plain	670	17.64	0.08	0.08	37,500	19,924	686	515
Total range		10-680	0.05-31.4	0-15.6	0-0.15	0-26,999,800	0-1,890,000	443-1,150	306-640
Guidelines[a]		<700 (irrigation)	0.1	0.2	In the order of 0.001	0 (drinking water) 1000 (irrigation) 10,000 (bathing)		120 (world average)[b]	80 (world average)[b]