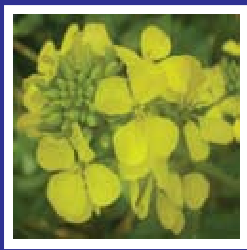
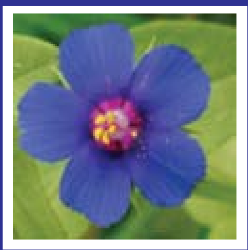
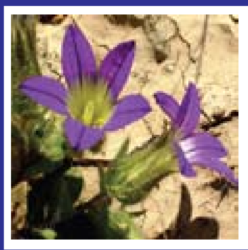
The University of Jordan

Macrofaunal and Floral Species in Jordan and their Use as Environmental Bio-indicators

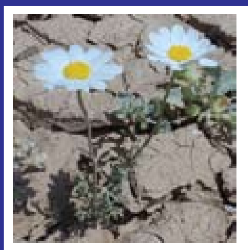
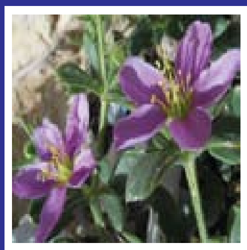
Ikhlas Alhejoj, Klaus Bandel and Elias Salameh



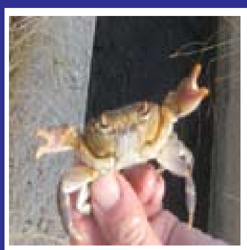






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Preface

This book on macro-faunal and macro-floral species as bio indicators of water quality in Jordan stems from the need to monitor and control the environmental situation in Jordan's surface water resources. It is thought to serve as reference basis of information to compare with it any future quality changes in the composition of surface water bodies which are not routinely analyzed such as pharmaceutical and industrial chemicals, biocides, radioactive substances and many heavy and trace elements.

The use of macro-flora and macro-fauna as water quality bio-indicators is a rapid integrative method to monitor changes in the water quality. It very rapidly tells about changes in the chemical constituents, biogenic content or physical parameters which have taken place in a surface water body as reflected in the appearance or disappearance of species living in the water.

Bio-indicators actually do not tell which water quality parameters have changed. Specifying those parameters requires chemical, biogenic and physical analyses. The use of macro-organisms as bio-indicators differs from collecting a water sample and analyzing it in that faunal and floral species are the result of long-term exposure to water quality. It is an integrative way over time of looking at water quality and changes which have taken place in that quality during last days, weeks or months.

The authors of this book express their sincere thanks to the University of Jordan, Jordan and University of Karlsruhe, Germany for using their facilities in field, laboratory and office work.

Special thanks are extended to SMART Project for sponsoring the book from its budget (BMBF, Bundesministerium fuer Bildung und Forschung).

Hoping that this book will serve its purpose in assisting technical staff, students and scholars of water sciences in their studies and research and hoping it will serve as a basis for studying future changes in the water quality of rivers, lakes, pools and canals in Jordan and in the surrounding countries.

The author

Macro-faunal and -floral species living in and from surface water bodies have been used as water quality indicators since countries. The fact that macro-organisms can serve as water quality indicators may be recognized even by a layman because, for example, not all fish lives in salty water not all fish live in fresh water.

The physical and chemical constituents of a water body give information on the quality of that water. But the large members of chemical substances and physical properties which are found in nature and produced industrially do not allow analyzing water on every possible substance and property, which may cause water quality deterioration.

Contrary to that, macro-organisms are readily recognized in a surface water body. In addition, chemical and physical analyses may take a long time to be carried out, sometimes days and hence, it is not a suitable practical way for fast judging the quality of a water source, especially when that water is being used for drinking purpose, because in such situations of water quality changes (especially in the case of water quality deterioration) fast actions are required before the water reaches users and cause health detriments.

In contrary, living organisms especially faunal species react very rabidly to deteriorating water qualities. They die or migrate if that quality becomes unsuitable for them. Therefore, their use as water quality indicators is superior to chemical and physical water analyses.

In addition, water analyses, for uncommon substance may take days to weeks. For instance, pharmaceutical residues and radioactivity among many other parameters require long procedures for sampling and analyses, whereas, identification of faunal and floral species is momentous.

One of the basic tasks of a water supply is to continuously control the quality of the raw water, because no water purification plant is designed and constructed to deal with all chemicals and physical properties which cause quality deterioration. Generally, only a few substance and properties are analyzed in a routine water control scheme, others are not analyzed. Here, faunal and floral species serve as control in a very effective way.

In addition, long term changes along river course are accounted for when using bio-indicators than using general physical and chemical parameters which are snap-picture wise.

In Jordan, macro-fauna was used as water quality indicator by Bandel and Salameh in 1981 on a relatively small number of wadis in the further surroundings of Amman.

Since that time many changes which affect surface water qualities took place in that study area and elsewhere in Jordan, such as increasing population and urbanization, increasing industrialization and intensified agriculture and the improving living standard of the population accompanied with increasing use of chemicals, such as pharmaceutical products, agro-chemicals industrial chemicals etc.

This look on macro-fauna and -flora as water quality indicators (bio-indicators) summarizes the results of a four years study on macro-fauna and -flora and on the water quality characteristics in which these organisms live in.

Behind this book stands intensive field work in almost all parts and physiographic unit of Jordan.

It adds very much to the old Bandel and Salameh publication of 1981, in terms of the surveyed area, inclusion of floral species and additional faunal species.

Chapter 1

INTRODUCATION

In this work aquatic macrofauna and flora found in different water bodies, springs, creeks/rivers and ponds in Jordan were studied as indicators of water quality. Water, especially, in semi- arid countries, such as Jordan (with unpredictable seasonal rainfall) subjected to scarcity of water and to an ever- increasing demand from the rising human population) represents a great problem for scientist, planner and policy makers. Surface water resources in Jordan can be negatively impacted by development through the addition of urban, industrial, and sewages. So it is important to protect Jordan's surface water resources in order to keep these aquatic systems in a healthy and productive condition reflected in the aquatic life surviving in them.

The aim of the present book is to investigate the occurrence of aquatic organisms in running surface water of springs, creeks, rivers and streams located in the area extending along Jordan, but concentrating on the are extending from River Zarqa in the north to River Mujib in the south to determine correlations of their abundances with various chemical parameters (e,g., temperature, pH, salinity, biological oxygen demand, chemical oxygen demand).

The studied biotas are used as bio-indicators for the quality status of surface water in Jordan. They are describing not only the water quality but also reflect their habitat conditions. The selected size of organisms to be used as bio-indicators is larger than about 0.5 mm, so that they can be seen with the naked eye (macro-organisms). The smallest animals to be considered in this concern belong to the ostracoda, representing tiny crustaceans.

The largest are frogs and crabs. Several groups of animals and plants can be utilized to characterize the quality of water. Annelid worms, the larvae of insects, mites (arachnids, spiders), gastropods and crustaceans may belong to the common aquatic animal species in Jordan. Less common but often quite indicative to specific environments are some sponges, different worms, fish, and decapodan crabs.

In this book the species or groups of species that are characteristic to a certain environment of the water and its degree of pollution will be characterized. Here the specific communities for specific environments such as clean water of different types, weakly to strongly polluted water and water affected by different degrees of salinity will be described and characterized.

Examples will be mentioned for specific places in Jordan. The abundance of aquatic macrofauna depends mainly on the physical and chemical properties of the water they are living in. Further, aquatic organisms are known to respond to changes in the quality of water, which enables their use as bio-indicators.

The term bio-indicator species was used by Kolkwitz and Marsson in 1908 regarding the impact of pollution on aquatic organisms. Because of their extended residency periods in specific habitats and the presence or absence of particular aquatic species in a particular environment, they can be used as bio-indicators of specific environmental and habitat conditions. As stated by Kumar et al. 2006, water condition changes are reflected in the structure and composition of the biotic community as shown by occurrence, diversity and abundance pattern of species.

This statement can be well confirmed in Jordan, for example in Wadi Shueib creek, clean spring water enters a creek, downstream, sewage flow is added to that water from the effluents of Salt treatment plant. This creek, then polluted by wastewater discharged from the sewage treatment plant in Salt area, flows further down the valley with reduced water quality (Oxygen degradation, high amount of organic sludge).

The elevated phosphorus concentration in this creek is reflected in the high growth and reproduction of sewage worms or tubifex worms. Tubificide is an almost certain indication that the water quality has degraded by sewage or other oxygen-consuming organic matter.

Tubificid worms can tolerate water almost totally lacking of oxygen. The wide occurrence of the tubifex has been shown to be a useful tool in the assessment of organic pollution in Jordan.

Aquatic bio-indicators are affected by different kinds of stresses related to water quality, including; Oxygen degradation, direct toxicity, loss of microhabitat, siltation of habitat, food availability changes. The changing water conditions will often produce different aquatic organism communities which can live and survive within the water, for example the presence of nutrient tolerant species (e.g., chrinomidea, tubifex and physa gastropods) associated with organic loading (high nutrient concentrations, high algal growth and low dissolved oxygen) in Wadi Mujib site are observed.
Scientists have traditionally assessed the status of the water quality by measuring physical, chemical and biological parameters (e.g., temperature, chemicals dissolved in the water, nutrients, among others phosphorus, pH, conductivity, aquatic species) but, in later years there has been a global trend to improve the quality control to complement their judgment by the use of biological indicators such as diatoms, macro algae (diatoms are algae- thus distinguishing micro and macro-algae), macro invertebrate or fish.

Using biological indicators to estimate the habitat characteristics and its water quality is vital and is different from measurements of physiochemical character measurements of water quality. Several reasons and advantages can be summarized for the importance of bio-indicators such as:

- Aquatic organisms have limited sensitive range to pollution. Some of these organism species are tolerant where as anothers are intolerant to pollution, so the presence or absences of those organism species give a good sign about the environmental quality analysis and environmental pollution assessment.

- Animals occur in spring, creek, rivers and lake waters with a good number of different species of very different systematic groups.

- Bio-monitoring methods give scientists accumulative information about the water condition for long term changes during the occurrence of those organisms, like a videotape. In contrast, the classical measurements of the physical and chemical parameters characterize the information that was accurate only at the time of sampling, similar to a “snapshot”.

- The long life time of macro-bio-indicators (e.g, worms, insect, and mollusk) could show the water quality conditions and changes taking place for more than one month and sometimes for several years. Whereas, Micro-organisms (e.g, Protozoa, bacteria) reflect the water quality for short periods (some weeks).

- Biological indicator techniques are relatively rapid assessments which take shorter time than chemical testing. Once the bio-indicators are recognized, the quality of the water as well as changes occurring or having occurred can rapidly be assessed.

- Also finally, bio-indicator organism collection and identification techniques are less expensive in comparison to chemical analysis and other methods of water testing. One needs the general knowledge of the biological system to which the animals belong and rapid comparison of species can be carried out with a picture-catalogue in the field. Final species determination for more detailed analysis needs only a microscope.

Biological indicators, in addition, deliver important contributions (under conditions of non-chemical effects) to the ecosystem by indicating organic pollution, toxic and intermittent such as; (eutrophication, sediment loading, thermal pollution) where changes in water quality are not easily detected by chemical means.

Animals and plants in and near the water to be analyzed present additional information which cannot easily be gathered by physical analysis. The quality of a water body is rapidly analyzed by looking at the community of organisms and their numbers. Macro-invertebrates as bio-indicators are widely applied as one of the best biological indicators and have been cited as ideal organisms for biological monitoring studies.

Macro invertebrates offer numerous advantages as bio-indicators. First, macro-invertebrates are a major component of the biological diversity, about 99% of animal species are invertebrates so they are abundant in almost every water body; they are easily caught and can be seen with the naked eye, so macro-invertebrates communities reflect water condition since they are sensitive to changes in a wide array of environmental factors and they play an important role in the process of transport of organic matter, serve in purifying surface water and provide available food source for large animals.

Another advantage of macro-invertebrates is their better suitability as bio-indicator candidates than vertebrates because of their diversity, relatively rapid response to environmental change, and inability to adapt outside of particular physiological constraints.

Bio-monitoring is recognized by Mandaville (2002) as one of the most valuable tools available in the arsenal of environmentalists. He suggested that in order to achieve and maintain the highest water quality in lakes, rivers, and streams, the resident organisms living in these waters can serve as sensitive indicators of change. Bio-monitoring is based on the premise that living organisms are the ultimate indicators of environmental quality. Analysis of the macro-invertebrate communities in water bodies can theoretically be structural, functional, taxonomical and non-taxonomical in approach

Most of the actually used bio-monitoring systems are however structural and taxonomical, what means relying for example on the presence or absence of particular taxa, the sensitivity of particular taxa, the taxa richness, taxa abundance, taxa diversity such as certain indicator groups (e.g. Plecoptera, Ephemeroptera, Gammaridae) and/or indicator species. Earlier bio-indication techniques were purely descriptive or qualitative indicator groups. But since the early 1950, the entire complex biological information converted into numerical form, including indices and scores

Bio-indicator organism techniques were the object of interest of many authors around the words. Several studies have been performed in Europe, USA, Australia and other countries using aquatic biota as bio-indicators in order to monitor the quality of surface water. These model studies are available and the way in which they have been carried out can also be utilized in Jordan.

In Jordan only one study in the early eighties, Bandel & Salameh, 1981, has been carried out where the status of the water resources in Amman-Zarqa area was studied by correlating the hydrochemistry of a water source to its hydrobiology. These authors were able to assign grades of pollution to the different sources ranging from 1 for the best water quality to 10 for heavily polluted water. This study can be utilized for the present work and even improved. Other historical examples of bio-indicators (since the beginning of the twentieth century) using macro-invertebrates to assess water quality and degrees of pollution in rivers subject to sewage contamination can be traced back to the pioneering work of two German scientists, Kolkwitz and Marsson, in the early 1900s. Their publication on saprobity (degree of pollution) led to the development of indicator organisms.

Kolkwitz and Marsson (1902, 1908, 1909) were the first or among the first to exploit these effects and present a practical system for water quality assessment using biota. Their system, known as the Saprobic system, has been used mainly in Central Europe. At the beginning, bio-monitoring was performed on micro-organisms but after a while macro-invertebrates as bio-indicators rapidly gained importance.

In Jordan where water sources are small and rivers in international considerations, except the Jordan River are not found, only small surface water flows of generally few tens to few hundreds of liters per second are found. Such small discharges are vulnerable to small amount of pollutants. Hence, the fast recognition of changes in their quality is very essential for water users, especially, when that water is used as a source of drinking water. As an example on that is the water of King Abdullah Canal (KAC) and its feeding sources, which is used after purification for the drinking water supply of Amman. Pollution events along KAC have taken place more than one time a year since the operation of the drinking water supply from KAC.

The pollution events were not detected before the polluted water reached the inhabitants and caused sickness and public unrest and interruptions in the water supply. The problem was that the water samples collected for quality checks require transportation to the laboratories and rigorous chemical and physical time-consuming analyses. Biological indicator organisms' disappearance or appearance can easily show that something happened to the water quality. It needs only a trained person controlling the canal water. Such application of bio-indicator results can save time, health detriments, trouble in purification plants and social unrest.

The method bases on the use of aquatic fauna and flora in evaluating the quality of the water (Fig. 1.1) This has been done by assessing selected physical characters such as: (water temperature, pH (acidity) and conductivity) which were measured in the field and chemical data such as nitrate, phosphate, hardness (calcium, magnesium and total hardness), BOD (Biochemical oxygen demand) and trace elements (e.g.: Copper, iron, zinc, boron) which were analyzed in the laboratory. Data were assembled from each site from which fauna and flora were collected and determined.

The aim is to use that information to evaluate the water status. The occurances of flora along water bodies which grow under different water conditions were studied in several locations in Jordan including fresh water stystems such as Wadi Hasa, Wadi Shita, Wadi Sir and others while salty environments like Karama dam area, Azraq, Taba in Wadi Araba and Aqaba in the south of Jordan. On the other hand samples of living animals were collected from 50 sites selected from 7 localities, mostly with running water.

The study area extends from north Jordan to its central part (Zarqa River, Wadi Hisban, Wadi Shueib,Wadi Shita, Karama reservoir-area, Wadi Mujib and Wadi Atun) (Fig. 1.2). Organism samples were collected from 2010 to 2014 during the late winter to early spring time, from December to April from the chosen localities. From each selected locality the organisms were isolated and determined according to their place in the taxonomic system as far as possible.

Sampling was generally carried out with a sieve of 0.5 mm but also coarser nets were applied. Water plants and rocks were washed in a screen. Those aquatic animals that cling to rocks, boulders, aquatic plants and often found under the rocks were collected with a pair of forceps and were brushed off. The living organisms were handled with care in order not to damage them and they were carried to the laboratory in sufficient amounts of fresh water from the site.

Also freshly collected animals were placed in alcohol right in the field as to preserve their skeletal characters in well conditions. After study in the laboratory, selected individuals were placed in 70% ethyl alcohol. In some cases the organisms stack in sieves, on plants or on fine sediments so they were rinsed carefully in order not to lose them. For example in Ostracods collection method, after collection, the samples were transferred into plastic bottles. The bottles were sealed, labeled and placed in a cool box with cold temperature condition for transport to the laboratory.

In the laboratory, the material was searched for aquatic organisms which were then placed into beakers and dishes containing water from the same sampled site and 70% alcohol added for identification. Aquatic biota sample analysis includes taxonomic identification. Freshly collected organisms in the laboratory were documented by using S6 D Leica stereomicroscope with magnification of 6.3x to 40x, connected to a digital camera. The collected organisms were determined according to their place in the taxonomic system as far as possible. Taxonomic determination of the sampled organisms to species level was based on the literature, and regarding the diatoms on palynological studies while ostracod samples were determined by Steffen Mischke, Free Berlin University. Mayfly larva determination was done by Jean-Luc Gattolliat, Museum of Zoology (Switzerland).

Figure 1.1: Sampling and analysis of aquatic macro organisms.

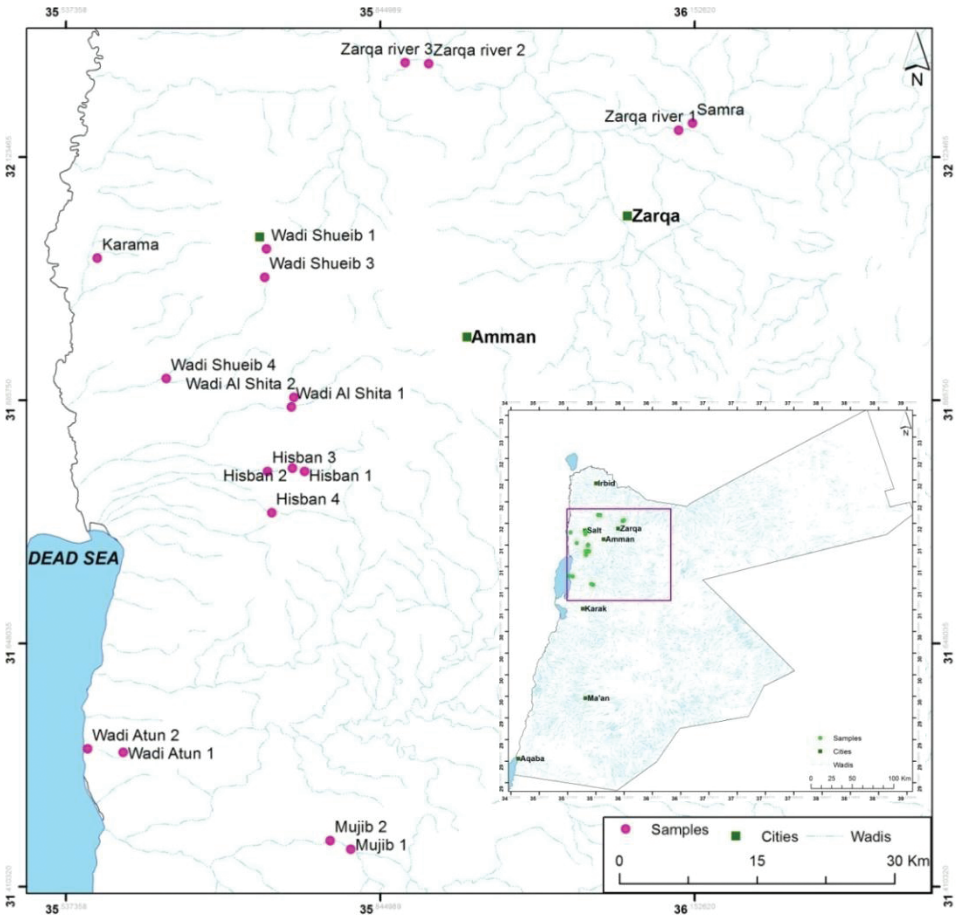

Figure 1.2: Locations of animal samples, which covers wadis pouring into the Jordan Valley and the Dead Sea, extending from Zarqa River in the north through Karama reservoir-area, Wadi Shueib, Wadi Hibsan, Wadi Shita, and Wadi Atun to Wadi Mujib in the south.

Chapter 2

HYDROLOGY OF JORDAN

2.1 Background of Jordan

- **Topography**

The country consists of different distinctive topographic units trending in a general north-south direction. These units seem to be dictated by a major geologic event which incorporates rifting along the Jordan Valley - Dead Sea - Wadi Araba - Red Sea line, which, during the last few tens of millions of years, has led to the formation of the rift valley along the same line, with the corresponding highlands on both sides, sloping in Jordan to the steppe in the east (Fig. 2.1).

The rift valley forms the western part of the country. It trends in a general south-north direction from the Gulf of Aqaba through the Dead Sea to Lake Tiberias. The elevation of the bottom of the valley ranges from sea level in Aqaba at the shores of the Red Sea to around 240 masl at a distance of 80 km to the north. From there it drops gradually to about 400 m BSL at the present shores of the Dead Sea and further to around 750 masl at the bottom of the Dead Sea, (Emery and Neev 1967). To the north of the Dead Sea, the floor elevation rises gradually to around 210 masl at the shores of Lake Tiberias. This rift valley, with a length of 375 km, is about 30km wide in the area of Wadi Araba and narrows to around 4km in the Lake Tiberias area.

The highlands east of the Jordan rift valley rise to elevations of more than 1000 masl in the north at Ajlun and Balqa mountains and to more than 1200 masl in Shoubak and Ras El Naqab areas. The width of this zone ranges from 30 to 50 kms and extends from the Yarmouk River in the north to Aqaba in the south. These elevations drop gradually to the plateau in the east, but more sharply to the rift valley in the west. The mountains forming the highlands consist mainly of sedimentary rocks with deeply incised wadis draining in a westerly direction.

The steppe or plateau of Jordan developed at the eastern toes of the highlands with elevations of drainage areas ranging from 1000 masl in the south to 700m in the northeast. The deepest part of this plateau lies at an elevation of 500 masl; Azraq Oasis.

The plateau is a peneplain with hills and weakly incised wadis, but generally a smooth topography. Surface water, if not captured by westerly draining wadis, discharges into desert playas or Qaas forming extended shallow lakes in winter and dry mud flats in summer.

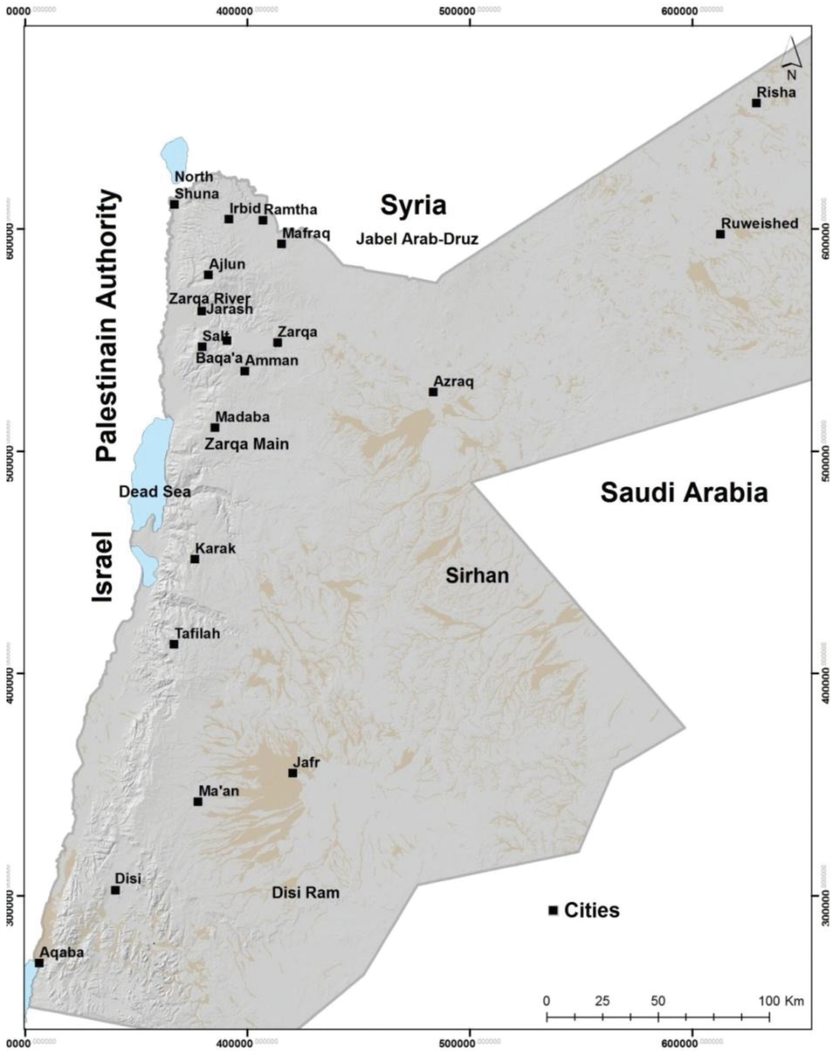

Figure 2. 1: Location map of Jordan with major cities and sites.

Jordan Rift Valley, Wadi Araba Rift Valley, Highland Plateau, and Pan Handle

The north eastern part of the country "the pan handle" is a flat plateau with a very smooth topography which rises from 500 masl in Azraq area to about 900 masl at the Jordan-Iraq border (Fig. 2.2). It is interrupted by volcanic mountains which rise to about 150 m above the plateau level.

The southern desert forms also a flat area intersected by partly deep incised wadis. The topography rises in its south western parts to more than 1500 masl (Aqaba Mountains).

The most southern part of the plateau, which lies to the south of the Ras El Naqab escarpment, is considered a different topographic unit, although it belongs to the same plateau. This is because it is separated from the plateau by the prominent topographic feature; the escarpment, because it drains to the Red Sea and because of its steep topography dictated by a different geology consisting of sandstones and a granitic basement complex. The elevation of the area is around 900 masl, with a north-south width of around 100 kms. This part of the country is sometimes referred to as the southern desert. It is strongly dissected by wadis with very rough topography in the western part and smooth topography in the eastern part.

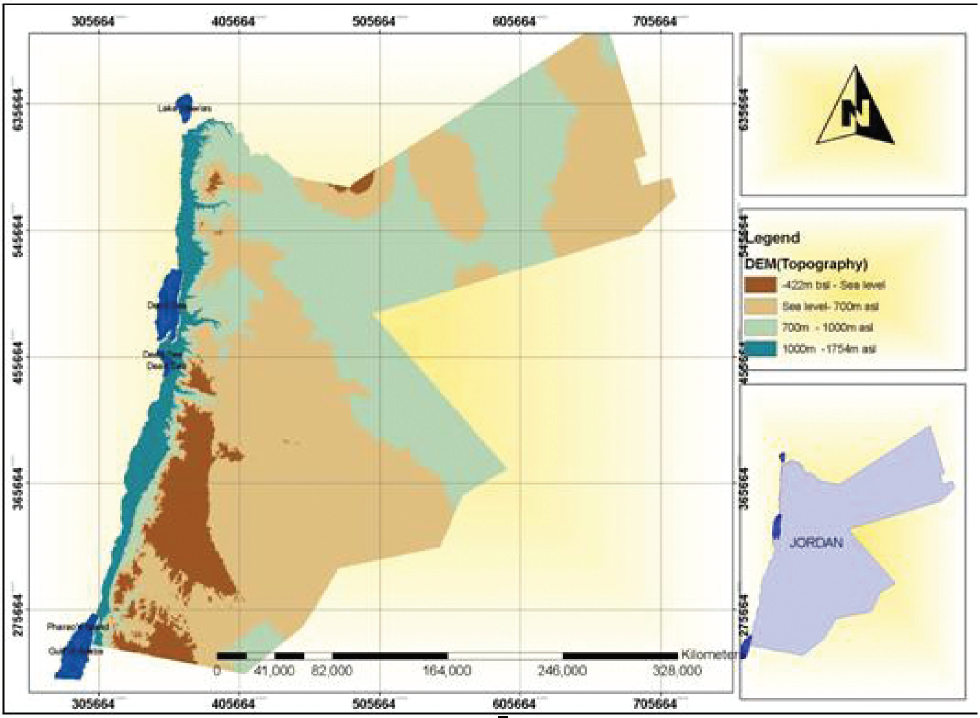

Figure 2.2 : Main Topographic Zones in Jordan (MWI, open files)

- **Climate**

Jordan can be classified as a semi-desert area. Only the highlands, with a width of around 30 km and a length of some 300 km, enjoy a Mediterranean type climate.

Temperatures in the Jordan Valley, Wadi Araba and Aqaba can rise in summer to 45➡C with an annual average of 24➡C. In winter the temperature in this area reaches a few degrees above zero. Frost is a seldom event.

Along the highlands the climate is relatively temperate; cold and wet in winter with temperatures reaching a few degrees below zero during the night, to hot and dry in summer with temperatures reaching 35➡C at noon, but with a relative humidity of 15-30%, which makes the heat more acceptable. During the hot summer, temperatures at night drop to less than 20➡C and cause dew to form.

The plateau; the eastern and southern deserts are hot in summer and cold in winter. The temperature may reach more than 40➡C during summer days and drop in winter to a few degrees below zero, especially during the night. Also here, the relative humidity is low. In winter it is generally around 50-60%, and in summer it sometimes drops to 15%.

The low relative humidity throughout most of the year makes the hot summer days more tolerable and the cold winter days more severe.

Precipitation

Precipitation (ppt) in Jordan falls normally in the form of rainfall. Snowfall occurs generally once or twice a year over the highlands. The rainy season extends from October to April, with the peak of precipitation taking place during January and February. These peaks become less pronounced the scarcer the rainfall an area receives.

The highest rates of precipitation fall over the highlands of Ajlun, Balqa, Karak and Shoubak which receive long-term annual averages of 600, 550, 350 and 300 mm. To the east of these highlands, and more strongly to the west, precipitation decreases drastically (Fig 2.3), e.g., it decreases from an average of 600 mm/year in Ajlun to 250mm/year in the Jordan Valley within a distance of 10 kms and a difference in altitude of 1200 m. The decrease in easterly direction is twice to three times slower than to the west; e.g., from 300 mm/year in Shoubak to 50 mm/year, some 30 kms east of the town.

A part of the precipitation water form floods that flow in wadis, and either collects in dams or in desert playas. Another part infiltrates and joins the groundwater resources of the country.

The dry climate, the atmospheric dust and the low intensity of precipitation affects also the quality of precipitation water, generally reflected in increasing salt contents.

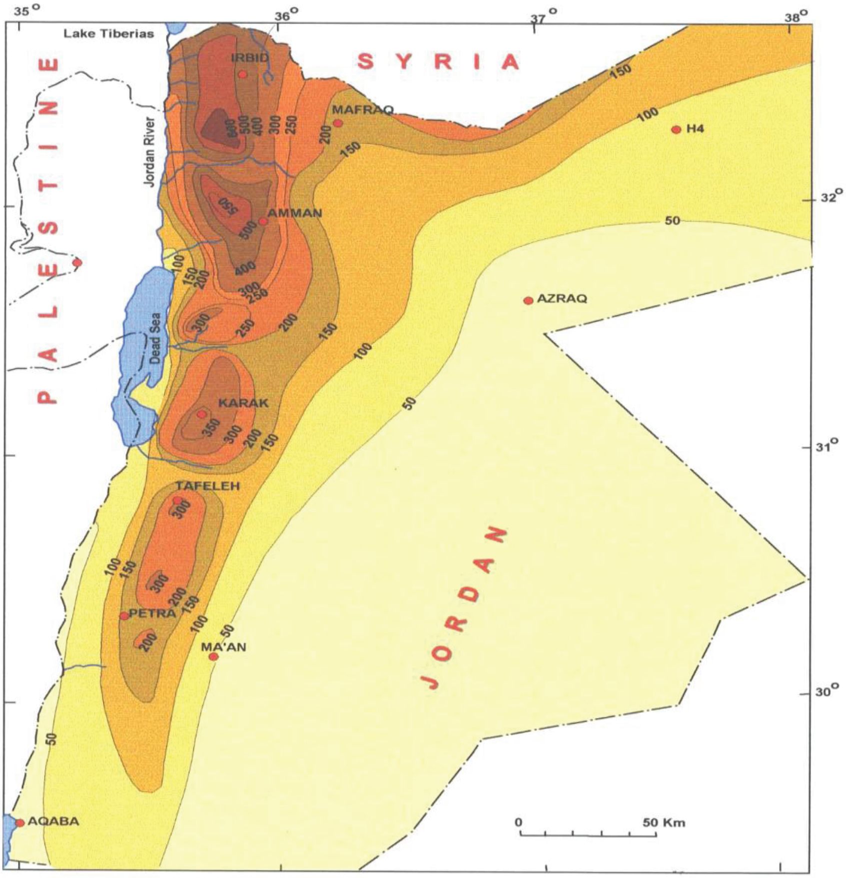

Figure 2.3: Rainfall Distribution in Jordan mm/yr. (50 – years Average, MoWI Open files).

- **Evaporation:**

The climatic conditions in Jordan do not only affect the amount and distribution of precipitation, but they also impact strongly on the potentials of evaporation. The potential evaporation rates range from about 1600 mm/year in the extreme north western edge of the country, to more than 4000 mm/year in the Aqaba area. Along the rift valley the potential evaporation increases from a minimum of 2000 mm/year in the north, to some 2500 mm/year in the Dead Sea and to more than 4000 mm/year in Aqaba. These rates are 5 to 80 times the average amounts of precipitation falling over these areas. Potential evaporation rates of the plateau areas increase in easterly and southerly directions: from an average of 3000 mm/year at the eastern toes of the highlands to around 4000 mm/year in the centre of the plateau. The southern rates are 3500 to 4400 mm/year.

Potential evaporation rates of the plateau and southern desert are 12 to 100 times the amount of precipitation falling over these areas.

The high evaporation potential all over the country makes precipitation, especially in the eastern and southern parts of the country, ineffective because precipitation water readily evaporates, leaving soils deprived of their moisture content and hence, not allowing for the development of plants. The high evaporation rates and the low precipitation amounts lead generally to salt concentrations of the water which increases the salinity of infiltrating water.

2.2 Water Resources of Jordan

- Surface Water Resources

Jordan does not possess rivers in the world-wide known scale, except the Jordan River which used to discharge around 1400 MCM/year into the Dead Sea before the development of the water resources in its catchment. Even this river is a very small source compared with international rivers like the Nile or Euphrates, because its total annual discharge amounts to only 1.5% of the former and 4.3% of the latter.

Other surface water resources in Jordan are found in the Yarmouk and Zarqa rivers and in wadis like Karak, Mujib, Hasa, Yabis and El-Arab, in addition to flood flow wadis in the different parts of the country. The main surface water flow directions are illustrated in Fig. 2.4. A summary of surface water resources in Jordan is given in Table 2.1.

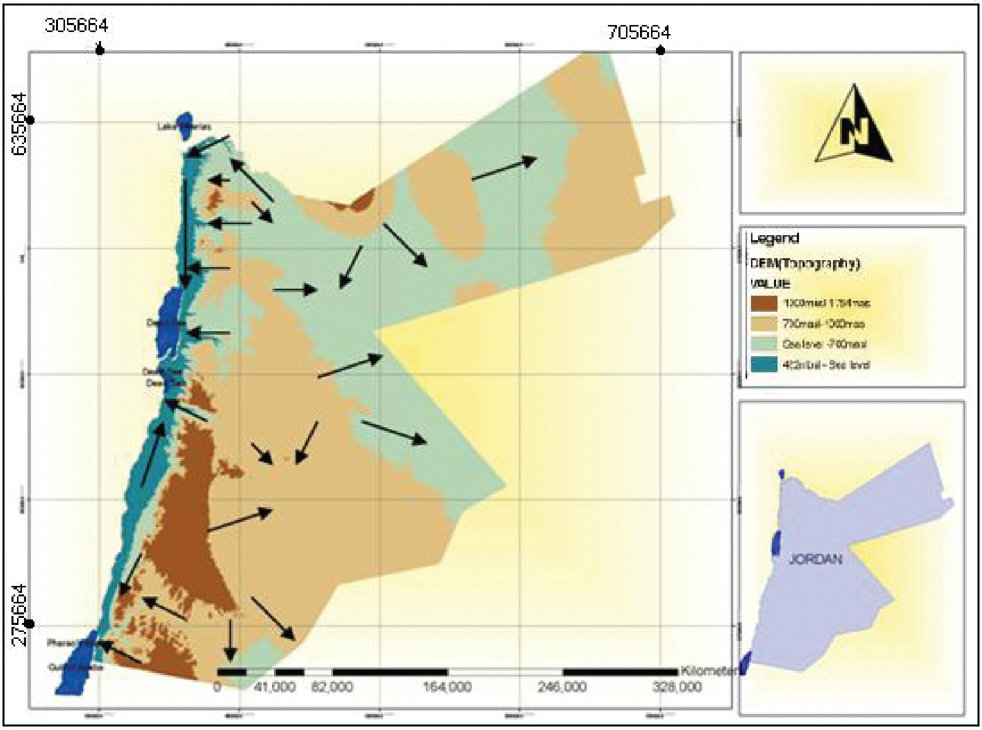

Figure 2.4: Main Flow Pattern of Surface Water in Jordan-indicated by arrows- (MWI, open files).

Table 2.1: Surface water resources in Jordan: Natural system before development (theYarmouk River before the rigorous Syrian extractions starting in the 80s of the last century) in MCM/yr.

Surface Water Basin	Base Flow	Flood Flow	Total Flow
Yarmouk at Adasiya	130	155	285
Jordan Valley	19.30	2.4	21.70
Northern Jordan River side wadis:	36.07	13.90	49.98
Inter-catchments	23.7	4.54	
Wadi Arab	1.49	5.00	
Wadi Ziglab	7.68	0.23	
Wadi Jurum	10.27	0.2	
Wadi Yabis	2.62	1.63	
Wadi Kufranja	5.88	1.00	

Wadi Rajib	3.42	1.31	
Southern Jordan River side wadis:	24.76	5.85	30.34
Inter-catchments	1.4	2.13	
Wadi Shueib	5.6	1.8	
Wadi Kafrain	13.44	1.35	
Wadi Hisban	4.32	0.3	
Zerqa River	33.51	25.67	59.18
Dead Sea	53.95	7.2	61.15
Inter-catchments	29.88	1.03	
Zerqa Ma'in	17.74	3.00	
Karak	6.33	3.17	
Mujib	38.10	45.54	83.64
Hasa	27.40	9.04	36.44
Wadi Araba North	15.63	2.57	18.20
Inter-catchments	3.90	0.19	
Wadi Feifa	11.74	0.26	
Wadi Khanzira	3.76	0.42	
Wadi Dahal	0.03	0.23	
Wadi Fidan	3.34	0.38	
Wadi Buweirda	0.88	0.16	
Wadi Musa	0.88	0.7	
Wadi Howr	0.09	0.23	
Wadi Araba South	2.44	3.16	5.6
Inter-catchments	1.84	0.80	
Wadi Abu Burqa	0.60	0.37	
Wadi Roulaia	0.0	0.19	
Wadi Yutum	0.0	1.8	
Southern Desert	0.05	2.15	2.2
Azraq	0.6	26.8	27.4
Sarhan	0.0	10.0	10.0
Hammad	0.0	13.0	13.0
Jafer	1.92	10.0	11.92

- **Ground Water Resources in Jordan**

The groundwater aquifers of Jordan are divided into three main complexes, (Table 2.2& Fig. 2.5).

- Deep Sandstone Aquifer Complex.
  This complex forms one unit in southern Jordan. To the north, gradually thick limestone and marl formations separate it into two

aquifer systems which, nonetheless, remain hydraulically interconnected.

- Upper Cretaceous Aquifer Complex. This complex consists of an alternating sequence of limestone, dolomite, marl stone and chert beds. The total thickness in central Jordan is about 700m. The limestone and dolomite units form excellent aquifers.

- Shallow Aquifer Complex. It consists of two main systems:

i. Basalt Aquifer:

Basalts extend from the Syrian Jabel Druz area southward to the Azraq and Wadi Dhuleil region, forming a good aquifer of significant hydrogeological importance. The recharge to this aquifer system is provided by precipitation in the elevated area of Jabel Druz. From there the groundwater moves radially to all directions. Geological structures favoured the formation of three main discharge zones namely, the upper Yarmouk River basin, the Wadi Zarqa basin and the Azraq basin.

ii. Sedimentary Rocks & Alluvial Deposits of Tertiary and Quaternary Ages:

These rocks form local aquifers overlying partly the previously mentioned aquifer complexes or are separated from them by aquitards. They are distributed all over the country, but are mainly concentrated in the eastern desert, Wadi Araba - Jordan Valley, Jafr Basin and the Yarmouk River area. Recharge takes place directly into these aquifers themselves or via the underlying basalt aquifer, as in the case of the Azraq basin, or from the surrounding aquifers, like the cases of the Jordan and Wadi Araba valleys.

The groundwater flow in this system, in the eastern desert, is directed radially towards the Azraq oasis and towards El-Jafr depression from the west and south of the basin. The groundwater flow in the main valley fills depends on the underground conditions. But it mainly takes place from the escarpments into the valley deposits.

Table 2.2: Ground Water Resources in Jordan (MWI, open files)

Ground Water Basins	**Safe Yield MCM/ year**
Yarmouk Basin	40
Side Wadies Basin (North Jordan Valley Basin)	15
Jordan Valley Basin	21
Amman-Zarqa Basin	87.5
Dead Sea Basin	57
Northern Wadi Araba Basin	3.5
Southern Wadi Araba Basin	5.5
Al Jafer Basin	9 Renewable 18 Fossil
Azraq Basin	24
Al Sirhan Basin	5
Al Hammad Basin	8
Disi	125 Fossil
Total	**418.5**

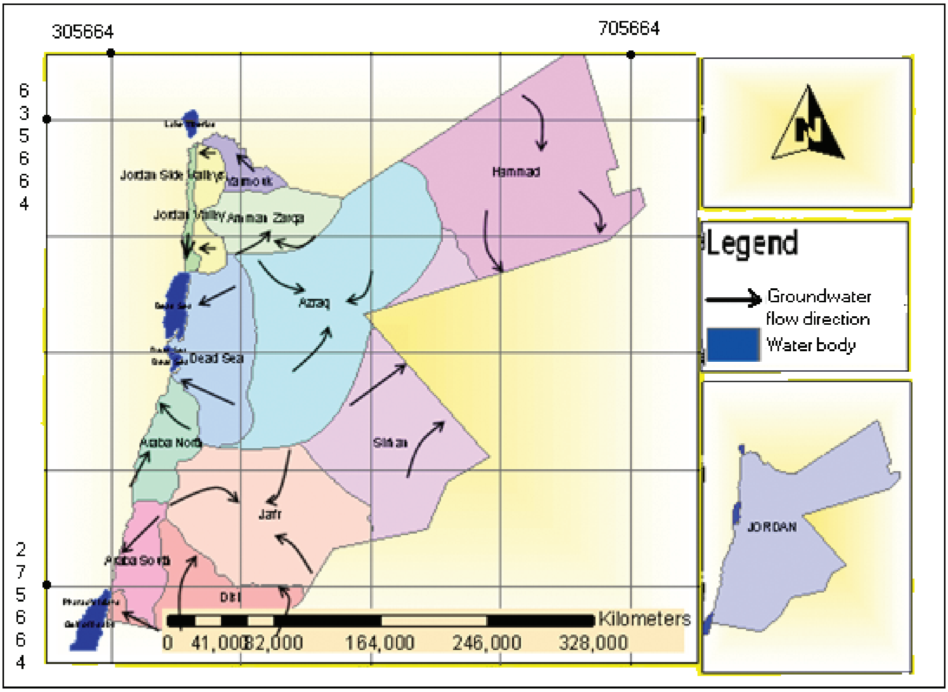

Figure 2.5: Main Groundwater Basin and Groundwater Flow Directions (MWI.open files)

Chapter 3

WATER POLLUTION IN JORDAN

3.1 Introducation

Two issues should be clearly and strictly separated from each other when considering the quality of a water source.

A. Natural water quality: water characteristics as affected by natural conditions.
B. Water quality as affected by human activities: changes on the original water qualities due to human activities of urbanization, industrialization, agriculture and building of structures.
   For any type of water use the water quality issue is as vital as the water quantity or availability itself.

3.2 Natural Water Qualities

- **Precipitation**

Generally, precipitation water in Jordan has salinities ranging between 30 µS/cm and rarely more than 350 µS/cm. It has pH values of more than 5.6; which is the biogenic pH value. This means that precipitation water contains high concentrations of dissolved substances as a result of dust in the atmosphere which also neutralizes any acidic, low pH gases and that the country is not affected by any type of acid rain.

Pollution in precipitation water is only found in Amman, (traffic), in Zarqa (industry), in Hashimiya (refinery and thermal power station), in Fuheis and Rashadiya (cement factory, dust), in Hasa (phosphate dust) and in Safi Potash dust.

- **Flood flows**

All over the country floodwaters, which have generally only short contact times with the country rocks, contain small concentrations of chemical components, their physical properties; pH-values, temperatures, dissolved oxygen and electric conductivities and their biological contents indicate natural conditions. Therefore, they can be considered good quality waters after the settlement of their turbidity .

The floodwater salinities expressed in EC units range from 123 to 530 µs/cm, depending on a variety of factors such as precipitation water quality, rock and soil types covering the catchment areas, their topographic features, rainfall, ground surface temperatures, and land use (Table 3.1).

Table 3.1: Flood flow composition along the plateau wadies (Da.: Daba, Qas: Qastal, Rw: Rweished, Saf.: Safawi Kh.: Khalidiya, Ma.: Mafraq, Mu.: Muwaqqar, Azr.: Azrqa, Yut.: Yutum, Shi.: Shidiya). (All chemical measurements in meq/l except NO_3 and PO_4 in mg/l and EC in µS/cm).

Parameter	Da	Qas	Zizya	Rw	Saf	Kh	Ma	Mu	Azr	Yut	Shi
EC	123	212	233	229	218	291	220	186	214	135	130
pH	8.55	8.53	8.55	8.25	8.43	7.76	7.8	8.48	7.7	8.21	8.27
Ca	1.2	1.53	1.73	1.9	1.28	1.8	0.59	1.1	1.18	0.74	1.30
Mg	0.4	0.69	0.72	0.4	0.19	0.26	0.45	0.2	0.20	0.13	0.35
Na	0.27	0.92	0.41	0.31	0.75	0.92	1.08	0.93	0.94	0.25	0.62
K	0.22	0.05	0.05	0.09	0.05	0.18	0.13	0.11	0.13	0.01	0.16
Cl	0.15	0.4	0.60	0.4	0.35	0.22	0.2	0.23	0.4	0.35	0.60
SO_4	0.35	0.39	0.94	0.41	0.24	0.2	0.23	0.25	0.34	0.10	0.38
HCO_3	1.55	1.82	1.46	1.91	1.35	2.45	1.57	1.94	1.65	0.76	1.52
NO_3	0.54	10.2	13.8	2.1	4.2	4.8	16.2	6.8	7.2	2.4	3.2
PO_4	2.8	0.92	0.62	0.16	0.09	0.96	0.61	0.72	0.81	0.00	0.62

- **Base flows and Groundwater**

The base flow of a water course consists of spring discharges and other seepages within the catchment area of that water course. Hence, its characteristics reflect, to a certain degree, the qualities of the groundwater underlying the drainage area.

According to their quality characteristics different groups of base flows are found in Jordan.

Group I: Base flows and groundwater suitable for all common uses.

Such groundwaters are discharged from springs all over the country generally at elevations of 100 m ASL and higher. The water flows then along the different wadis in the area extending from the Yarmouk in the north to Ras-en-Naqab in the south.

Springs along the Yarmouk River, Wadi El-Arab, Ziqlab, Kufranja, Rajib, Yabis, Zarqa River, upstream of King Talal Dam, of Shueib Dam, of Kafrain Dam and of Hisban diversion dam, Udheimi, Zarqa Ma'in, Shqiq, Mujib, Wala, Hasa upstream of the thermal spring discharges, Tafilah, Shoubak, Finan and Gharandal discharge fresh base flows with low salinity and normal chemical composition suitable for all common uses.

Table 3.2 shows some examples of spring and baseflow discharges of waters suitable for all common uses.Generally, the EC is less than 1500 µS/cm; none of the other parameters has a higher concentration than recommended by the WHO or by Jordanian standards for drinking water. Slightly elevated nitrate, calcium, chloride and phosphate concentrations indicate some type of domestic pollution. (Ya. R: Yarmouk River, Kuf: Kufranja, Abd: Abdoun Ras El-Ain, Z. R: Zarqa River Jarash Bridge, Z. M: Zarqa Ma'in.

Para-meter	**Ya. R**	**Yabis**	**Kuf**	**Abd**	**Z. R**	**Hisban**	**Z. M**	**Mujib**	**Karak**	**Hasa**
EC	530	430	307	160	392	235	182	183	165	301
pH	7.91	8.37	8.05	8.42	8.01	7.97	8.36	7.78	7.98	8.38
Ca	1.9	2.87	2.46	1.6	2.36	1.58	1.00	1.02	1.16	1.60
Mg	1.4	1.43	0.59	0.2	0.32	0.29	0.40	0.42	1.57	0.20
Na	1.70	0.95	1.03	0.29	1.22	0.53	0.59	0.58	1.12	1.02
K	0.15	0.17	0.41	0.08	0.16	0.10	0.13	0.10	0.22	0.09
Cl	1.58	1.10	0.4	0.25	1.20	0.50	0.23	0.27	0.78	0.39
SO4	0.85	0.84	0.63	0.41	0.74	0.16	0.13	0.16	1.04	2.04
HCO3	2.97	2.91	2.99	1.42	2.04	1.72	1.73	1.82	2.66	2.04
NO3	18.5	18.2	13.4	5.3	18.0	9.2	4.80	5.8	4.2	6.6
PO4	0.73	0.12	1.37	0.55	0.53	0.38	0.84	0.252	0.24	0.87

Group 2: Water with high salinities and or high temperatures

Such waters are found naturally in Jordan (Table 3.3). According to their salinities and other properties such as temperature, pH, presence of certain gases (carbon dioxide, radon, hydrogen sulphide) or certain elements at a high concentration, e.g., iron, manganese and others, these waters are differentiated into several subgroups.

Table 3.3: Spring and base flow discharges along the upper reaches of wadis, unaffected or very slightly affected by domestic type of pollution

Parameter	Yarmouk River	W.El-Arab	W. Ziqlab	W. Yabis	Ras El-Ain Zarqa R.	Zarqa Ma'in*	Hisban	Bahhath	Mujib	Karak	Hasa
EC µS/cm	980	820	665	844	780	618	540	530	712	784	1424
pH	8.15	7.8	7.72	8.57	7.7	7.3	7.50	7.45	8.40	7.97	8.49
Ca meq/l	3.06	5.0	2.9	2.66	5.02	3.9	3.66	2.97	3.50	1.96	3.35
Mgmeq/l	2.56	2.6	2.6	2.56	0.75	1.7	2.08	1.29	2.10	1.68	5.71
Nameq/l	4.10	2.28	1.13	3.60	1.22	1.00	0.76	0.67	2.40	4.1	5.52
K meq/l	0.17	0.10	0.02	0.10	0.10	0.04	0.05	0.04	0.18	0.24	0.13
Cl meq/l	3.10	2.15	6.65	2.7	1.87	1.72	0.98	1.23	2.08	3.85	6.0
SO_4 meq/l	1.64	1.6	0.57	1.75	0.12	0.6	0.23	0.19	1.23	1.84	2.65
HCO_3meq/l	4.38	5.11	4.2	3.60	6.01	3.52	4.79	3.06	3.78	1.96	4.72
NO_3mg/l	23	21	12	11.8	20	28	24	27	15.0	13.5	11
PO_4mg/l	0.35	0.38	0.11	0.17	0.32	0.17	0.27	0.03	0.025	0.86	0.016

*Zarqa Mai'n,Upper Reaches

<u>Waters with high salinities:</u>

Examples of that are the discharges of the Jordan River, Wadi Mallaha, Azraq area, and generally, the deep groundwater in the country. These waters', according to their salinities, have only a limited range of uses. If their salinity is low enough, 1500 µs/cm up to 4000 µs/cm, they can be used to irrigate salt semi-tolerant or tolerant crops. But, if their salinities are higher, then they cannot even be used for those purposes. Nonetheless, they can serve as a source of raw water to be desalinated or mixed with fresh water to be used for different purposes. Table (3.4) shows the examples of the composition of such water. The salinity of brackish and saline water ranges from the upper limit of fresh water salinity of ca. 1500 µs/cm up to 18000 µs/cm in Wadi Mallaha. The major constituents such as Ca, Mg, Na, Cl, and SO_4 are the main parameters contributing to salinity. In Wadi Mallaha and Karameh Society well, both in the Jordan Valley and in Sumaya Spring (Zarqa River), irrigation return flows or domestic type of pollution or both canbe concluded from the higher nitrate contents. This type of water can partly be used to irrigate salt-tolerant crops, or it can be mixed with fresh water for general irrigation purposes, or it can serve as a source of raw water for desalination.

Table 3.4: Chemical analyses of waters with high salinities in the different parts of the country

Parameter	Jordan River*	Wadi Mallaha	Wadi Araba UM-3	Sumaya Spring Zarqa River	Omari Well 2 Azraq	Jafr Well 17	Reasheh W.2 Hamad	Karameh Society Valley
EC µS/cm	8810	18100	5300	2250	2430	5790	4330	4100
pH	8.26	7.62	6.63	7.00	8.0	7.8	7.4	7.4
Ca meq/l	28.10	34.0	13.03	5.81	7.15	16.7	12.05	9.1
Mg meq/l	12.28	50.0	9.19	8.28	7.75	17.5	14.0	13.0
Na meq/l	42.7	117.2	16.12	9.70	9.48	23.69	20.17	17.70
K meq/l	2.39	5.54	0.21	0.36	0.3	0.5	0.3	0.55
Cl meq/l	73.75	147	29.84	14.39	12.57	46.86	19.68	31.94
SO4 meq/l	6.94	59.6	4.255	3.08	7.85	8.10	26.67	3.40
HCO3 meq/l	4.02	3.96	1.0	5.02	3.75	3.32	7.13	4.20
NO3 mg/l	24	60	6.5	75	3.5	20	2.1	42

* Jordan River, King Hussein Bridge, Dry Season.

Water with high salinity and elevated temperature

This type of water results from deep percolation of infiltration water and from very long contact times with the aquifer matrix, undergoing oxidation/reduction processes. Such water, due to its temperature of more than 5°C above the ambient temperature can be classified as curative water. It is generally found along the slopes overlooking the rift valley. Examples of this type of water are the springs of Zarqa Ma'in, Zara, Mujib, Deir-Allah, Abu Thableh and the wells of Hisban, and Abu Ziad. Table (3.5) gives the composition of such waters and some of their therapeutic agents. Generally, these waters have salinities of more than 1500 µs/cm, a temperature of more than 33°C. Gases such as CO_2, H_2S and radon are discharged with the water. These characteristics and composition allow the water to be classified as thermal-mineralized water with therapeutic properties.

Table 3.5: Composition of the thermal water with high salinity. (All chemical measurements in meq/l except NO_3 and PO_4 in mg/l and EC in µS/cm). Z.M: Zarqa Ma'in Shallala, Sp.: Spring, H. T: Hisban Thermal W., D.ALL: Deir-'Alla Spring, AB.T: Abu-Thaleb Spring, AB.Z: Abu-Ziad Well.

Parameter	**Z.M**	**Zara Sp. 40**	**H.T**	**D.All Sp**	**AB.T Sp**	**AB.Z Sp**
EC	3050	1786	4190	3440	1928	2300
pH	6.8	6.3	6.37	6.5	6.82	6.9
Ca	7.39	4.58	11.84	12.5	7.6	7.25
Mg	2.82	1.90	8.87	8.84	4.3	4.17
Na	14.13	7.86	29.02	13.61	7.74	10.96
K	1.30	0.63	2.40	0.75	0.38	0.40
Cl	19.07	9.26	28.05	18.45	9.30	11.71
SO_4 meq/l	4.31	2.77	7.37	12.10	4.03	4.4
HCO_3	3.00	2.84	13.10	6.58	7.65	6.33
NO_3 mg/l	0.00	0.00	2.5	0.0	0.00	0.02
T c°	55.0	53.5	33	36	36.8	50.2
Rn nci/l	14.25	25.5	4.3	1.7	15.65	17.3
H_2S mg/l	0.18	0.04	Smell	smell	Smell	0.5

Water with low salinity and high temperatures

Thermal water discharges are not restricted to saline or brackish springs. Many springs along the slopes overlooking the rift valley discharge fresh thermal water. The temperature may reach more than 50°C, but the salinity remains less than 1500 µs/cm.

Such water presents a source for all common uses after some cooling and aeration. Table (3.6) shows the composition of thermal water springs and wells with low salinities. Radon and H_2S gases can easily be removed by aeration, which makes the water potable.

Table (3.6) Composition of thermal water with low salinities. (All chemical measurements in meq/l except NO_3 in mg/l, Rn in nci/l and EC in µS/cm). (Ibn. H: Ibn Hammad Upper, Sp.: Spring, Himm: Himma Spring Yarmouk River, N. Sh: North Shuna Therm spring, Man: Manshiya).

Para-meter	**Afra Sp**	**Weidaa Sp**	**Ibn.H**	**Himm**	**N.Sh**	**Man Well 2**
EC	545	610	847	1320	863	735
pH	6.96	6.5	6.8	6.98	7.06	6.34
Ca	2.17	3.80	4.2	6.21	4.08	3.4
Mg	1.40	1.21	2.42	2.7	3.66	3.25
Na	1.48	1.68	2.57	5.87	3.31	0.91
K	0.02	0.21	0.10	0.44	0.21	0.06
Cl	1.68	2.48	4.51	6.03	2.81	1.03
SO_4	1.35	1.77	2.44	3.45	1.76	0.90
HCO_3	1.98	3.00	3.05	5.54	6.38	7.33
NO_3	0.00	0.0	0.0	3.10	1.24	0.0
T C°	45.9	33	37	41.4	52.7	54.3
Rn	7.38	2.86	5.9	31.46	2	16.5
H_2S	0.0	0.0	0.0	2.8		5.83

In summary the natural water resources quality can be described as follows:

All floodwater resources in Jordan have high qualities but they generally suffer of turbidity which requires settlement or filtration to remove silt particles. All renewable water resources (in their natural states) along the highlands and on the plateau are of high quality with low salinity and circum neutral pH values. The natural groundwater qualities in the intermediate and deep aquifers with a free water table are of high quality with low salinity and circum neutral pH values.

The natural groundwater qualities in the Jordan Valley are also suitable for all common uses except when they are in contact with the salty deposits in the valley such as the Lisan Formation, salt bodies, or originate from Triassic and Jurassic rocks.

The confined deep aquifer and the confined B2/A7 and A4 portions contain water with high salt concentrations, CO_2, H_2S and radon gases and have temperatures exceeding the ambient temperature by more than 5°C reaching a maximum of 64°C. Hence, it is generally not suitable for the survival of higher organisms, except after treatment which may incorporate desalination.

Brackish, saline and highly saline water is found in the Jordan Valley area. The salt contents originate from contacts with Triassic and Jurassic rocks, salt bodies and salty formations such as the Lisan Marls. Salinities in the Jordan Valley can reach 50 000 µS/cm.

3.3 Water Quality as affected by Human Activities

Generally, water resources are exposed to pollution factors which affect their qualities; these include human activities like the disposal of solid and liquid wastes of urban and industrial areas, the use of biocides and fertilizers in agriculture, the return flows to surface and groundwater resources from irrigation water, as well as the overexploitation of groundwater resources.

- **Pollution Sources:**

For the case of Jordan, the drastic increase in the population and the improving living standards and industrialization have demanded increases in the water supplies, which have lead to increasing amounts of waste water and irrigation return flows, and have also led to the total use of all available surface water resources in addition to overexploitation of aquifers.

The results were deteriorating surface and groundwater qualities. Following is a discussion of the major polluted areas and the causes of water quality deterioration.

- **Domestic Wastes**

Wastes produced in households consist of waste water, solid wastes and gases emitted into the atmosphere. In Jordan, the two main waste types which result in water pollution are waste water and solid wastes. The waste water of households is disposed of in two ways:

- Cesspools and septic tanks.
- Collection via sewerage systems and treatment in waste water treatment plants.

Each of these ways has its impacts on the local surface and groundwater resources. Human sewage contains relatively higher concentrations of nitrates, phosphates and higher salinity than the supply waters. If not handled properly it contaminates surface and groundwater resources, produces odour and may pollute soils, threaten the health of cattle and contaminate crops and negatively affect organisms surviving in the water. Therefore, it represents a significant problem for all communities and countries, because abating their impacts requires relatively large investments, know-how and safe reuse schemes.

Generally, waste water contains higher dissolved salt concentrations than those in the supply water. The increases in salt contents result from use, evaporation and addition of chemicals and are a function of the per capita water consumption. The less it is the higher the concentration of salts. Waste water treatment can remove a variety of pollutants and substances but salts can only be removed by very expensive techniques, such as desalination. Hence, they are not removed from the waste water during treatment. Crops grown in Jordan; vegetables and fruit trees produce the largest yields per unit of land if the salinity of the water is less than 1500 µS/cm. If salinity increases beyond that, the result is a reduction in crops. But as can be deduced from Table 3.7 the salinity of waster water treatment plant effluents is generally and in all seasons less than 1500 µS/cm Therefore, the use of treated waste water does not negatively affect crop producton. On the contrary, the treated effluents contents on fertilizer substances such as nitrates, phosphates and potassium enhance the productivity of agriculture.

Table 3.7: Some characteristics of the effluents of selected waste water treatment plants in Jordan (nm = not measured)

Treatment Plant/Parameter		Khirbet Es Samra	Salt	Wadi Es Sir	Kufranja	Wadi Hassan	Aqaba	Fuheis	Tafila
Discharge m^3/d	Av.	206167	4773	3015	1883	1101	6592	2003	1431
	Min.	184612	4168	1460	1559	866	4471	1880	1289
	Max.	224711	5162	3443	2395	1207	8557	2143	1696
TDS mg/l	Av.	Nm	820	908	1146	Nm	550	nm	1203
	Min.	Nm	489	823	838	Nm	508	nm	743
	Max.	Nm	956	982	1297	Nm	621	nm	1426
Ph	Av.	7.2	Nm	Nm	7.2	7.64	7.1	8	Nm
	Min.	7.0	Nm	Nm	7.1	7.0	7.0	7.4	nm
	Max.	7.39	Nm	Nm	7.3	8.0	7.2	7.76	nm
BOD5 mg/l	Av.	8	11.5	45	88	7.1	5.0	10	46
	Min.	6	2	26	50	4.0	4.0	7	38
	Max.	11	36	83	128	11.0	7.0	14	56
COD mg/l	Av.	47	76	141	403	59	20	82	162
	Min.	37	41	92	295	42	15	55	122
	Max.	54	119	406	549	89	26	111	184
PO4 mg/l	Av.	18	17.8	29	41	11.3	2.1	19.1	35.5
	Min.	13	Nm	19	40	4.0	0.9	17.2	33.4
	Max.	21	Nm	34	42.4	26.0	3.1	23.1	37.8
NO3 mg/l	Av.	14	1.3	8	Nm	Nm	61	20.3	2.0
	Min.	1	Nm	1.5	Nm	Nm	45	15.1	1.4
	Max.	17	Nm	18	Nm	Nm	78	45.3	2.35

a. Cesspools:

Many towns, villages, settlements, higher education centres, military camps ... etc. are still not connected to sewerage systems and waste water treatment plants. Even in towns with sewerage systems there are households still using cesspools. In addition, sewerage pipes are not totally tight, therefore, untreated waste water leaks from them.

Generally, cesspools are not designed to hold the waste water to be trucked later on to a waste water treatment plant. The bottoms and walls of cesspools are normally permeable, especially in those types of rocks, generally found in the highlands, such as karstic limestone, fractured chert and silicified limestone, sandstone or disintegrated shale. These conditions allow the infiltrated sewage water to reach the underlying water bodies, especially phreatic ones (Table 3.8)

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Table 3.8: Examples of domestic waste water pollution infiltrating from cesspools and sewer systems into the aquifers (Sp: spring, W.: well and Munic.: municipality, Ras: Ras el Ain Sp Amman, Z.R: Zarqa Muni, Sar:

Water source		**Ras**	**Ruseifa Sp.**	**Z.R**	**Na'ur Sp.**	**Sar Sp.**	**Jad**	**Kuf**	**Um.I**	
	1966	1995	1995	1995	1995	1995	1995	1995	1995	1996
EC µs/cm	520	950	915	1780	740	1160	706	830	1350	770
Ca meq/l	3.71	5.95	2.5	5.2	4.0	6.26	3.8	4.51	8.80	4.65
Mg meq/l	1.15	1.45	1.7	1.25	2.13	1.94	1.40	2.21	2.55	2.41
Na meq/l	0.3	2.09	2.47	8.70	1.12	3.1	1.75	1.81	2.95	2.1
K meq/l	0.06	0.12	0.10	0.12	0.19	0.26	0.5	0.61	0.15	2.23
Cl meq/l	0.67	2.54	3.84	9.83	1.30	3.49	0.5	1.65	3.22	3.29
SO_4 meq/l	0.75	0.52	0.42	3.02	0.65	0.46	0.52	1.21	3.80	1.07
HCO_3meq/l	4.22	5.4	1.82	5.02	4.20	5.5	3.70	4.62	6.20	3.77
NO_3mg/l	30	72								

Sara Sp Karak, Jad: Jadour Sp. Salt, Kuf: Kufr Assad W. Irbed, Um. I: Um Irshed Sp. Hartha).

b. Solid waste disposal

The impacts of solid waste disposal on surface and groundwater resources are well recognized and documented in the literature (Farquhar 1989). The problem is that once these impacts are recognised in the composition of a groundwater body manifested in the detection of pollutants, the repair becomes very difficult or even impossible.

Generally, municipal solid wastes contain only limited numbers and amounts of dangerous chemicals. But, in certain cases where separation of wastes is not practiced, even dangerous chemicals, such as insecticides, pesticides, all types of medicaments, batteries, paints, mineral oils among others, reach the solid waste disposal sites, become dissolved and leak to ground and surface water bodies. Of concern here in Jordan are the solid waste disposal sites distributed all over the country. The sites of Amman, Zarqa, Salt, Madaba, Ukheider, Karak, Hartha, and Aqaba among others were not exposed to sophisticated environmental impact assessment in advance. Hence, they do not fulfil present-day environmental criteria.

In addition most of the sites are located along wadis or depressions of abandoned quarries or karst holes, forming therefore a direct threat to the ground and surface water resources. Solid waste in Jordan consists of about 49.5% food waste 25.9% carton, 6.5% plastics, 3.3% glass, 2.5% metals and the rest of natural materials; wood, earth, stones, construction refuse ...etc, (El-Natour, 1993). The composition of the leachates originating from the solidwaste disposal site of Amman is given in Table (3.9). The table shows also the composition of the liquid waste pool in Wadi El-Kattar in the immediate neighbourhood of the solid waste site.

In practice, many years may elapse before the solid waste disposal site reaches field capacity to generate leachate, which are almost entirely; 98% composed of calcium, magnesium, sodium chloride, sulphate, nitrogen compounds (as ammonia, nitrate and nitrite) and bicarbonates. Also time is required before peak concentrations of the various parameters are reached. However, once this peak is reached, it continues at the same level for tens or hundreds of years after the disposal is stopped.

Poorly biodegradable, low-solubility contaminants appear and reach peaks way after the normal chemical constituents mentioned above. Hence, they persist longer and affect the water resources for long periods of times, tens to hundreds of years, (Farquhar, 1989). In the other areas of Jordan solid waste disposal sites are not better off than the one in Amman. Serious impacts on the surface and groundwater resources are unavoidable if not already there.

Table 3.9: Analyses of the solid wastes leachates, and the liquid waste pool, southeast of Amman (EC in mmoh/cm, all others in meq/l)

Para-Meter	**Temp (C°)**	**EC**	**pH**	**NO_3**	**HCO_3**	**CO_3**	**SO_4**	**Cl**	**Ca**	**Mg**	**Na**	**K**
Old dump	14.6	138.000	8.46	12.1	6.09	0	11.5	150	7.3	8.6	142	23.2
New Dump	14.4	5.500	8.10	0.06	4.48	0	1.9	34.1	2.4	3.2	37.6	1.18
Waste-pool	15.6	18.560	8.68	89	3.50	0	4.88	159	7.7	9.77	154	2.65

c. Industrial Effluents

Waste water effluents of industries in Jordan can be categorizied concerning treatment into the following:

a) Treated effluents.

b) Untreated effluents.

c) Semi-treated effluents.

The majority of industries in Jordan (>90%) possess waste water treatment plants. Some of them produce effluents which comply with regulation and standards, many do not, and most of them produce semi-treated waste water. Considering the way of effluent disposal, industrial waste water can be categorized into:

One) Connected to a domestic waste water treatment plant, especially Khirbet-es-Samra.
Two) Discharging into the nearby wadis.
Three) Used for irrigation in the surrounding of the effluent-producing industry.
Four) Transported to a collection pool or allowed to infiltrate and/or evaporate in a spreading basin.

Around 44% of the industries discharge their pre-treated effluents to domestic waste water treatment plants. Others are not allowed to do that because their effluents contain substances which pose great threat to the treatment processes of domestic WWTP. They discharge their effluents to the nearby wadis. Some industries, such as yeast, partly the refinery and others use the effluents in local irrigation. Some industries with effluents of a few cubic meters per day transport their waste water by trucks to pools and spreading basins where they infiltrate or evaporate. According to the quality degradation parameters contained in industrial effluents, they can be classified into the following:

a. High salinity effluents.
b. High organic loads effluents.

c. High trace elements effluents.
d. High contents of other specific substances such as phosphates and ABS.
e. A combination of any group of a) to d).

The majority of industries have effluents with high salinity or high organic load or both. A few of them have high trace element concentrations, and very few have high concentrations of specific parameters.

Trace Elements

High concentrations of trace elements are found in the effluents of some industries (Table 3.10). These effluents end up in the surface and groundwater bodies and in the soils. Locally, they may threaten surface and groundwater bodies and may, if connected to domestic waste water treatment plants, kill the active bacteria and algae and hence stop the biological activities involved in waste water treatment.

The destination of these trace elements in the Amman/Zarqa area is King Talal Dam (KTD). Therefore, the inflows to KTD whether, the base or the floodflows, contain some trace elements dissolved in the water itself and attached to or bound into the suspended particles which are transported by the water. In KTD the particles settle to the bottom of the reservoir, but they partially become released into the water again due to the eutrophication processes, taking place there. Afterwards they are discharged along Wadi Zarqa with the water used for irrigation in the Jordan Valley area.Until now these trace elements did not represent a threat to downstream irrigational uses. But, a combination of factors such as less irrigation water per unit land, water depletion of oxygen and high water salinity may activate these trace elements and make them available to plants which would weaken the resistivity of these plants to diseases and may end up in crop failure.

The total loads of trace elements to the whole water system in the most industrialized area in Jordan, the Amman - Zarqa area, is relatively small and it does not represent any threat on the system as a whole. But on a local scale some trace elements such as lead (battery industry) or mercury (chemical Industries or chlorine filling plants) represent an acute danger to surface and groundwater resources. Therefore, these industries should treat these trace elements adequately before any waste water releases to the surroundings. The outlet water of KTD contain some high concentrations of trace elements such as lead, 15-40 µg/l (1994) nickel, 50-100 mg/l, chromium, 50-62 mg/l, cadmium, 0-20 mg/l, zinc, 70-88 mg/l, Cu, 2-12 mg/l, manganese, 120-180 mg/l and iron 70-80 mg/l. This water is generally mixed with other less polluted water in irrigation in the Jordan Valley area.

Table 3.10: Examples of Industries with high trace element concentrations in their treated effluents (mg/l)

	Discharge m3/d	**Fe**	**Mn**	**Zn**	**Cu**	**Cd**	**Cr**	**Ni**	**Pb**	**Hg**
Tanning	370	0.43	0.16	0.32	0.120	0.052	1.92	0.25	0.25	0.001
Yeast	330	4.20	2.00	0.18	0.072	0.020	0.08	0.23	0.072	0.001
Battery	12	16.30	6.50	0.45	0.620	0.020	0.08	0.25	6.32	0.005
Chemical Ind. (Detergents)	8	0.50	0.32	0.21	0.09	0.090	0.21	0.26	0.32	0.15
Sulpho-chemicals	62	3.50	1.40	0.16	0.090	0.700	0.23	0.25	0.35	0.001

Chapter 4

AQUATIC FAUNA IN JORDANA

4.1 Introduction

The type of macro-faunal and floral species living in and from surface water bodies have been used as water quality indicators since countries. This fact that macro-organisms can serve as water quality indicators maybe recognized even by a layman because, for example, not all fish lives in salty water not all fish live in fresh water.

The physical and chemical constituents of a water body give information on the water quality of that water. But the large members of chemical substances and physical properties which are found in nature and which are produced industrially do not allow analyzing water on every possible substance and property, which may cause water quality deterioration. Contrary to that macro-organisms are readily recognized in a surface water body. In addition, chemical and physical analyses may take a long time to be carried out, sometimes days and hence, it is not a suitable practical way for fast judging the quality of a water source, especially when it is used for drinking purpose. In contrary, living organisms especially faunal species react very rapidly to deteriorating water qualities. They die or migrate if that quality becomes unsuitable for them. Therefore their use as water quality indicators is superior to chemical and physical water analyses.

In addition, water analyses, for uncommon substance may take days to weeks e.g, pharmaceutical residence radioactivity –among many others where as identification of faunal and floral species is momentous. One of the basic tasks of a water supply is to continuously control the quality of the raw water, because no water purification plant is designed and constructed to deal with all chemicals and physical properties which cause quality deterioration. Generally, only a few substance and properties are analysed in a routine water control and the others are not analysed. Here, faunal and floral species serve as control in a very effective way. In addition, long term changes along river course are be accounted for using bio-indicators than using general physical and chemical parameters.

In Jordan macro-fauna was used as water quality indicator by Bandel and Salameh in 1981 on a relatively small number of wadeis in the further surroundings of Amman. Since then many changes took place such as increasing population and urbanization, increasing industrialization and intensified agriculture and the improving living standard of the population which was connected with increasing use of chemicals, such as pharmaceutical-products, agro-chemicals industrial chemicals etc.

This book on macro-fauna and flora as water quality indicators (bio-indicators) summarize the results of a four years study on maro-fauna and flora and water quality characteristics in which they live in. Behind it stands an intensive field work in almost all parts and physiographic unit of Jordan. It adds very much to old Bandel and Salameh publication of 1981. In the survey area, floral species and faunal species were studied. The different groups of aquatic fauna studied in this work include: sponges, insects, aquatic worms, mollusca, and crustacea groups. In this chapter we discussed the sponges group while the other groups are studied separately in different chapters of the book.

4.2 Sponges group

Most sponges (Porifera) live in the sea, and only a few belonging a restricted group (Spongillidae) live in fresh water. They have a simple organization in which cells can perform many different functions, but similar cells do not combine to form body organs. In terms of gross morphology, sponges have no mouth or inner organs and also the shape of their body may differ strongly among individuals. They are supported by a skeleton made up of the protein collagen (spongin) and hard needles (spicules), which among sponges of fresh water are siliceous. The sponge body contains inner chambers which are connected by canals to each other and to the exterior. Water enters the body through a system of tiny pores (ostia) in the outer walls, driven by the beating of flagellae (cilia) which are located on specialized cells called collar cells (choanocytes). Each of these cells is equipped with a flagellum and they line the surface of the chambers and produce a current of water.

Food particles which usually consist of micro-organisms are retained and ingested by the collar cells. The flow of water through the sponge is unidirectional, connected by a series of canals, and exits through larger openings (oscula). Fresh water sponges are asymmetrical and their final shape is not fixed but reflects somewhat the environment. It looks different when it grows on a boulder with large surface or on a reed with less space. The skeletal elements, collar cells, and other cells are imbedded in a gelatinous matrix.

Asexual reproduction is by means of external or internal buds, which can survive unfavorable conditions, when the rest of the sponge dies. During sexual reproduction male gametes are released to the water by a sponge and enter the pore systems of its neighbors. Spermatozoa are "captured" by collar cells, which then lose their collars and transform into specialized, amoeba-like cells which enter the inner gelatinous layer and here carry the male cell to the eggs. In most sponges the fertilized egg develops into a blastula larva, which is released into the water. These larvae remain in the water free swimming for only several hours until they settle to hard substrate. Here it transforms into a tiny functional sponge which begins to filter water for food. The sponges fauna description in this work was taken from Eggers & Eiseler (2007) and Storch & Welsch (2004).

The sponge noticed in Jordan resembles Spongilla of the family Spongillidae that includes species mostly living in fresh water of lakes and slow streams. Its skeleton includes siliceous needles of simple straight shape and with pointed ends. In Jordan Spongilla was found attached to the surface of boulders in River Mujib and is continuously washed by its water. The color is greenish grey-brown. The greenish tint is due to unicellular green algae which live in the sponge in a symbiosis- probably providing the sponge with oxygen and benefitting from the mineral waste products by of sponge produced during digestion. When exposed to excessively harsh situations, the sponges produce gemmulae, which are highly resistant "buds" that can remain living and rest after the mother sponge has died. When conditions improve, the gemmulae starts growing into a new sponge.Sponges were noted in Jordan only in Mujib River, a few kilometers below the dam site (2013) (Fig. 4.1). Here they form crusts on larger stones in the river bed in turbulent places and below water. This locality of sponge growth was destroyed during the spring flood in April 2014 when gravel and boulders in the river were ground against each other and all sessile animals disappeared, but it is expected that sponges will return and again be present as readily visible bio-monitor for good quality river water. The most common fresh water sponge in Europe, Spongilla lacustris is of similar shape and lives in rivers as well as in lakes. Its shape is also variable differing somewhat in reaction to the environment of growth.

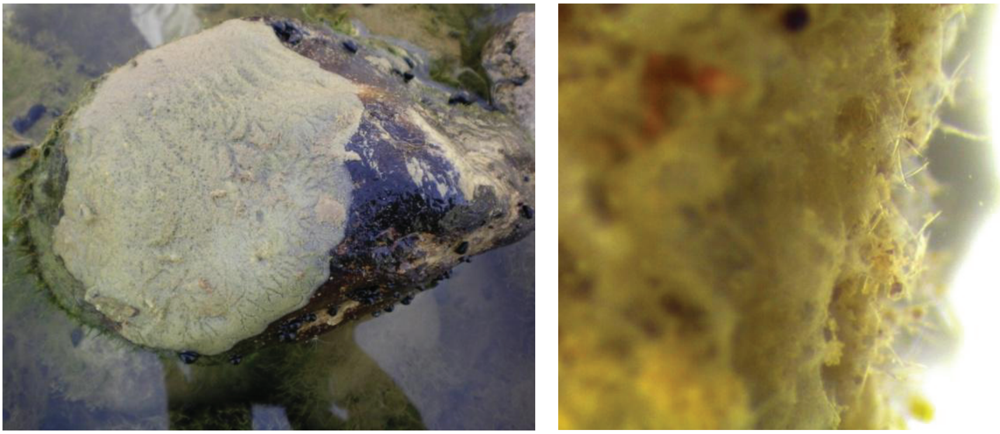

Figure 4.1: a. Spongilla was found attached to the surface of boulders in River Mujib, b. Magnified fresh water sponge with needle-like shaped (Wadi Mujib).

Chapter 5

INSECTS GROUP AS BIO-INDICATORS

5.1 Introducation

Aquatic invertebrates are important components of aquatic systems and are effective tools for measuring the condition of streams and lakes. For example, some species are tolerant to pollution, so when a stream has a large number of these tolerant organisms, it is an indication that there are potential water quality problems.

The use of biological components to monitor water quality can be used to augment professional programs and subsequently improve early or long term monitoring programs. Among the Arthropoda many species of insects spend part of their life in water. Often eggs are placed in or near water and larvae hatch from them and grow here until they metamorphose into the adult that lives on land.

This larval development can be carried out in quite a wide variety of aquatic environments. The location in which the youngs of a distinct insect species can grow and develop may be quite different among species even of the same group. Some need running water, others quiet water, some tolerate no pollution, others with some pollution, and a few even strong pollution and some have their larval life only in fresh water, while others prefer brackish or even salty water for early development.

Especially larvae of mayflies belonging to the order Ephemeroptera, Caddisflies of the order Trichoptera, dragonflies of the Order Odonata, stonefly of the Order Plecoptera, Heteroptera (Order Rhynchota = Hemiptera), Beetles of the Order Coleoptera, and true flies of the order Diptera, can be encountered in Jordanian waters.

5.2 Order Ephemeroptera (mayflies)

Ephemeroptera (mayflies) contains many species, which usually have a larval stage that grows up in fresh water and sometimes also in brackish water, by increasing its size connected to shedding its skeleton (molting) many times and by a final metamorphosis into a flying insect that molts one last time during that stage first into a subimago and finally into the imago. These larvae (larvas, nymphs) have 6-7 pairs of gills on their abdomen. During the larval stage each increase in size is connected to shedding the former skeleton and that may occur up to 20 times, differing among species.

Most species feed on algae or diatoms, but a few species are predatory. Feeding is supported by bristles attached to the head carried out by the first pair of appendages. Some species are collectors, other filter feeders on floating material while others are scrapers which actively remove material from the rocks.

The larva stage may last from several months to several years. Most mayfly larvae have seven pairs of gills on the sides of their abdomen, and carry three long tails (cerci) at the end of the abdomen (Fig. 5.1). Some species have only two tails and can be mistaken for larvae of stone flies (Plecoptera). Gills are moveable and their vibration increases the amount of water moving over them.

Gills are also used as swimming paddles in some species. In the last aquatic stage, dark pads with forming wings are visible. Nymphs are often dorsoventrally flattened to allow them to live clinging onto the underside of rocks in fast flowing streams.

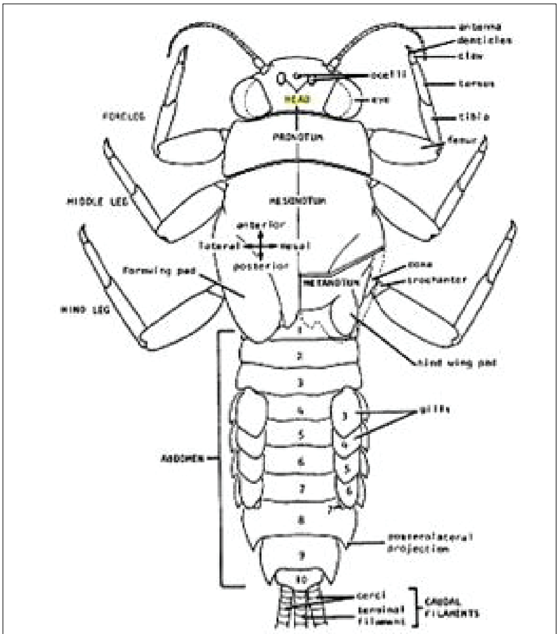

Fig. 24. Nymph, *Ephemerella*.

Figure 5.1: General morphological features of mayfly larvae. (This figure is adapted from Edmunds, Jensen, and Berner 1976, fig. 24. p42)

Mayflies are unique among the winged insects in that they molt one more time after acquiring functional wings. This winged larval stage (subimago) does not last more than a few hours and is succeeded by the full adult. The lifespan of an adult mayfly is short and varies depending on the species. The primary function of the adult is reproduction. Their mouth parts are vestigial, and the digestive system is filled with air. The hind wings are much smaller than the fore wings, and may be vestigial or absent.

Adults have short antennae, large compound eyes and three ocelli. In most species the eyes of the males are large and the front legs are unusually long, for use in locating and grasping females during mid-air mating. Mating occurs in a swarm, and at these times there may be dense clouds of mayflies in the air near streams.

Once a male has successfully mated, he guards the female to make sure that no other male mates with her. The female then flies to water to lay eggs. She dips into the water while flying and releases a few eggs each time. The eggs sink to the bottom and their surface changes. When a larva hatches from the egg it is less than 1 mm long and has no gills.

The different growth stages of the larvae may look quite different from each other and thus determination of species is difficult. Gattolliat et al (2012) described species of Cloeon and Baetis from Jordan and from Israel Malzacher (1992) described some Caenis. Gattolliat checked the material 2013 and confirmed the identification of larvae of ***Caenis antoninae***, ***Cloeon gr simile*** and of ***Baetis monnerati***.

Accordingly, species of ***Baetis monnerati*** were always found in running water while *Cloeon sp* colonized standing water that is still part of the streams. The larvae of ***Cloeon gr*** **simile**, and ***Cloeon dipterum***, are very similar in appearance, and to tell the difference gill structures have to be examined. Some mayfly larvae are quite sensitive to pollution and are used to evaluate water pollution and stream health.

Alhejoj et al. 2014 studied the aquatic mayflies as biological indicators of water quality in Jordan and stated that Bestisdes group is commonly associated with Caenidae larvae in running freshwater body (Fig 5.2). *Baetis monnerati* found to be is an indicator of very clean to moderately polluted water and tolerance to saline water. *Baetis Sp* occur in clean freshwater but is rare so that it is not a useful indicator in Jordan. Caenidae sp can take some amount of household pollutant while *Caenis antoninae*is a good indicator species for standing to slow flowing clean to weakly polluted water.

Cloeon gr simile could tolerate salty water and can be considered as a good indicator of unpolluted saline water. Only one species is present in mineral water, ***Nigrobaetis vuatazi***, with high $Sr^{2+}$and Br^{-}concentrations in the water. In Jordan, species of Baetidae family show more tolerance to pollution than Caenidae family but aquatic mayfly fauna are absent from eutrophic and thermal water bodies. They concluded that mayfly fauna are qualified bio-indicators for water quality monitoring in Jordan.

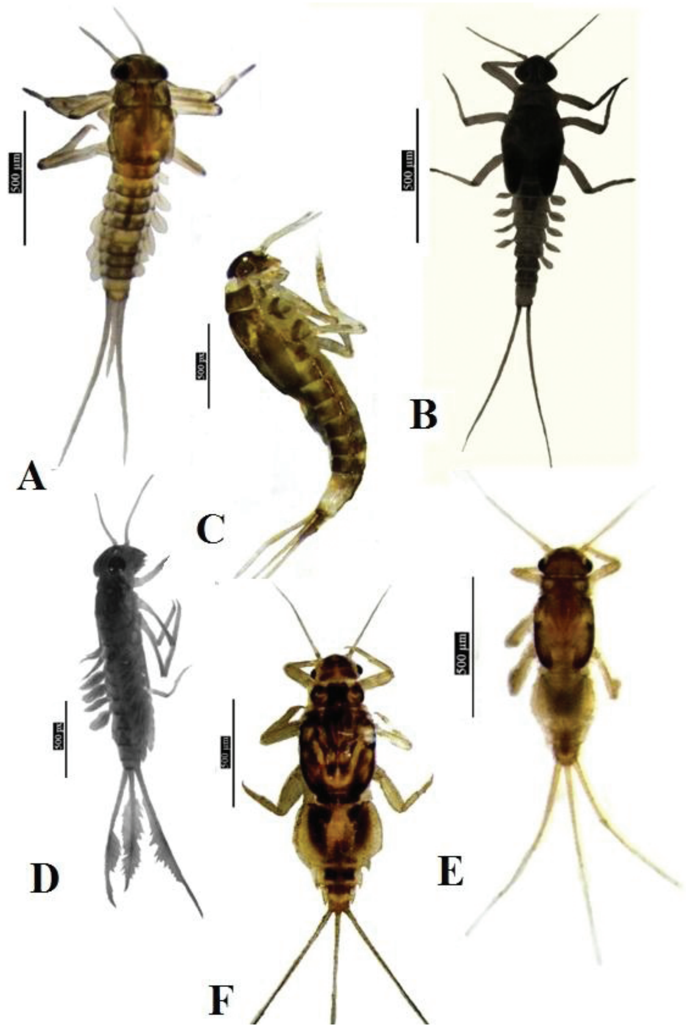

Figure 5.2: Examples of common mayfly larvae species collected from the study area and documented by S6 D Leica stereomicroscope; A. *Baetis monnerati* from Wadi Hisaban, B. *Baetis Sp* (the larva has two long caudal filament without terminal filament; C. *Nigrobaetis vuatazi* (Wadi Atun 1); D. *Cloeon gr simile* from Karama area; E. *Caenis antonina* appear with flattened shape, long three tails and square plate like gills shaped from Wadi Hisban; F. *Caenis Sp* has distinct square plate like gills from Wadi Shueib

5.3 Order Trichoptera (Köcherfliegen, caddisflies)

Caddisflies (Trichoptera) are quite a diverse group of insects, which are interpreted to have 13,500 species described from almost all aquatic environments. They are very useful as bio-indicator species which have distinct responses to pollution and other environmental impacts.

Many species of caddisflies construct a larval home which can be tube-like and carried around or have funnel shape attached to hard substrate or consist of a large number of rather visible naked larvae arranged on hard surfaces in creeks oriented according to the current close to each other. They may use an attached funnel shaped tube composed of agglutinated sand in connection to a net spun at its opening to catch food from by flowing water. Those without protective tube or other constructions when changing from aquatic life to the flying insect secrete and construct a more or less characteristic pupa.

This may be produced of agglutinated sand grains or of fine organic secretions composed of silk. All these types of life have been encountered among the caddis flies that live in Jordan and especially the occurrence of naked larvae attached in groups on rocks in creeks are the most common and conspicuous.

The caddisflies larvae found during field work in Jordan are thus represented by four distinct types. Determination to the species would be very difficult, since species are defined according to the flying imago stage. These insects occur only for a short period, while their larvae can be distinguished from each other more easily and placed into several groups arranged by their feeding strategy and also the type of pupa they form at the end of their larval life.

The adults are small moth-like insects having two pairs of hairy membranous wings. In most cases the adult stage is short-lived lasting only a few days to 1–2 weeks. Most adults are non-feeding and their existence has the purpose just to mate as rapidly as possible. During that stage of live they can fly and thus can reach locations far from their living place during their larval existence in water. Once mated, the female caddis-fly lay eggs usually enclosed in a gelatinous mass and attach them above or below the water surface. From the eggs hatch, after a few days, aquatic larvae which remain in the water for an extended period of time that is much longer than the existence as imago, often lasting a year. During its course the skeleton is shed and renewed about 5 times.

The body of a caddisfly larva is divided into three parts, head, thorax, and abdomen. The head of the nymph is with thick hardened skin, has very short or rudimentary antennae and at the mouth strong functional mandibles with biting parts. On the thorax three pairs of legs are attached. The size of protective plates and the thickness of the skeleton can differ among species and also in the different larval stages within a single species. The final segment of the body often ends with large hooks (anal claws), which are used for attachment to the substrate especially in such larva which live free and are oriented parallel to each other in the current of running water.

Respiratory gills are attached to their abdomen and they may also exchange gases through the body surface by diffusion from the water. The gills can be single or branched or of comb-like shape and can be visible or hidden, and their shape and size also differ during the growth stages of the same species.

When eggs hatch, the released nymphs behave differently depending on the species. Some start with case building and construct a portable tube by attaching grains of sand or other available particles together with the help of silk threads. Case-making caddis-flies thus construct portable cases by secreting silk and using it to cement substrate materials such as small fragments of rock, sand, small pieces of twig or aquatic plants. Many use the retreats or cases throughout their larval life, adding to, or enlarging them as they grow.

The shape, size and construction of these tubes can be characteristic to a species or a group of species. The tube is first constructed by the young larva and is retained by the nymph until the larval stage is ended and a pupa formed. During larval growth material is added to it at its larger end, and the posterior end can be modified, since the larva can turn around in its tube and reconstruct the posterior opening as well. Caddisflies with portable cases use it also as pupa by attaching it to some larger object and by sealing the front and back apertures. Once fully developed, most pupal caddisflies cut through their cases with a special pair of mandibles, swim up to the water surface, cast off skin and the now-obsolete gills and mandibles, and emerge as fully formed adults.

Two different tubes were observed while being constructed of fine sand grains in Wadi Atun, and another larger one of larger sand grains in Zarqa River. Both are of weakly curved cylindrical shape (Fig. 5.3). The tubes from Wadi Atun are approximately 5 mm long. The animal inside the tube has a rounded head with tiny antennae and small lateral eyes. Its skeletal parts are coated with fine black hairs and the body is yellowish-white as are the plates of the three thoracic segments. The gills are strongly branched.

The tube-like case that was found at the lowest part of Zarqa River before its diversion into a pipe line near Deir Alla, is larger and well sorted. It was only encountered at one visit in fall 2012 when also *Physa* lived here. During later visits to the same locality 2013 and 2014 showed no more larger larval insects. The quality of water had profoundly deteriorated.

Other trichopteran larvae, forming agglomerations of many animals together settling on stones in fast flowing creeks, were observed in Mujib River, Hasa River and the creeks that leave the mountains on the eastern side of the Dead Sea. The nymphs here sit side by side close to each other and directed with their bodies parallel to the current, from which they catch food particles. When larval life ends they produce round pupae of sand grains glued to each other by silk. Since the taxonomy of caddisfies in Jordan is only poorly known the encountered species were compared with those presented in the "Atlas of central European Trichoptera larvae" by Warninger & Craft (2011).

Here members of the Hydroptilidae have their larvae living free and attached to stones in running fresh water. They produce laterally flattened, often purse shaped cases when they pupate. It is spun by silk to which sand grains are attached. The cases measure 1-2 mm in size and occur commonly in Wadi Hisban and Wadi Mujib. Those of Wadi Mujib are smaller and more laterally compressed than those in Wadi Hisban.

The caddisflies with attached cases can spin threads which are used to filter food particles from the water that flows by. Such funnel shaped constructions, connected to a net of threads, were seen in Mujib River. The retreat constructors catch food items such as algae, aquatic invertebrates and zooplankton from the flowing stream using their silk net.

Caddisfly larvae are missing in Zarqa River due to its pollution and may occur here only locally in areas where water pollution decreases as a result of self-purification enhanced by ample sun-light and water aeration, observed only once in the course of this study. Caddisfly larvae are found in clean water, mineral water as in Wadi Atun (Fig 5.4) and also in creeks with slightly salty water as in the creeks originating from springs of the wadis just east of the Dead Sea. Species of Caddisfly larvae are also present in freshwater springs such as Wadi Shita spring (Fig. 5.4).

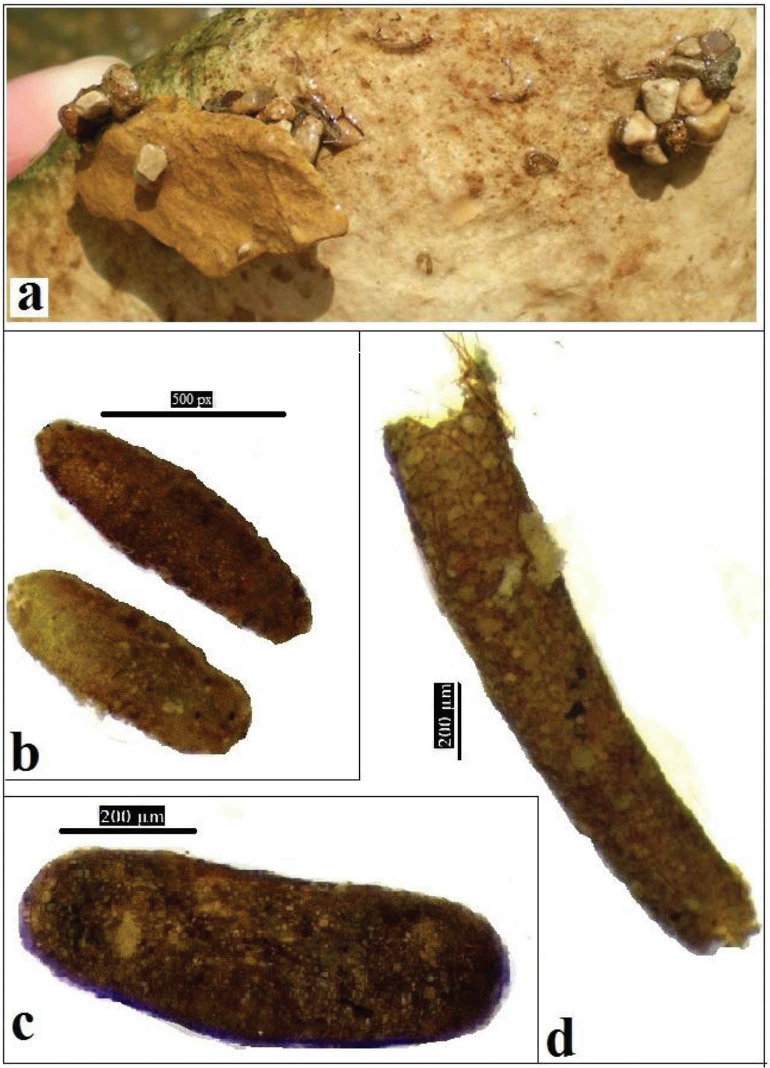

Figure 5.3: different cases of cadissflies from Jordanian water bodies, a. caddisefly with pupa cases found togather with black fly in Wadi Sir downstream of Wadi Es Sir treatment plant, b. Jordanian caddisfly cases belonging to the Hydroptila genus with purseshaped case made mainly of silk and covered with fine sand grains found in Hisban locations, c. Purses haped case of Hydroptila genus from Wadi Mujib, d. tubecase shaped belonging to the Limnephiloidea family, the case is built of fine sand grains (Wadi Atun).

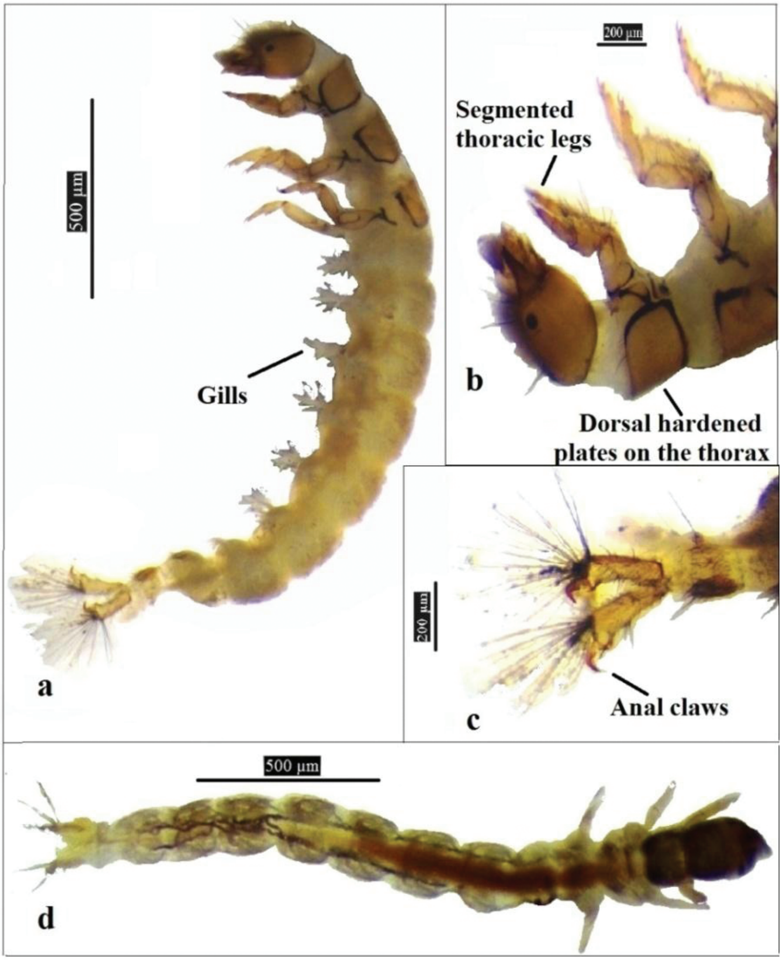

Figure 5.4: Free living caddisfly larva from Wadi Atun, a. Hydroptilidae family, long bristles on the head and pronotum, with the seven abdominal segments with gills, and well developed sclerotized plate on all three thoracic segments, b. Segmanted legs of aquatic caddisfly, c. Close-up of the anal claws hooks shaped brush of hair at the end (Ac: Anal claws), d. Free-living caddisfly larva found in Wadi Shita location.

5.4 Order Odonata (Libellen, Dragonflies & Damselflies)

The order Odonata holds more than 5000 species and is divided into the three suborders**:** Zygoptera or Damselflies which can fold their wings which are of about the same size over their abdomen, Anisoptera or Dragonflies which cannot have frontal wings and thus hold their wings straight out from their thorax and Anisozygoptera representing an ancient suborder possibly once containing the seeds of both the other 2 more modern suborders, but now containing only two species from Japan.

Anisoptera means 'unequal wings' and the members of this suborder have their hind-wings broader than their fore-wings. They are also normally stouter, larger and much more acrobatic in their flight: Zygopterans tend to fly slowly and leisurely. Eggs are laid either inside the living tissue of a plant or into or onto the water or the mud of river banks. Eggs are normally laid in batches and a species can lay several thousand per laying episode.

Larvae are aquatic, normally living in rivers, streams, ponds and lakes. Zygopteran larvae swim by flexing their abdomen from side to side, and anisopterans tend to walk or use jet propulsion by expelling water from their anal respiratory (breathing) orifice. Zygopteran larvae breath by way of caudal gills (their tails), while larva of Anisoptera breath through their anus. Which is an enlarged cavity with special internal folds to increase the surface area, water is pumped in and out to increase water flow across the respiratory membranes.

Larvae are carnivorous detecting in most cases, their prey by sight and catching it by means of a rapidly extensible grasping modification of the labium. They eat mostly other invertebrates. Most temperate species therefore overwinter at least once as a larvae as well as an egg. Most of a dragonfly's life is spent in the larval stage where it molts from 6-15 times.

Larval development varies from the common 1-2 years to as many as six years. The larvae of some species can tolerate quite a wide range of conditions, while others are highly adapted to specific habitats. Factors which can affect the distribution of larvae include water pH, amount and type of aquatic vegetation, and whether the water is still of flowing. 1-2 days before emergence, the larvae stop feeding and the tissues are withdrawn from the terminal part of the labial mask. Finally the gills cease to function, and the spiracles (pores for air intake during respiration) begin to open. Dragonflies and damselflies do not have an intermediate pupal stage before becoming an adult, thus are hemimetabolous and undergo gradual metamorphosis. There should be plenty of larvae in the Mujib River downstream of the dam- since the latest empty larval stages are seen on the rock sides near the river (Fig. 5.5). Larvae of Damselflies were present in clean water in Hisban spring in spring 2013 (Fig. 5.6).

Figure 5.5: Empty larval stages of dragonflies on rock cliff in Mujib River.

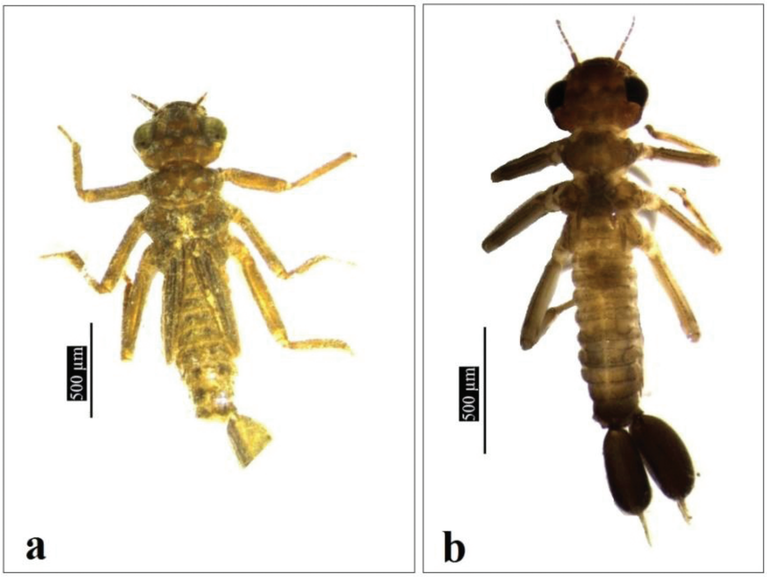

Figure 5.6: a. Damselfly (Zygoptera) larva from a lake near Wadi Mujib dam, b.Damselfly larva (Wadi Hisban spring).

5.5 Order Plecoptera (Steinfliegen, stonefly)

Stoneflies, order Plecoptera have aquatic larvae and is usually found clinging under rocks and debris in water bodies. The body of the larva may be yellow to dark grey-brown with the last few abdominal segments fused into complete rings. The abdomen ends with a tuft of cylindrical, feather-like gills, retractable so that only the tips are visible, and two long caudal filaments (Fig. 5.7). A larva is 4-21 mm long.

The larvae (nymphs) generally inhabit fast flowing waters and may be quite good indicators to very clean and oxygen rich water. Females lay their eggs on the surface of the water where the eggs are washed off the abdominal tip and fall to the substrata. Stoneflies have incomplete development consisting of three stages (including, egg, larva, and adult). Eggs are placed on water and sink to the bottom. Larvae have many molts before they pupate.

Eggs are spherical to flattened, often with ridges around the outside. The larvae feed on algae and detritus or are carnivorous. Small larvae breathe through the skin, larger larvae through gills on segments of the thorax and in others on other segments. The larval stage lasts for a year with up to 30 molts.

The last larval stage crawls from the water and changes to the winged stage outside the water, leaving the last larval skin there. Genera are Perla, Nemoura, Eustenia, Leuctra etc. Aquatic stoneflies are pollution intolerant insect indicating clean water, fast flowing with much oxygen. This group of insects was absent in the studied water bodies in Jordan.

to function, and the spiracles (pores for air intake during respiration) begin to open. Dragonflies and damselflies do not have an intermediate pupal stage before becoming an adult, thus are hemimetabolous and undergo gradual metamorphosis. There should be plenty of larvae in the Mujib River downstream of the dam- since the latest empty larval stages are seen on the rock sides near the river (Fig. 5.5). Larvae of Damselflies were present in clean water in Hisban spring in spring 2013 (Fig. 5.6).

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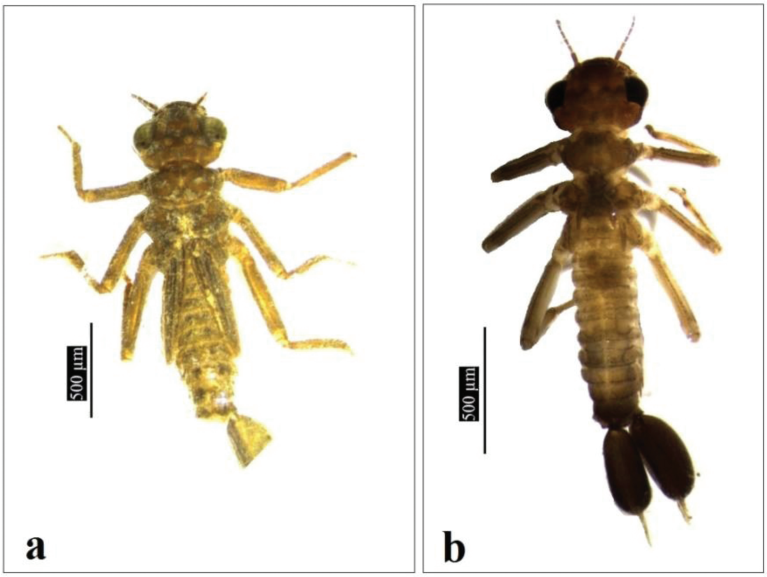


Figure 5.6: a. Damselfly (Zygoptera) larva from a lake near Wadi Mujib dam, b.Damselfly larva (Wadi Hisban spring).

5.5.1 Chironomidae (blood worms, nonbiting midges)

The most obvious larvae seen in Jordanian waters are those of the Chironomidae which often form burrows in soft substrate and attached tubes composed of mud and often feacal pellets. The larva has a slender worm-shaped body with well developed head. Here the lip (labium) is species specific and the mouth appendages (mandibles) are strong. The body consists of three thoracic and nine abdominal segments (Fig. 5.8). Legs or pro-legs are rudimentary and have hooks.

The pro-legs are paired, one pair lies just behind the head on the first thoracic segment (pro-thorax) and the other pair has its position on the last abdominal segment. Some larvae have a sucker to attach to rocks but mostly they occur with many individuals together in or on the substrate especially, when it consists of mud. Tube construction is aided by glands which can secrete threads.

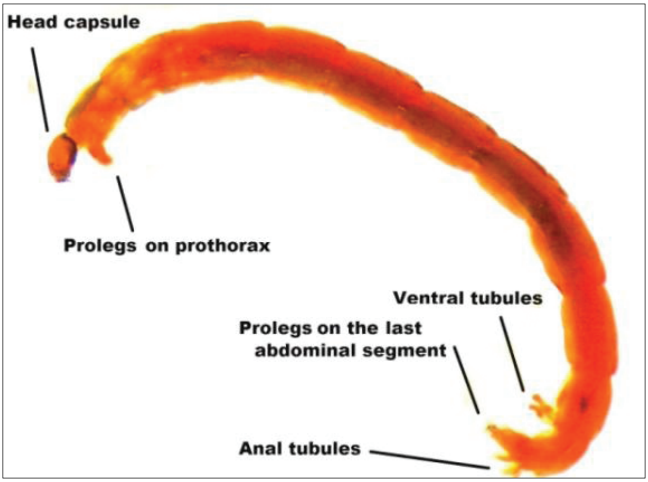


Figure 5.8: Larva of Chironomid showing the main morphological features (Sample from Wadi Shueib)

Chironomid larvae present in Jordan belong to quite a number of different species. It was not possible to determine species even though it was recognized that Chironomidae would represent very good bio-indicator species, since they live in many different types of water qualities from very strongly polluted, less polluted to clean water, and in fresh water as well as salty water.

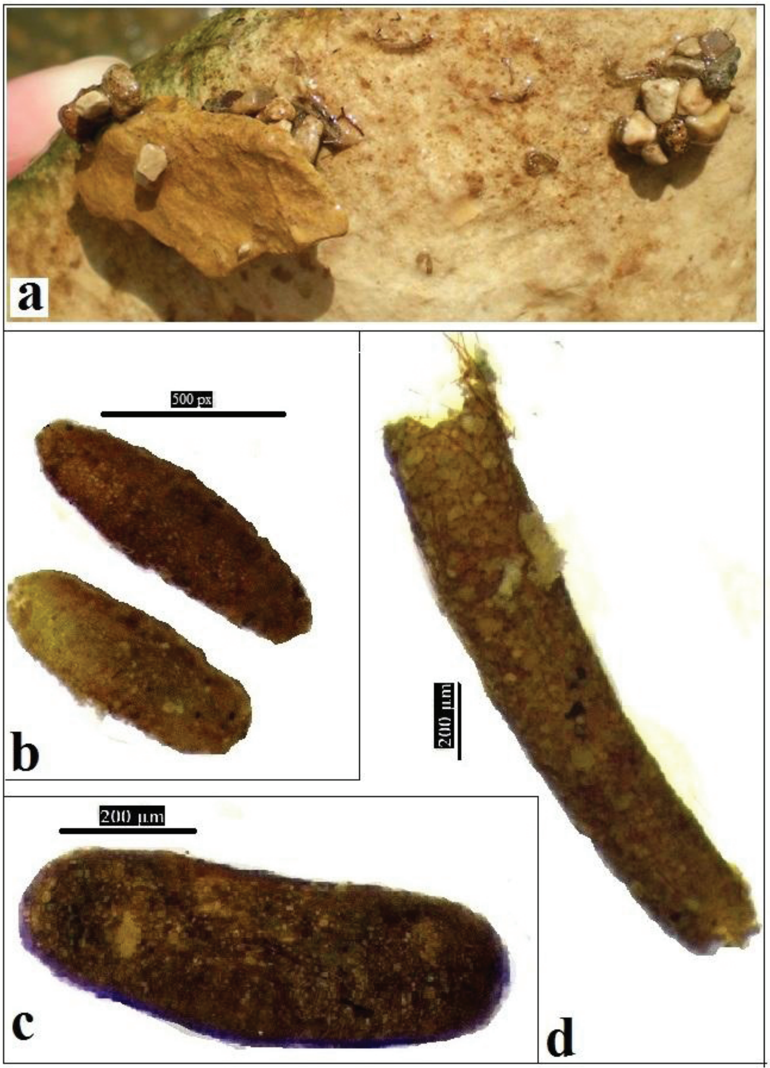


Figure 5.3: different cases of cadissflies from Jordanian water bodies, a. caddisefly with pupa cases found togather with black fly in Wadi Sir downstream of Wadi Es Sir treatment plant, b. Jordanian caddisfly cases belonging to the Hydroptila genus with purseshaped case made mainly of silk and covered with fine sand grains found in Hisban locations, c. Purses haped case of Hydroptila genus from Wadi Mujib, d. tubecase shaped belonging to the Limnephiloidea family, the case is built of fine sand grains (Wadi Atun).

margin of the lake. The eggs survived after being placed in diluted alcohol for three days even hatched as tiny orange larvae. This observation documents that the eggs of some chironomid are highly tolerant to pollution.

But chironomid larvae live also in clean water may be free-living or may construct mucus coated burrows attached to hard substrates or tubes in mud. Burrows and tubes are cemented by threads secreted by the larva. Agglutinated tubes attached to rocky surface are common in moderately polluted water as that of Mujib Reservoir and such tubes were also seen right downstream of the dam, while further downstream the water quality improved much and their presence was no longer observed (Fig. 5.11).

Chironomid larvae with yellow body color were noted in somewhat salty water, such as that in Wadi Atun which is fed by springs of warm mineral water. Here the larvae tolerate a relatively high concentration of Sr (37.41 ppm), Br (10.39 ppm) and slightly raised salinity of 2040 µS/cm.

The larvae found in a brackish creek that issues into Karama Reservoir Lake live with a salinity of about 16120 µS/cm (Fig. 5.12). Within the lake of Karama reservoir the salinity had risen to 23600 µS/cm and thus too high for any type of chironomid larvae.

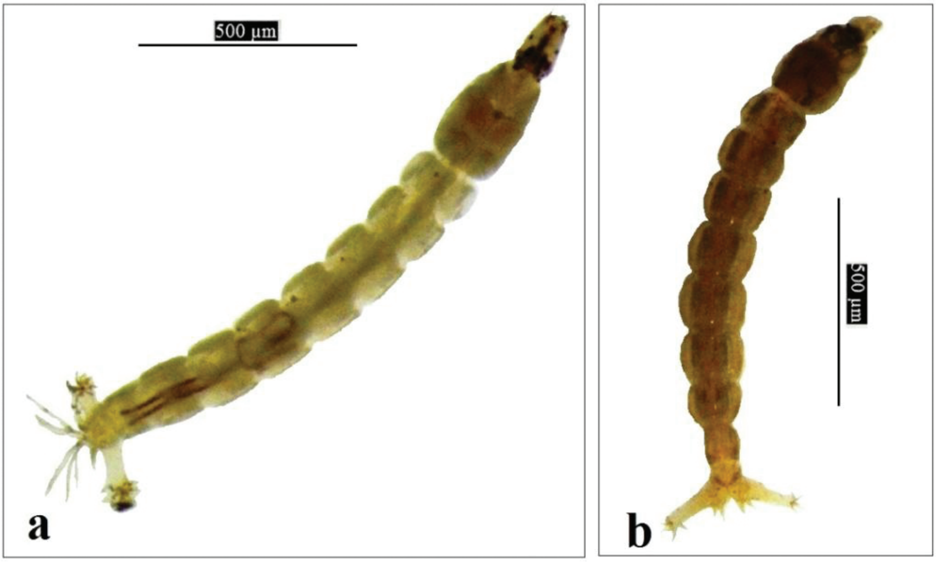


Figure 5.9: a. Whitish chironomid larva collected from Wadi Shita spring, b. Larva of Chironomid from Wadi Mujib Lake.

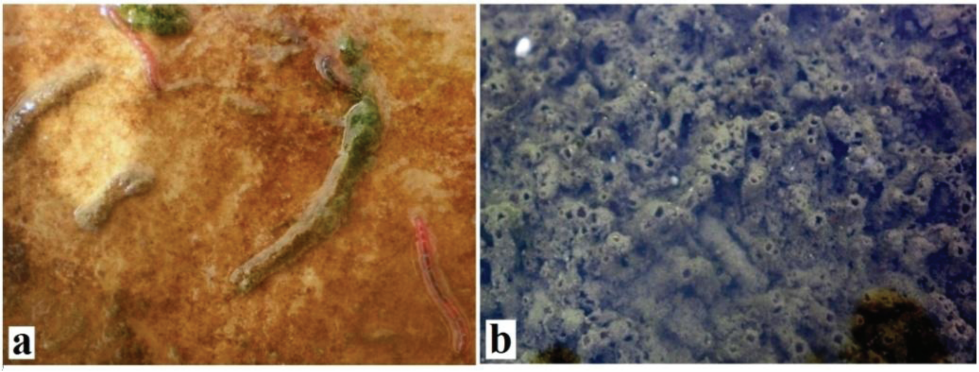


Figure 5.10: a. Bloodworms with and without their cylindrical tubes which allow them to attach to a stone in Zarqa River, b. Dense settlement of red chironomid larvae which transformed the mud to a dense pattern of living tubes in the eutrophic stream downstream of the wastewater treatment plant in Wadi Shueib.

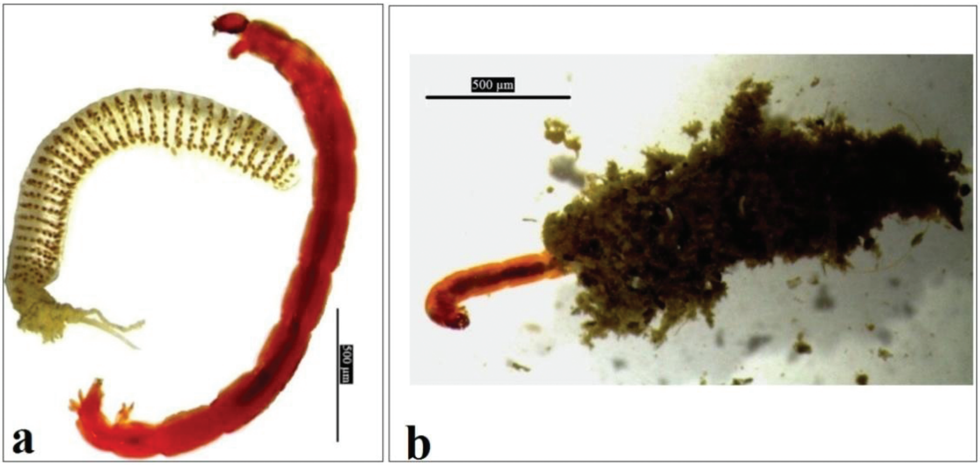


Figure 5.11: a. Fully grown bloodworm and its eggs from Wadi Shueib, b. Bloodworm halve exposed in its shelter of agglutinated pellets from a pond just downstream of Wadi Mujib dam

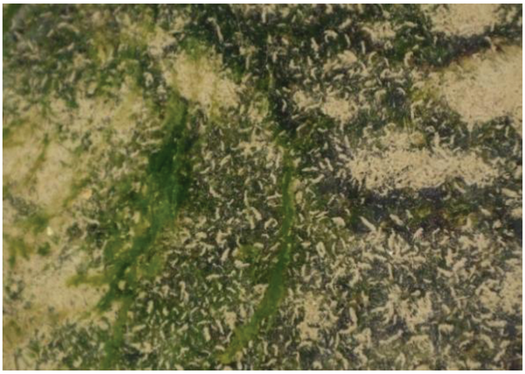


Figure 5.12: a. large number of tubes of Chironomid larvae attached to filamentous algae and crusts formed by cyanobacteria on the mud in a brackish water pond near Karama Reservoir Lake

5.5.2 Simuliidae (black flies)

The Simuliidae have many species and their development includes a complete metamorphosis. Some species may complete their life cycle in a few weeks while others require several months, and time of development may vary also with regard to environmental conditions. Females commonly lay 200-500 eggs in masses on wet rocks or aquatic plants or drop them directly onto the water surface. Both sexes of the imago live on nectar or suck blood.

Blood sucking species are active during full sunlight, in contrast to other blood sucking insects, such as gnats or mosquitoes which prefer more shady times for feeding. The preference of food depends on the species of which there are several in Jordan.

The larval stage of Simuliidae in water is represented by a smooth, worm-like larva that is distinctly swollen towards the lower part of its abdomen (Fig. 5.13a). The head is sclerotized and completely separated from the thorax. Simuliid larvae live almost exclusively in running water. Here they attach with short hook-like spines on their abdominal end supported by an adhesive disc to a substrate, such as a rock or plant. Often many larvae are attached arranged in such a way that their heads point in the direction of the current of the creek.

In case they leave their place of attachment they move similar to butterfly larvae (caterpillar) by attaching with their legs in the frontal part of the body in alternation to the abdominal hooks and sucking disk. Black fly larvae breathe through the skin and thus oxygen is taken directly from the water.

On the mouth of the larva the upper lip carries two pairs of fans of comb-like composition, which together form a sort of basket that is used in filtering algal cells from the water that passes by (Fig. 5.13b). Cylindrical antennae are located near the base of each head fan. The feet can be extended and have hooks. The posterior circle of hooks attaches the larvae to the surface of plants or rocks, and the anterior is used when the larva moves and changes its position.
After six to nine larval stages the larva is fully grown and spins a cocoon that is attached to the substrate and in which metamorphosis occurs. The cocoon is spun by silk secreted by glands next to the mouth and oriented in such a way that it extends free into the current of the creek. Such characteristic pupae, with funnel shape pointing towards the current and the margin of the side lying opposite to current direction and provided with organic threads, was noted in clean creeks such as in Wadi Hisban and Mujib attached to the lower side of stones.

Within the pupa stage, the larva breathes through a branched filament close behind their heads, which extend outside their cocoon. At the end of the pupa stage mature black flies emerge within a bubble of air, which takes it to water surface and releases it there without the wings becoming wet. Most authors have recorded the Simuliidae as a family with larvae which can tolerate organic pollution.

They used them as indicators of water degradation and stated that the number of black fly larvae increases in water with poor quality due to contamination by sewage effluent. In addition swift currents provide even more favorable habitat conditions for black fly larvae.

Simuliid larvae may occur in large numbers attached close to each other on rocks and aquatic vegetation. In Wadi Atun and Wadi Shueib, simuliid larvae associated with chironomidae larvae occur in great numbers and they may be confused with each other when they occur together at the same habitat. The larvae share the presence of a prothorax with pro-legs, but in simuliid larvae there is only a single pro-leg pair on the thorax, while chironomidae larvae have a pair on the thorax and on the abdomen. Furthermore simuliid larvae have no hemoglobin and thus no red pigment and they avoid standing water. But both of these larvae have high tolerance to organic pollution and also to some raised salinity of the water. Aquatic black flies were present in mineral waters in Wadi Atun.

Wadi Atun simuliid species (Fig. 5.13c) can survive and grow under slightly salty water and relatively high ratio of Sr (37.41 ppm) and Br (10.39 ppm). Other species are tolerant to relatively organic water pollution which heavily occurs attached to rocks in Wadi Shueib stream (Fig. 5.13d).

But black flies are absent from Zarqa and Mujib Rivers. Clean water species are less common in Jordan and they are represented only in one spring at Wadi Hisban with low population. In Jordan, Simuliid larvae inhabit water of different degrees of pollution raging from clean to polluted.

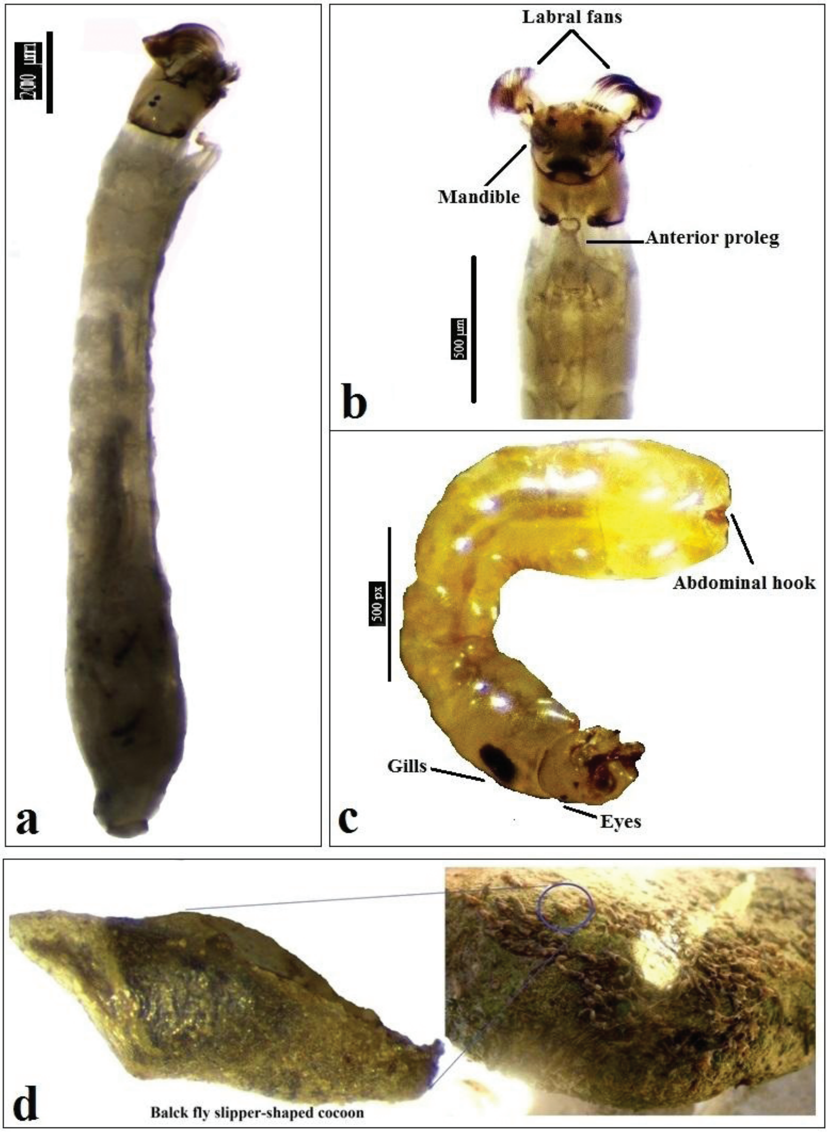


Figure 5.13: Larva of black fly in Jordan, a. Main characteristic features of black fly species with worm-like shape (Wadi Shueib), b. Magnified ventral side of a black fly larva showing its morphological features (Wadi Shueib), c. Mature larva with two large dark spots of developing gills and two pairs of small dark eyes (Wadi Atun), d) Black flies with their Slipper-shaped cocoons attached to a rock (Wadi Shueib downstream of Es Salt treatment plant).

5.5.3 Ephydridae (shore fly, sometimes brine fly)

Ephydridae (shore fly, brine fly) are tiny and can be found in large numbers on muddy wet grounds, for example at Karama reservoir which holds salty water. They assemble here in large numbers and feed on algal cells washed to the shore. High population of shore flies larvae occur on rocks and salt-encrusted sandy shore in the salty lake of Karama dam where the salinity is about 20500 µS/cm (Fig. 5.14).
Great numbers of Ephydrids pupae and empty pupa cases coated by salt crust with a dome like appearance are found on the beach. The shore flies in Jordan can be considered as indicator of brackish to salty environment. Eggs are laid onto the surface of the water next to the shore. Here they are anchored by projections which prevent them of being washed away. Shore fly larvae have reduced head which is retractile into the thorax. The antennae are small or absent. They have 8 pairs of reduced legs present in rows with hooks or spines.

The hooks are used to hold to the substrate. Their crawling locomotion is slow and they may also swim by bending the body sideways back and forth. Shore fly larvae feed by collecting small particles, usually one cell algae, filtered through the mandible that is moving vertically. Larvae breathe by abdominal respiratory tubes.

Pupae may be aquatic and remain underwater or they are attached above water surface to plants. The body surfaces of adult flies are supported by waxy layer and an air bubble layer that allow them to enter the water for feeding or breeding.

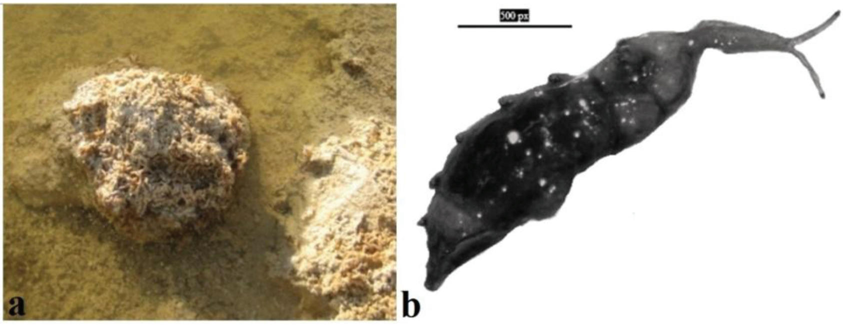


Figure 5.14: a. Shore fly larvae from Karama Lake, b. Shore fly pupae covered by salt crust, occurring on submerged rocks and the sandy shore of the Karama reservoir lake.

5.5.4 Culicidae (Mosquitoes)

Culicidae include some species such as those of the genus Anopheles which may spread malaria disease, and others spreading yellow fever. The adult mosquito has a body with cylindrical shape and narrow wings covered by scales. The head contains large compound eyes and the mouth part of females has needle-like mouth parts used for piercing skin to suck blood or other body liquids. The antennae of the male are feathery and can recognize the vibrations of wings of the female.

Mosquitoes of both sexes may feed on plant juices and nectar but while males use these only to survive, the female, in many species, uses its complex mouthparts for sucking blood of humans and animals such as goats, birds and frogs. They need that type of rich food for producing eggs.

The eggs are deposited while the female settles on the water surface. Anopheles produces eggs singly with eggs remaining on the surface held here by air chamber. Culex eggs (200-300) glued to each other until hatching are laid in floats.

Mosquito larvae have their bodies coated by tufts of hair. The head is large, sclerotized, of rounded shape and well separated from the thorax and with simple antennae. The upper mouthpart carries brushes used for feeding. They move from the outside inwards and thus form whorls, in the water which wash food particles, such as algal cells, to the mandibles.

These mandibles are used for grasping, crushing, or cutting the food. The thorax is large and without legs. From the eighth segments a respiratory tube or siphon in the case of Culex is found. Such air-breathing siphon is not present in case of Anopheles which breathes by a hole on the backside of the eighth segments, thus lies directly on the water surface when exchanging air. The skeleton of the larval stage is exchanged 4 times. The pupa hangs below the water surface in such a way that the mosquito can emerge from it above water.

A life cycle from egg to larva, pupa, and adult takes only between 7-10 days. The length of life of the adult mosquito usually depends on temperature, humidity, sex of the mosquito and time of the year. Males are shorter lived. Mosquito larvae can take advantage of any puddle of water even if not well aerated since they breathe on the surface.

In Jordan several species of mosquitoes occur in both fresh-water ponds and also artificial water containers. They were found in a small pool of mineral water in Wadi Atun with slightly raised salinity (2040 µS/cm) and low oxygen level (Fig. 5.15). Here mosquito larvae formed a very high population and freshly hatched individuals covered the surface of the water. Mosquito larvae tolerating an even higher salinity and water temperature were found next to Karama Lake (16000 µS/cm) together with chironomid and mayfly larvae.

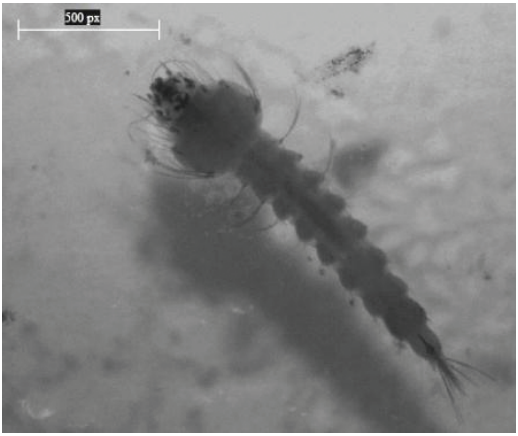


Figure 5.15: Mosquito larva from the brackish water of a pond near Karama Lake.

5.6 Order Rhynchota = Hemiptera = Heteroptera (Schnabelkerfen, true bugs)

The order of Hemiptera has species with a great range of different structural and behavioral features occupying a wide variety of habitats over the world. Hemiptera species may be either terrestrial or semi aquatic and even aquatic four families of aquatic Hemiptera families are reported from Jordan, Corixidae (water boatmen), Veliidae (small water striders or riffle bugs), Naucoridae (back swimmers or creeping water bugs) and Pleidae (pygmy back swimmers).

Typically Hemiptera vary in body shape from oval to elongate. Primarily they are characterized by the modified mouthparts with beak-shaped which extend from the front of the head and usually fold under the body. Also their legs are modified for feeding, swimming or standing on the surface of the water.

The groups were characterized by Roldan (1988) and Polhemus (1996) and their descriptions are used here. Like all insects the body of Hemiptera is divided into three main parts: the head, the thorax with three indistinct segments, and the segmented abdomen. The head supports a pair of antennae and eyes. The thorax is divided into three segments, each with a pair of legs. The abdomen appears with eight to nine segments. An adult has a pair of fore wings and hind wings attached to the thoracic segment, in contrast the pad wings are present at the nymph stage.

Most aquatic Hemiptera (Wasserwanzen, Hydrocorisae) do not rely heavily on dissolved oxygen in water, but instead obtain oxygen from the atmosphere. Due to their ability to utilize atmospheric oxygen, Hemiptera are often able to exist in water bodies with low levels of dissolved oxygen. Most aquatic and semi-aquatic Hemiptera are predatory. After grasping a prey, these predatory Hemiptera inject enzymes into the prey with their beaks, first to poison and then to digest the insides of their prey. The softened internal structures are then sucked up through the beak.

Naucoridae (creeping water bugs) have small oval body with the strong flattened femur in the front legs for grabbing prey and usually middle and hind legs modified for swimming. Their antennae are small, sometimes invisible and situated under the eyes. In Jordan Naucoridae insects can be seen in clusters crawling amongst the vegetation and debris or by rapidly swimming through running brackish water. They are completely adapted to aquatic life. Their small oval body with the strong flattened femur in the front legs for grabbing prey and usually middle and hind legs are modified for swimming. Their antennae are small, sometimes invisible and situated under the eyes.

They feed on small aquatic organisms such as crustaceans and insect larvae. Most of Naucorida breathe by capturing bubbles of air at the water surface and use them as an air supply when they go under water. Some others used plastron gill. They often crawl as well as swim. The female deposits its eggs singly to underwater plants, and after an average of 18 days the eggs hatch. Jordanian species (Fig. 5.16a) are found in shallow moderate to fast flowing brackish water, with algae and other aquatic plants. The body is dorso-ventrally flattened with size approximately 3 mm in length. The cylindrical beak and two dark large eyes on the head are seen, while antennae are invisible. Generally, it is light brown colored with a number of dark markings and the head is light brown with distinct centrally dorsal dark spots.

Dark striations along the segmented abdomen margin are present. Legs are brown without any marking. Abdomen segments are not distinguishable. They possess three pairs of legs, the forelegs are enlarged, flattened and the femur is broadly triangular (Fig. 5.16). Middle and hind legs are covered by numerous fine hairs.

Corixidae (water boatmen, Ruderwanzen) are found in a wide range of habitats. Often they are common insects in ponds and at the edges of lakes and slow flowing streams, amongst aquatic vegetation including willow (Salix) roots. They are swimmers and of fully aquatic life stages. Corixidae, generally have more or less flattened, elongate body shape with large eyes and short antennae.

Corixidae are distinguished from other Hemiptera species by broad triangular beak and straw-like mouthparts that allow them to ingest solid food particles as well as liquids. Corixid bugs are predators or macrophyte piercers. They feed on either insects, such as mosquito larvae, or the juice of aquatic vegetation depending upon the species of bugs. The modified tarsi of the forelegs are used for feeding. The middle legs are usually used for grooming or hanging on to submerged objects, and the hind legs are used for swimming.

Corixid adults are excellent fliers and can easily move from one water body to another. They are often one of the first colonizers of newly formed ponds. The air reservoir consists of a bubble of air over the exposed abdominal surface and beneath the wings. The air is replenished through spaces between the head and pronotum by the bugs breaking the surface film with the pronotum. Individuals of this group live in Wadi Atun in the creek with mineral water (Fig. 5.16, 2).

The family Pleidae (pygmy backswimmers) has its species with aquatic life stages inhabiting standing and moving water habitats. Pygmy backswimmers can be distinguished by their tube-like beak on the ventral side of the head and their generally beetle-like appearance. The small animals of only about 3 mm in size have a strongly convex body with the middle and hind-legs with long hairs used for swimming in a position upside-down. They breathe by taking an air bubble on their ventral surface when they swim underwater and they periodically come to the surface to renew their air supply. Pleidae are predators that feed mainly on mosquito larvae, ostracods and other crustaceans.

Only in Wadi Atun Pygmy backswimmers were present and on aquatic vegetation. They have a highly convex ovoid shape (Fig. 5.16,3a) with the small head strongly compressed and the first segments of the thorax or pronotum sclerotized plated. The anterior margin of the head curves strongly downward. Seen from the side, the middle part of the body is much wider in its posterior balloon-like shape (Fig. 5.16,3b). The animal has a brown color with some irregular dark brown markings. The forelegs are short and the margin and ventral side of the abdomen is fringed with long hairs. Front legs are slender and middle and hind legs fringed with long fine hair.

Notonectidae or Backswimmers, as the commonest name indicates, these aquatic insects swim on their backs, vigorously paddling with their long, hair-fringed hind legs. They represent a cosmopolitan family of aquatic insects. They swim upside down especially when changing the air which they store around their body. They are similar to Corixidae (water boatmen) but can be separated by differences in their dorsal-ventral coloration, front legs, and predatory behavior. Their convex dorsum is light colored without cross striations. Their front tarsi are not scoop-shaped and their hind legs are fringed with hairs for swimming. Notonecta is the most common genus of backswimmers characterized by having streamlined, deep-bodied bugs up to 16 mm long with green, brown, or yellowish appearance. Their food consists of tadpoles (frog larvae) and small fish, and can inflict a painful "bite" on a human being (actually, similar to a mosquito "bite", it is a stab with their tubular mouthpart). They inhabit standing freshwater bodies. Although primarily aquatic, they can fly well and so can disperse easily to new habitats.

Hydrocorisae and Nepidae (Wasserwanzen, Skorpionswanzen) like Nepa have a long tube for breathing air at their abdomen which they can extend over the surface of the water. Amphibiocorisae (Wasserläufer) move on the surface of water on ponds (Gerridae) or can dive into the water as the Velidae.

Veliidae (riffle bugs or water striders) are skaters on the surface of the water. Members from Jordan belonging here are present on freshwater surfaces. Their long antennae distinguish them from other Hemiptera. The head is shorter than the thorax and carries dorsally visible eyes. A cylindrical beak is present and as in all Hemiptera it has only four segments (Polhemus, 1996). The front pair of legs is adapted for grasping prey. Their legs and light weight are modified to permit them to run across the surface of the water. Body shape is variable from oval to elongate. Veliidae are spending their time on the surface of the water and breathe from the atmosphere but when they swim or are submerged underwater, they trap air bubbles in the fine hairs that cover their bodies. Species have only four instars. They are either scavengers, or prey on other small aquatic arthropods.

Figure 5.16,4 shows one of the Veliidae species which are mainly found at the water's edge of slow water flows to still water in Wadi Hisban. Jordanian Veliidae represent the largest Hemiptera in size with 9 mm in length. Jordanian Veliidae species have elongated body shape. General coloration is dark with yellowish to green lighting along the lateral sides of the abdomen. The back of the head has a light color stripe. Antennae are quite long, two times longer than the width of the head. They are wingless. Dorsally, plenty of black spots cover the thorax. Ten abdomen segments are distinguishable. Hind femur is short, and does not reach beyond the end of the abdomen.

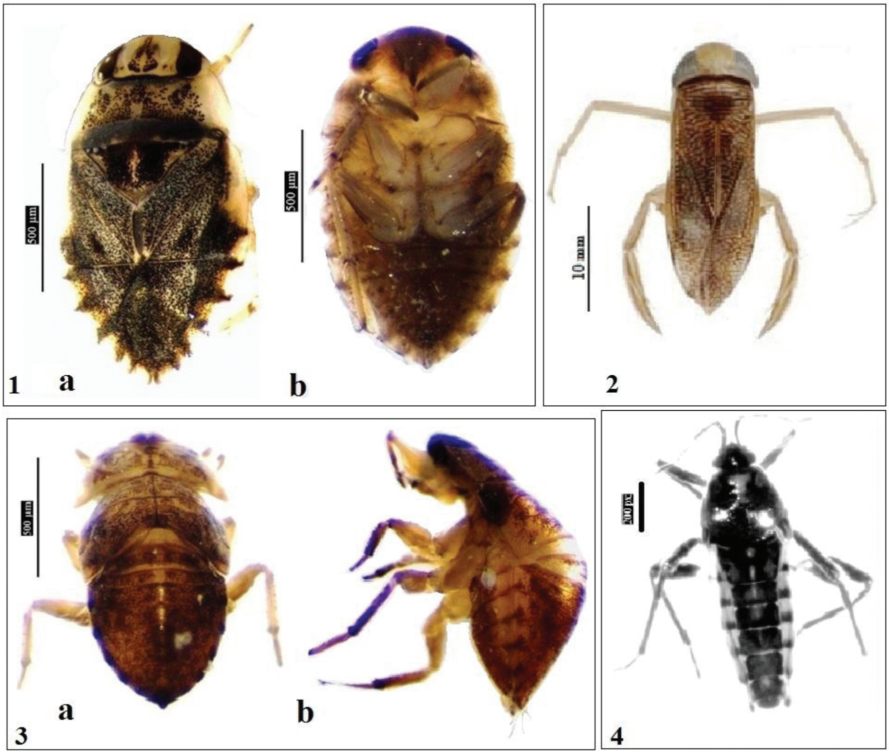


Figure 5.16: Jordanian true bugs. 1. Species belonging to Naucorida family: Oval-shaped Naucorida with brown color (Dorsal view).Three pairs of legs, (Ventral view). 2. General body shape of Corixidae species.3. Pleidae species: a) dorsal side showing the Pleidae with ovoid shape. b) Laterally view. 4. Dorsal view of cylindrical Veliidae body, with antennae longer than the head and the back of the head with a stripe.

5.7 Order Coleoptera (Beetles)

Coleoptera have about 350000 species with several families of water beetles, such as Dytiscidae (Diving beetles, Schwimmkäfer), Gyrinidae (whirlig beetles, Taumelkäfer), Haliplidae (crawling beetles) and Hydrophilidae (scavenger beetles, Kolbenwasserkäfer). This order is characterized by the hard shell-like front wings or elytra that cover the membranous hindwings as adults (Ward, 1992).

The adult usually has a smooth, elliptical and convex shaped body with varied antenna forms (e.g., clubbed, filamentous, serrate and, elbowed). Modified mouthparts are adapted for chewing. Nearly all water Coleoptera adults are air breathing, and rise periodically to the surface to draw atmospheric air into their elytra cavity.

The feeding habits of aquatic beetles are diverse. They can be detritivores, herbivores and some are carnivores. Williams and Feltmate (1992) discussed the Coleoptera feeding behavior and pointed out that adult and nymph Coleoptera do not always have the same feeding behavior. For instance, many larvae species are predators and they have modified mouthpart with stout mandibles, to inject digestive enzymes into their prey and then piercing the fluids, while the adults feed on detritus and plant matter.

Generally Coleoptera animals inhabit aquatic or/and terrestrial habitat. Most aquatic species can be found in freshwater flowing and standing represented in rivers, creeks, streams, ponds, lakes, reservoirs in addition to brackish water (Roldan, 1988). Williams and Feltmate (1992) divided Coleoptera into groups depending on the locomotion behavior including; clingers, swimmers, divers, climbers, sprawlers, and burrowers.

Dytiscidae commonly known as ‘diving beetles’, Dytiscidae species are true aquatic beetles as they live entirely in the water as both, adults and larvae. Dytiscid beetles live in a variety of freshwater habitats. They are most abundant in the littoral zone at the edge of ponds and lakes and are also found in water filled ditches, dams, pools in intermittent streams and inland saline lakes. This wide range of habitats includes numerous types of substrata; rock, pebbles, gravel, sand, mud, silt, peat and other organic debris. The water beetles of the Dytiscidae are described by many authors, among them are Miall (1895), Leech (1945) Johnson and Jakinovich

(1970), and Jach and Marglit (1987). The mature Dytiscidae have a hard, smooth, elongated, and streamlines shaped body. The head is broad and closely joined to the prothorax. Their mouth with double toothed mandible is adapted for chewing and internal digestion.

The antennae are long with around 11 segments and usually filamentous in shape. The scutellum (small triangle region located centrally between prothoracic and the top of elytral) can be visible or absent, depending on species. The Dytiscidae prothoracic width is as narrow or only slightly narrower than the elytral width and their elytral cover all abdomen segments. They have three pairs of legs comprising spurs on their tibia and tarsus with five segments. The hind and mid legs are longer and narrower than front legs. The modified flattened hind legs are fringed with hairs for swimming.

Both adults and larvae are predators on other aquatic animals, including insects, crustaceans, worms, leeches, molluscs, tadpoles and even small fish. The feeding method may differ between adults and larvae of the same species. All adults and some larvae ingest solid and liquid food through a mouth opening. Most larvae have closed mouth openings and so use mandibular channels to inject digestive enzymes into their prey and suck up the resulting fluids.

Larvae and adults breathe atmospheric air. The term ‘diving beetle’ comes from the adult behavior of coming to the water surface to replenish air supply then returning to swimming well below the surface. Adult dytiscid beetles store oxygen in a bubble beneath the elytra whilst larvae use a siphon located at the tip of the abdomen to draw in air. There are two general forms of larvae; 1) creeping and burrowing forms which are denser than water and must climb or swim to the surface, 2) buoyant forms which put in efforts to stay submerged.

After mating, females deposit eggs onto aquatic plants often in pits made by an ovipositor or they use crevices among rocks. These eggs may be attached with the help of silk and may even be contained in cocoons threads. The earliest instar (animal of the larval stage) usually remains near an aquatic plant and uses the oxygen produced by it for breathing. The second and third instars need to breathe surface air, which is taken in through two tubes (paired spiracles) at the tip of the abdomen.

All larvae are carnivorous and move slowly attacking prey by injecting a liquid that dissolves the interior of their prey so that it can be sucked into the larva. Pupation takes place in a cell formed by larvae in damp soil, but out of water. New adults return immediately to the water. Dytiscus and related water beetles feed also on large aquatic animals such as frog larvae and young fish.

Two different species of Dytiscidae were recognized in Jordan, one in the clean water downstream of Mujib dam and the other in the mineral water of Wadi Atun with a water salinity reaching 2000 µS/cm. While the first is shiny golden and occurs together with Melanopsis and Theodoxus gastropods (Fig. 5.17a), the second is dark colored with yellow dots (Fig. 5.17b). It is quite possible and even likely that there are more species of water beetles present in Jordan, but they occur only in not polluted or weakly polluted water.

Gyrinidae (Taumelkäfer, whirling beetles) often swim rapidly on the surface of the water in circles and their larvae are carnivorous. Their first pair of legs is long and serves for catching prey. The posterior legs are flattened and are used for swimming. Males have on their frontal legs sucking pads. Rapid movement on the water is carried out by the paddle-like hind-legs. They catch prey and eggs are glued to water plants. Larvae are elongate and have gills, and can thus breathe under water. They pupate in the mud of the shore and rest in moss.

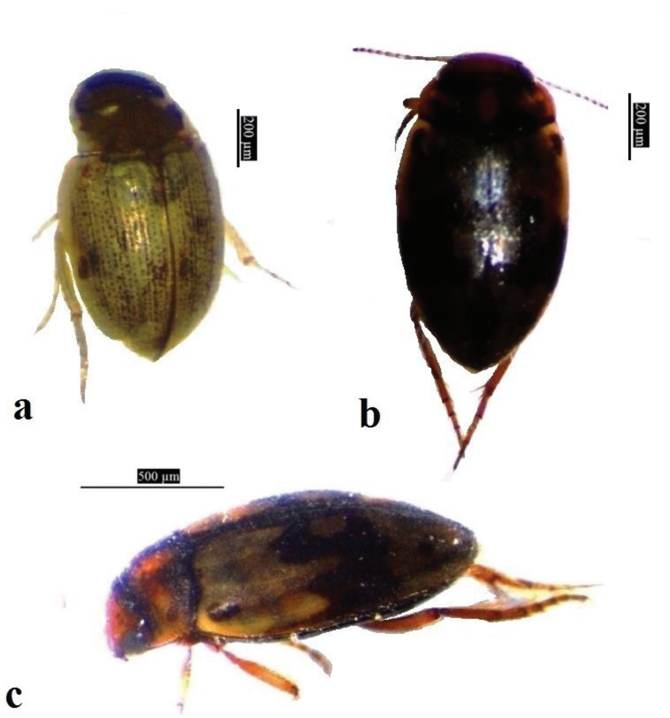


Figure 5.17: a. Dytiscid has oval and convex shaped with shiny golden color (Wadi Mujib), b. Aquatic Dytiscid with dark and elongated shape collected from Wadi Atun (dorsal view), c. Lateral view of Dytiscid showing the small head and the strongly jointed thorax and elytral overlap the abdomen segments. (b and c pictures of the same species but with different light reflections and views).

Chapter 6

AQUATIC WORM GROUP

6.1 Introducation

Aquatic worms represent a diverse group of animals that can commonly be found both in running and standing waters. While many species live in the sediments, others are closely associated with aquatic plants. Flatworms (Class Turbellaria**,** Platyhelminthes) and segmented worms (Annelida) of the Oligochaeta and Hirudinea are considered as water quality bio-indicator.

6.3 Turbellaria (flat worms)

Platyhelminthes (flat worms) are bilaterally symmetrical animals. Thus their left and right sides are mirror images of each other. They have distinct top and bottom surfaces and distinct head and tail ends. Movement is along the sole of the foot and here motion is due to cilia and by stretching and contracting small portions. The result is a gliding movement similar to that found in gastropods.

Their body is composed of three main cell layers, an outer layer and intermediate layer and the layer with the gut. Platyhelminthes have no internal body cavity and the space between the skin and gut is filled with mesenchym, a connective tissue made of cells and is reinforced by collagene fibers that act as a type of skeleton and provide attachment points for muscles.

Flat worms have no gills, no heart and their body liquid moves with the movements of the body. Thus they are small animals in which oxygen can reach and carbon-dioxide can leave all parts of their bodies by simple diffusion. Flat worms are carnivorous and catch insect larvae as well as crustacean by mucus and suck their body liquid. Most of them have no anus and regurgitate material that is not digested through the mouth. The gut is lined with a single layer of cells which absorb and digest food.

The layer between it and the outer layer (mesenchym) contains all the internal organs and in it oxygen, nutrients and waste products are transported. It also has omnipotent cells which can transform into any other type of cells. Among them, flame cells which received their name because the beating of their flagella looks like a flickering candle flame, extract water that contains wastes and function as simple kidneys.

Flat worms have an ability to regenerate if divided by cuts across their bodies and some of them clone themselves by transverse division, and may reproduce by budding. Fresh water flat worms turbellarians, need water rich in dissolved oxygen and preferably cold (Engelhardt 1962, 2003). Thus in Jordan they have only been encountered next to springs, one species with two eye dots and the other with numerous smaller eye dots at the anterior part of their head.

The species with two eye dots resembles *Planaria*/*Dugesia*, while the other is close to *Polycelis* that usually has many small eyes on the margin of the anterior end (Fig. 6.1).Several species of *Planaria* as known from Europe are similar as species of *Polycelis* also common in Europe.

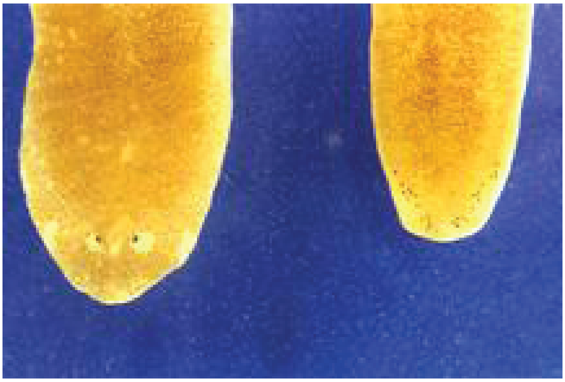


Figure 6.1: Dugesia tigrina and Polycelis coronate (sources:University of Alberta:bio-ditrl.sunset.ualberta.ca).

Most turbellarians are detritivores, feeding on dead particulate organic material, or zoophagous, feeding on small living or moribund invertebrates. In Jordan they live in springs and places which remain wet throughout the year. Flat worms were found in the clear springs of Wadi Shita (Fig. 6.2a), and Wadi Hisban (Figs. 6.2 b&c) in the highland and were also seen in a small spring in Wadi Mukheiris near the Dead Sea.

Flat worms in Jordan can be recognized by their yellowish white color their small size and their typical movements as ciliary creepers.

They crawl on the bottom of the water or on plants and are indicators of water with good quality with no pollution. Their tolerance to increased salinity has not been checked, but the spring in Wadi Mukheiris has slightly brackish water (2500-3000 µS/Cm).

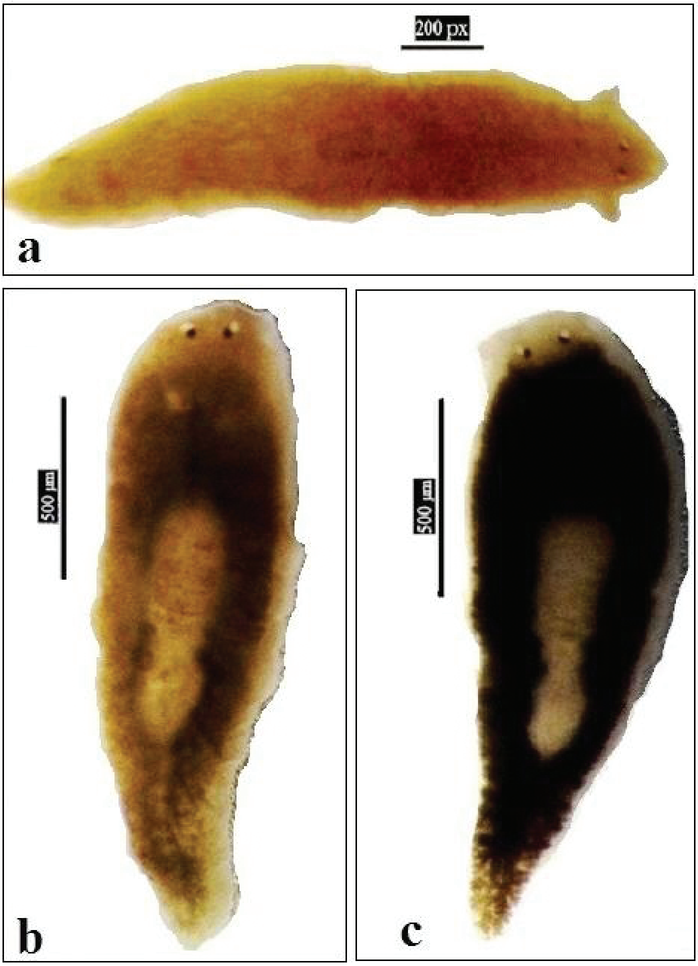


Figure 6.2: Jordanian turbellarian worms, a. Turbellaria from Shita spring has a light brown color with head end showing the characteristic triangular shape and ear-like structure, b. Turbellarian worm from Hisban spring with two eyes and rounded head shape, c. Dark black colored species of turbellira from Hisban spring.

6.3 Annelid worms

The body of annelid worms is usually clearly segmented. They are divided into three classes, Oligochaetes (earthworms), Polychaetes, and Hirudinea. Among those living in fresh water, class Oligochaeta is represented by two quite different subclasses: the Clitellata and the Hirudinea. In contrast to Polychaeta which usually live in the sea, they do not have parapodia but may have bristles on each segment in case of the Clitellata (Stoch & Welsch 2004).

They usually are cylindrical, thin (some are very thin), with segmented body usually with short not always visible bristles or hairs (setae) that help with movement. They move by stretching through and pulling pressuring body liquid due to contraction of their muscles in a worm-like fashion.

6.3.1 Leeches

Leeches (Hirudinea) are specialized annelid worms of which many species have a parasitic mode of life living primarily in fresh water. Leeches have a somewhat soft, very muscular body flattened from top to bottom, without any bristle-like setae (Fig. 6.3a). They usually show black to brown color. Their body usually tapers towards the head and is made up of 34 segments and had 3 pairs of eye at the anterior. A leech has a small anterior sucker and a larger posterior one.

The anterior mouth contains three toothed plates or jaws. The head of the leech has multiple eyespots and a mouth located within its sucker. The last segment has a sucking device that forms when the animal is fully grown by fusion of several segments. Leeches are hermaphroditic, and reproduce only sexually. Because leeches undergo no metamorphosis as they age Juveniles can only be distinguished from adults by their smaller relative size.

Most leeches are predatory and consume the body fluids of their small prey by either consuming it whole or piercing and killing it with specialized mouthparts. Predatory leeches may feed on insect larvae, earthworms, snails, and other leeches, while parasitic leeches feed on the blood of fish, birds, amphibians, and mammals.

Leeches swim by rhythmic undulations of their body, slow in usual mode, but when agitated they can move at a much faster pace. Movement on land is by looping the body with the posterior sucker attached to a substrate, subsequently the leech stretches out and attach to the substrate with the anterior sucker. The posterior sucker is then detached and pulls up to the anterior sucker.

Leeches occur in practically all creeks and ponds in Jordan which are not strongly polluted. Their occurrence in a locality is rapidly recognized by their egg cases, with this characteristic shape. At all localities with leeches and also such where they were present, a short time ago, the cupola-like organic capsules are attached to hard substrates, preferably the lower side of stones. When fresh, the egg cases are transparent and contain developing youngs and when older they turn brown. Jordanian leeches were noted to parasitize fish, frogs and invertebrates such as snails. Clearly different species of leeches occur, but it was not undertaken to distinguish them from each other.

Leeches have a high tolerance for pollution and are thus only of limited value as bio-monitors. That could be improved somewhat by distinguishing their different species, which has not been determined in Jordan, but was used in bio-monitoring studies in Europe and the USA with some results. The absence of egg cases of leeches on the lower side of rocks in Jordanian rivers and creeks indicates unusually high pollution of that water.

6.3.2 Oligochaeta, Tubificidae

Of the freshwater annelids those of the subclass Oligochaeta display a great diversity and some of its species have great value as bio-indicator. A feature of oligochaetes is the small bristles and hair-like projections (setae) on the body wall. The shape and organization of these setae are important diagnostic features. The small part in front of the mouth of these worms is usually mobile. The gut begins with the frontal mouth and terminates at the posterior end of the body with the anus.

Most oligochaetes living in freshwater, feed by passing mud and debris of the substratum through their gut. Here organic matter from this material is digested. Some aquatic worms closely resemble terrestrial earthworms while others can be much narrower or thread-like.

Oligochaeta are hermaphroditic, thus they have male and female within the same individual. But during reproduction cross-fertilization is the rule. Their reproductive structure is the clitellum, which in terrestrial earthworms is a conspicuous swollen area about one third the way from the anterior end of the worm.

In most freshwater oligochaetes, the clitellum is not very conspicuous and usually becomes obvious only at the time of sexual reproduction. Within the few segments of the clitellum male sperma, and in others female eggs, are produced. Copulation is by connecting the clitellum of one individual next to that of the other one and exchanging sexual products. Eventually a cocoon is secreted by the clitellum that contains the fertilized eggs. It slips off the anterior end of the worm. From the eggs, small worms hatch without intermediate larval stage.

Oligochaete worms are diverse, and occur in a spectrum of fresh clean spring water to extremely polluted creeks and rivers. Lumbriculidae or earth–worms are common and widespread and represent large worms. Some are also found in standing and running waters, and were encountered among the reeds in Shita spring area (Fig. 6.3b).

Tubificid worms (sewage worms or sludge worms) of the fresh water oligochaetes are most commonly found in soft sediments rich in organic material. With increased organic pollution and decreased dissolved oxygen concentrations, *Tubifex* may become more abundant while most other benthic animals disappear. As long as some oxygen is at least periodically available, and toxic products do not accumulate, the rich food supply and less presence of competing benthic animals and predators rapid growth is permitted.

Because of this, the worm lives at the bottom of a stream and can not easily leave its living environment to swim away and to escape stress (contamination of sediments used as food). This worm represents an excellent indicator of a distinct type of organic contamination of water. Thomas (1972) discovered that the presence or absence of tubifex worms can be used as useful bio-indicators to assess the efficiency of wastewater treatment plants.

Tubifex worms feed primarily in the top 2 to 8 cm of the sediment and adjust their feeding depth to the lower strata when the density of individuals is higher. *Tubifex* worms have their head down in the sediment and the posterior part of the body projecting above the sediment

water interface, breathing with the posterior part of their digestive system that is rich in hemoglobin, thus bright red. They coat the mud in which they live with mucus thus producing tubes.

The worms selectively ingest particles at depth and digest the attached micro-organisms, primarily bacteria. Fecal pellets are deposited at the sediment-water interface and these mucus-bound pellets maintain their integrity for some time after deposition on the sediment surface. By forming a protective cyst *Tubifex tubifex* can survive drought and food shortage. Such cysts also functions in the dispersal of the worm.

Tubifex lives in areas which are heavily polluted with organic matter that almost no other species can endure, as is the case in Zarqa River. *Tubifex* occurs commonly in Jordan, but one has to watch out not to mistake it for some fly larvae of the Chironomidae which are also red and occupy similar muddy grounds. Tubificid worms and chironomid larvae are among the most abundant macrofauna species living in the sediment of eutrophied creeks and streams in Jordan and their population densities can be very high.

In Zarqa River, for example organic mud is produced in large amounts due to the growth of cyanobacterial crust in strongly polluted and well illuminated water. These mucus mats when detached from their substrate of growth, collect in places with little current and here due to bacterial activity, turn into anoxic mud.

This environment of predominantly organic composition is a preferred place for the establishment of huge populations of *Tubifex*. The worms feed on that material and thus mineralize some of it, and what has gone through their digestive system is expelled in the shape of pellets. These have a larger surface than the organic sludge and can be settled again by microorganisms and thus provide new food for the worm.

Mineralization of organic material is well documented in River Mujib downstream of the dam and results in a strong improvement of the quality of the water of the river (Figs. 6. 3b&c). It turns to very high quality resulting in a very diverse population of water animals. In case of the River Zarqa *Tubifex* is also actively transforming surplus organic material into a more acceptable food source for other organisms, but here the chemistry of the river is such that many other animals cannot live in that water due to its high chemical pollution. *Tubifex* worms were found in the muddy margins of the reservoir formed by the dam in Wadi Shueib and also along soft bottom environments in the creek here downstream of the Salt treatment plant (Fig. 6.3e).

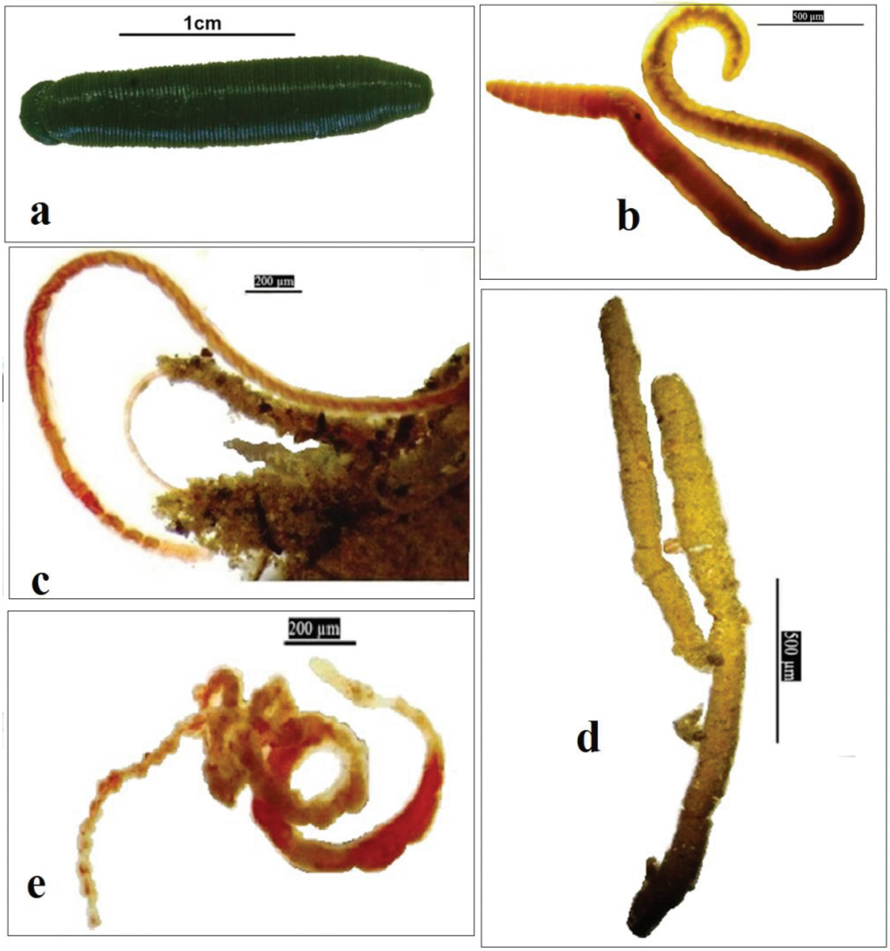


Figure 6.3: Annelid worms collected from different locations in the study area, a. Leech worm from Wadi Shueib, b. Oligochaet-Lumbricaria-like from Shita spring, c. Tubifex worms dwelling in muddy substrate (Wadi Mujib), d. Tubifex worms hidden inside muddy coated tubes from Mujib River downstream of the dam**,** e. Tubifex worm from Wadi Shueib**.**

Chapter 7

CRUSTACEA GROUP IN JORDAN

7.1 Introduction

Crustacea represent a large and diverse group among the invertebrates of the phylum Arthropoda. Crabs live in almost all aquatic environments regardless of warm or cold water, deep or shallow water, most of them in the sea, but also quite a few in freshwater and a few on land. They display high diversity in body shape, form, and size but all species are characterized by the presence of the legs with joined parts, and two pairs of antennae. The basic body structure consists of the three areas head (cephalon), thorax and abdomen. The head may be fused with the thoracic segments to produce a cephalo-thorax or it may be well separated from the thorax.

On the head, compound eyes may be present on eyestalks as is the case in amphibods and decapod crabs, or the eyes are without an eyestalks as for example among the isopods. Mouthparts consist of a pair of mandibles which are jaw-like and two pairs of maxillae.

The thoracic legs as well as the abdominal legs are arranged in pairs and can be modified for food gathering, walking and swimming. Crabs are usually covered by a hard carapace, made from chitin sometimes with calcite added to it, and it serves for protection of the soft body and for attachment for the muscles. Crabs breathe by respiratory gills and by diffuse gases across their thinner areas of the cuticle

The life cycle of crustaceans may directly or indirectly include a larval stage, which is common among species living in the sea. Among the species living in fresh water most develop directly without a larval form and metamorphosis. Usually the fresh hatched crustacean resembles mature individuals.Some crustaceans bear a brood chamber attached to their body, which holds the eggs and in which, after being fertilized, embryos are brooded.

In Jordan freshwater crustacean, include amphipods, isopods, decapods, ostracods and also occasionally copepods and phyllopods. The individual species which were collected range in size from less than 1 mm to several centimeters. In our samples ostracods are among the smallest crustaceans and the largest is the crab *Potamon* that measures up to 10 centimeters.

7.2 Crustacea in Jordan and their indicator values

Branchiopoda are crustaceans with branched legs. Among them the Phyllopoda (brine shrimps) have flattened leaf-like legs, often numerous, used in swimming. They may occur in huge numbers in ponds with brackish water. They were not found by us during our field work, but should be present in Jordan. *Artemia* has a segmented body to which broad leaf-like appendages are attached. The total length is usually about 10 mm and the exoskeleton is thin and flexible. *Artemia* have two widely separated compound eyes on flexible stalks and a median eye in the centre of the head. Brine shrimp can tolerate levels of salinity from 25‰ to 250‰, with an optimal range of 60‰–100‰.

They move by rhythmic beatings of the appendages and respiration occurs on the surface of the legs through feather-like plates. Adult female brine-shrimp ovulate every few days and can produce eggs only shortly after hatching. The eggs can survive extreme conditions and once placed in salty water, the eggs hatch within a few hours. *Artemia* eats cells phyto-plankton.

The order **Notostraca** of the crustaceans holds the Triopsidae with *Triops* (tadpole shrimp), which are found in Jordan. They have a broad, flat carapace, which conceals the head and bears a single pair of compound eyes. The abdomen is long and bears numerous pairs of flattened legs. The telson is flanked by a pair of long, thin caudal rami. *Triops* feeds on algae and small animals which rapidly develop at the bottom of temporary pools which, sometimes, in the winter, remain along periodically running rivers. *Triops* is about 2 cm long with dorso-ventrally flattened carapace and two pairs of short antennae.

The abdomen has body rings and the number of pairs of legs per body ring can be variable, up to six and legs become progressively smaller along the abdomen. The abdomen ends in a pair of long, thin, multi-articulate caudal rami (telson).

The eggs released by the female are held in a brood pouch for a short time before being laid. The eggs survive drying out of pools and long periods of dryness to hatch often several years later when a new pool forms at the place where they rest or have been transported to by wind or water. Here also clam shrimpspossibly belonging to *Cyzicus* and representing branchiopod bivalved crabs of the so called conchostracans also occur in the same environment. They have eggs which, as in the case of Triops, can tolerate long lasting dryness. Both were observed to occur in a periodical pond near Azraq.

The water flea ***Daphnia*** with 1–5 mm in length is a free swimming and filter feeding crustacean branchiopod that has a jumping style of movement. Swimming is powered mainly by the second set of antennae, which are larger in size than the first set. The action of this second set of antennae is responsible for the jumping motion. Beating of the other legs produces a constant current through the carapace which brings predominantly cells of phyto-plankton to the mouth and into the digestive tract.
Most of the body is covered by a carapace, with a ventral gap in which the five or six pairs of legs lie. *Daphnia* eggs are enclosed in a thick shell, consisting of two chitin plates, that encloses them. They are usually the product of sexual reproduction, while during further growth of a population parthenogenetic (asexual) reproduction is the usual. Females produce a brood of eggs every time they molt. From the eggs, larvae hatch which molt a further 4–6 times and within a week reach an age by which they are able to reproduce.
A **water flea** resembling *Daphnia pulex* was encountered in separated pools at the margin of the reservoir of Wadi Shueib at the edge to the Jordan Valley with a large number of individuals swimming with small jerks through the water and filtering phyto-plankton cells from it. The type of small egg that can easily be transported on a foot or the feathers of a water bird and the mode of reproduction by rapid asexual multiplication can produce a large population in a short time, as in the case of the puddles next to Shueib dam site as observed in spring time 2013.

Copepoda of the *Cyclops* relation which grow to a size of 0.5–1 mm have been observed in Shueib creek in Jordan 2012. The body has two parts, the cephalo-thorax and the abdomen and there are distinct long antennae. The abdomen ends in a caudal furca. Copepods are periodically abundant in the downstream area of Wadi Shueib, in the water downstream of the treatment plant. Males have claw like first antennae, which are used to hold the females during copulation.
Females carry the eggs in tow sacks on the body. Copepods feed on diatoms and other small organisms or filtrate and usually swim but may

also rest on the bottom muds present in the creek at that time. Although they are difficult to observe, *Cyclops* has five pairs of legs.

Ostracoda (seed shrimps) have carapace consisting of two valves connected to each other by a hinge. The body can be totally withdrawn below the shell and is bilateralsymmetric and horizontally compressed. The soft body consists of a head separated from the rest of the body by a constriction. They may be of a somewhat orange color but many species has brown, dirty-yellow and white in appearance. Ostracods are often used as bio-indicators of their environmental and when they fossilize they are important for paleo-environmental studies.
In Jordan they inhabit almost all water bodies under different environmental conditions. The determination of ostracods collected by us was carried out by Mischke (2013). Different species belonging to this group of crustaceans are common in Jordan in freshwater to slightly brackish water bodies including ***Heterocgpris reptans***, ***Cypridopsis vidua***, ***Humphcypris subterranean*** (Fig. 7.1a), and ***Ilyocypris sp***.

Other species of ostracods which have a high tolerance to salt in water are represented by *Heterocypris salina*, *Heterocypris reptan,* and *Cyprideis torosa*. But *Heterocypris salina* species can be also found in freshwater (e.g., Wadi Sir, Wadi Shueib, in the downstream area of Zarqa River), and also in thermal mineral water (e.g., Hemmet Thableh in Wadi Hemmah). By contrast *Heterocypris reptans* (Fig. 7.1b) and *Cyprideis torosa* occur only in salty water and are indicator species of environments with salty water.
Ostracods are opportunistic and can settle any aquatic environment rapidly due to the almost omnipresence of their eggs and their being transported by water birds attached on mud glued to their feet, their beaks and feathers. Thus they reach a new aquatic environment rapidly and their eggs remain after water has dried up. When the salinity of a puddle of water changes such species, which are tolerant to such changes survive and others, are replaced by species which can live in that specific type of water and that can occur within the time range of weeks only.
Ostracods are small in size, feed on even smaller organisms such as diatoms, and species with quite different requirements for life can live close to each other in a river, creek or pond. As bio-indicators to the

quality of water they are of limited use with the exception of those species that react to the salinity of the water.

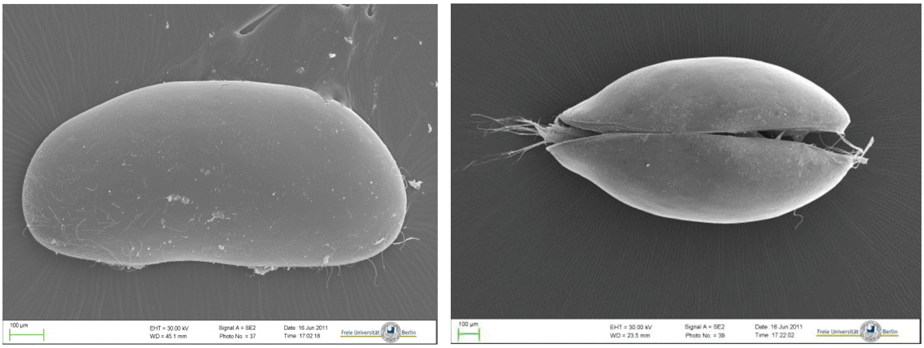


Figure 7.1: a. *Humphcypris subterranea* is a common fresh water species, b. *Heterocypris reptans* carapace (Salt water tolerant species of ostracods)

Amphipoda as suborder of the Malacostraca (higher crabs) are commonly known as scuds or side-swimmers due to their swimming behavior. Amphipods can walk, burrow and can swim sideways by rapid curving and stretching motion of their body. They feed on algae and detritus. Amphipods are an important source of food for many vertebrate animals such as fish, turtles, frogs, birds, and snakes. The body is laterally flattened and when the animal is resting it has hemicircular shape forming an even curve with its back. *Gammarus* moves sideways when crawling but when swimming the ventral side may be oriented upwards.

The body consists of the head with one pair of long and another pair of short antennae, first part of the thorax with four pairs of legs which differ from the three pairs behind them and on the last part three pairs of appendages which serve as gills. The back part carries the tail with two branches (Fig. 7.2). When animals move the gill plates together with the motion of the legs, propel the animal through the water.

Below the antennae lie the compound eyes. Of the seven pairs of legs the first two serve as food collectors, the next five for crawling and swimming. Food is eaten with a pair of chitin mandibles, two pairs of maxillae and held by the first legs. These instruments are very useful in their feeding, which relies predominantly on shredded leaves. In addition, crusts of bacteria and algae are eaten, as well as smaller animals.

Gammarus pulex living in Europe is a pure freshwater species resembling the animals found in Jordan. During its life time it changes the carapace up to 10 times within the first three months of its life. After fertilization, the female carries the eggs in the thoracic brood chamber until they hatch. The young amphipodswhen released go through several molts to reach maturity, and they develop directly without any larval form. The female may live for two years and may breed up to nine times during that time.

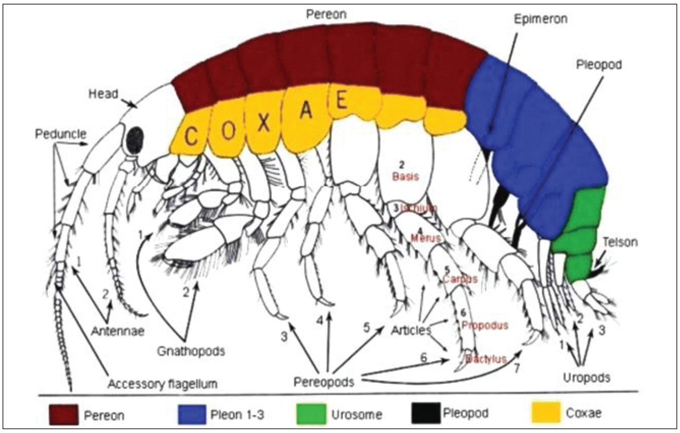


Figure 7.2: Morphological features of Amphipod (Gammaridean), adapted from Barnard and Karaman. 1991 (Gnathopods 1 and 2, pereopods 3-7)

In Jordan amphipods of the *Gammarus* type are found in large numbers hidden under rocks, plant fragments and among the aquatic vegetations in freshwater throughout the country when the water is clean and well oxygenated.

They have a yellowish light brown color, and range in length from 1 to 5 mm. In the cold water of Wadi Shita spring, Wadi Hisban springs (Fig. 7.3), and Wadi Shueib spring (Jadoor) they are common and occur abundantly in River Mujib some way downstream of the dam. Together with the gastropods *Theodoxus* and *Melanopsis*, turbellarian worms with different types of mayfly larvae are bio-monitors of clean fresh water.

They are absent from brackish or salty water, even when the salinity is low as in Wadi Atun and they, in addition, do not live in warm water as that of Zara. Amphipods represent good indicators for clean, cold, calcareous non saline freshwater springs and streams.

Figure 7.3**:** Yellowish and brownish amphipod fauna collected from Wadi Hisban spring.

Isopoda of the freshwater Asellidae (water slaters) are members of a group of crustaceans that contain species living in aquatic habitat ranging from fresh to marine water and have even become adapted to terrestrial environment. Asellus resembling those living in Germany, occur in Jordan commonly together with amphipods. Isopods have one pair of tail appendages and seven pairs of legs, which are more or less similar to each other. The head carries compound eyes. The gills are attached to the abdominal segments. Isopods get the oxygen through gills located at the bases of their legs. Isopoda life cycle is characterized by direct development without a larval stage or any metamorphosis. After mating, the fertilized female carries the eggs in brood chamber or sac in their body between the first four pairs of legs.

The development of the eggs and youngs is in that brood pouch and the youngs are released after about three weeks as miniature adults. Like in the case of amphipods, the freshly hatched isopods are similar to the adults but they have to go through several molt stages before they mature. ***Asellus aquaticus***, the most common species in Central Europe, can breed throughout the year and maturity can be reached in a few months under warm summer temperatures.

Life span varies from 9 months in warmer regions to 20 months in Northern Europe. Food consists of small organisms such as available in algal, bacteria films, and dead and decomposing plant matter such as decaying leaves. Isopods usually use their legs to move and are adapted for walking or clinging to aquatic vegetations. Freshwater isopods are primarily benthic and occur in the littoral zone of ponds, lakes, streams and springs. They may differ with regard to their tolerance to pollutants.

They have been used as water quality indicators (Maltby 1991). In Jordan *Asellus*-like isopods live only in clean water, and in contrast to *Gammarus* with more debris strewn bottom substrate. But in contrast to ***Asellus aquaticus*** from Europe they cannot be considered to be a representative of environment with polluted water, they rather live in clean water flowing over a lot of plant debris. As soon as the water quality decreases Jordanian fresh water isopods disappear.

In Jordan isopods are less commonly encountered than amphipods, but are usually found in places with relatively clean water with much organic bottom substrate, as is the case in Wadi Hisban and also the upper portions of Wadi Shita (Fig. 7.4a). Individuals living here have a length of about 6 mm, brown color with yellowish dots, small head and long antennae.

A second smaller and different species and was found clinging to algae in Shita spring. This species has transparent skin, a comparatively shorter and broader head and bears curved antennae. TheJordanian isopods inhabit clean and relatively cool freshwater, and are indicators of clean water with much vegetation.

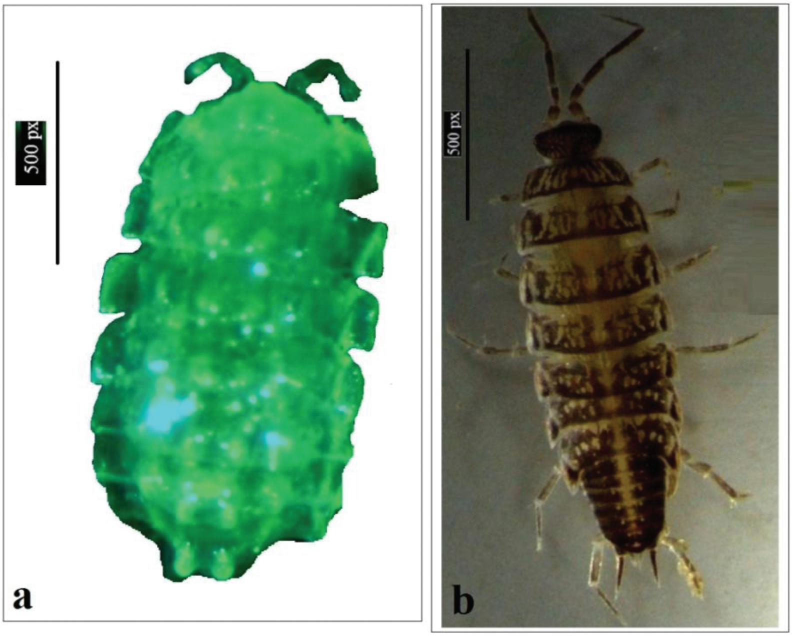


Figure 7.4: a. Isopod fauna clinging to algae in Wadi Shita spring, b. Isopod from Wadi Hisban (Artifical canal).

Potamon (fresh water crab) of the subclass Decapoda: Potamidae is a semi-terrestrial crab that belongs to the eastern Mediterranean species ***Potamon* (*Potamon*) *potamios***, as reviewed by Brandis et al. (2000). As with other crabs, the body is roughly square, with the reduced abdomen tucked beneath the thorax. The thorax bears five pairs of legs, the first of which is armed with large claws. The carapax is convex, without bristles, and the color is dark brown and variable. The basal part is yellowish or reddish brown. Males have larger claws than females while the females have a larger abdomen.

Reproduction may occur at two times in a year, but for those in Jordan that is still unknown in detail. The life span of ***Potamon fluviatile*** is up to 12 years. Females carry the eggs on their appendages on the abdomen until they hatch directly into juvenile crabs, having passed through the larval stages inside the egg, and the same is probably the case for *Potamon* in Jordan.

Potamon occurs commonly along rivers and creeks in Jordan, from the highland to the Jordan Valley. It constructs burrows on creek or river margins with their entrance on land but continuation into a long burrow that reaches water level. Adults occupy burrows, while smaller individuals shelter under stones. The entrances to the burrows may lie several meters afar from edge of the stream and are always above water level. *Potamon*, during daylight, is usually in its burrows excavated at the shore of creeks and it is active mostly at night.

Potamon is an aggressive species, mostly attacking with the larger right claw, since 90% of individuals are right-handed. These claws are sufficiently solid to crack the calcareous shells of *Melanopsis*, especially those of juvenile individuals with relatively thin shell margin. Food consists of animals as well as plants and also corpses of fish or other animals.

The crab can obviously resist much pollution and lives along the Zarqa River almost from its “spring” at the treatment plant to its end near Deir Alla where its water disappears into pipes. But the crab is also found along clean water, such as that of spring Hisban (Fig. 7.5), river Mujib (Fig. 7.6) and river Hasa. Since it avoids salty water, it can still be regarded as a useful water quality bio-indicator.

Figure 7.5: a. Crab from Wadi Hisban, b. Ventral view of Crab from Wadi Hisban


Figure 7.6: a. Crab with ventral brood chamber from Wadi Shueib, b. Crab burrow balcony-like near Zarqa River

7.3 Water mites, Spider

Relatedwater mites have species with semi-aquatic habits. The mites encountered in Jordan live under water and were encountered in the clear fresh water of Mujib River, in springs such as Shita and in creeks composed of mineral water as in Wadi Atun (Fig. 7.7). These water mites have orange, red and yellow colors and are well visible against a background of green water plants even though they are of small size. The water mites are often not tasty to fish and it is interpreted that the bright colors have evolved to warn the fish of their foul taste. Eggs are laid under water either on the surface of stones vegetation, or are placed inside living plant tissues or tissues of freshwater sponges.

In the case of the Jordanian species the preferred place of oviposition is unknown. Water mites may have an extremely complex life cycle that consists of four to six stages. The larval stage, which differs markedly from later stages by the possession of six legs (later they have 8 legs) and a highly modified set of mouthparts, it is the ectoparasitic phase.
During this period of growth water mites may be parasite on aerial insects which also represent an effective means of dispersal. They may also remain under water where they search for a host among insect larvae. The mite larvae feed on host blood and are often carried far from their water bodies, in case they had been attached to a larva.
That change of location may occur after its metamorphosis to a flying insect. The well-fed larva that has reduced its body construction as parasite transforms into active swimming or crawling predator after that stage of life and from now on preys on all stages of aquatic insects, crustaceans, and other mites. Gas exchange is by a system of fine tubes that allows oxygen to come close to the organs of the body and mites take the oxygen they need from the water and do not have to come to the surface for that. Their presence in a stream or spring in Jordan is an evidence for good water quality.

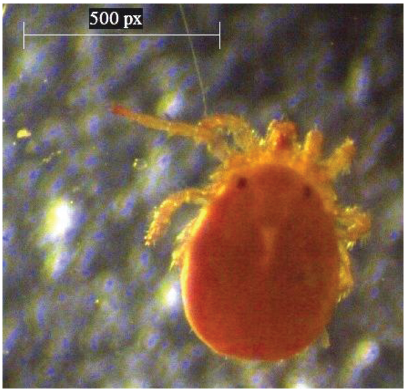


Figure 7.7: Mite from Wadi Atun

Chapter 8

MOLLUSCS GROUP AS BIO-INDICATORS

8.1 Introducation

11 species of gastropods and 4 species of bivalves live in the running waters in Jordan. Of these Theodoxus of the Neritimorpha group, Pseudamicola, Melanoides, Melanopsis of the Caenogastropoda, Ovatella, Galba, Bulinus and Physa of the Heterostropha order are found to be good bio-indicators and their occurrence can be used to characterize the quality of the water in which they occur. Also three species of bivalves are present but are restricted in occurrences to the Jordan Valley and here especially to King Abdullah Canal.

8.2 Molluscs as bioindicators of environmental conditions

Theodoxus jordani lives only in places with running clean water. Theodoxus is found in locally very restricted places, such as small springs, as for example in a spring of Wadi Um ed Dananir, several small springs in Wadi Sir, one spring in Wadi Shueib (Fig. 8.1), Wadi Hisban (Fig. 8.2), and Nimra spring near Suchknah, but it may also appear in Mujib river after its water improved in quality as below the reservoir (Fig. 8.3a). The usual shape of this very visible gastropod is rounded, more hemispherical when young, later less symmetrical. The flattened apertural side is more pronounced when fully grown.

Most individuals are black, but more rarely, totally white color morphs exist, and especially, in KAC individuals with lighter color have stripes and dots as ornament (Fig 8.3b). The shell is wider than high and on the aperture the inner lip is smooth and is covered by a more or less thick and smooth shell layer (callus). When fully grown, the shell is up to 10 mm high and 9 mm wide.

The aperture can be closed and tightly sealed by an operculum that is calcified and is provided with a ridge and a peg representing a solid structure on the inner side of the inner lip. It protects the snail very well, for example from the attacks of the crab Potamon.

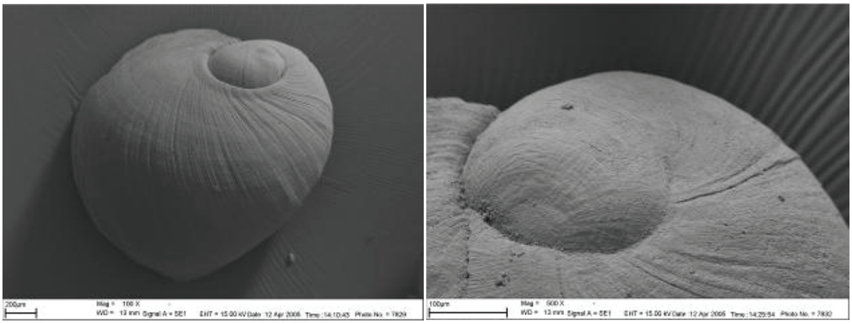


Figure 8.1: a. Shell of Juvenile Theodoxus (Wadi Shueib), the scale bar is 200µm, b. Theodoxus with embryonic whorl distinct from adult shell by growth lines (Wadi Shueib creek 2012, the scale bar is 100µm)

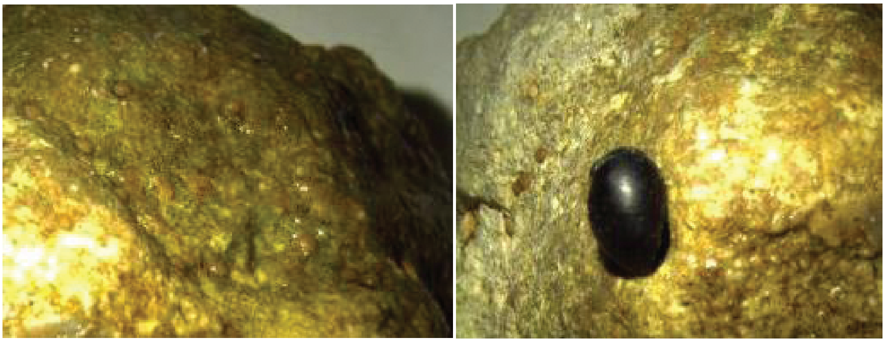


Figure 8.2: Egg capsules of Theodoxus on the surface of a stone from Hisban spring.

Figure 8.3: a. large number of theodoxus and Melanopsis in Wadi Mujib water, b. Theodoxus on the margin of King Abdullah Canal in March 2013

Several groups of morphologically different species of Melanopsis are recognized in Jordan with slightly different preferences to their ecology but unclear relation to each other.

Melanopsis stands in competion for food with Theodoxus and may be out-competed by Theodoxus on stony grounds in spring water as well as the concrete base of King Abdullah Canal. This canal can support huge populations of both genera, and at places with cleaner water Theodoxus is clearly predominating. Melanopsis are present in fresh water springs such as Wadi Hisban and Wadi Mukheiris (Figs. 8.4 a&b).

Species or varieties of Melanopsis living in Jordan have been determined. Commonly only one variety occurs in a location, but sometimes also two or three different ones live together. The most common among the Jordanian species is ***Melanopsis buccinoidea*** with smooth shell of 8 to 9.5 whorls and usually a height of around 25 mm and width about of 12 mm (Fig. 8.5). ***Melanopsis costata*** is ribbed and used to occur in Azraq Druz pond in 1995, but is now extinct here.

All other forms or species could be interpreted to represent hybrids between the smooth *Melanopsis buccinoidea* and the ribbed *Melanopsis costata*, but these varieties may occur in a large local population with one and the same, body morphology, present in many individuals and several generations.

Melanopsis produces single eggs, each surrounded by a gluy gelatinous cover that has particles of bottom substrate of the ground attached and is thus very well hidden. From each egg a minute young hatch with a shell consisting of little more than one whorl. In this stage of growth the gastropod can be carried from one locality to the other attached to water birds.

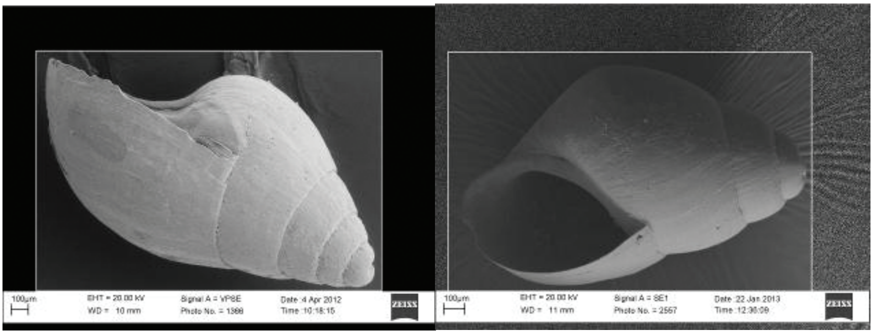


Figure 8.4: a. Juvenile shell of *Melanopsis buccinoidea* from Wadi Hisban spring, b. juvenile shell of *Melanopsis buccinoidea* from Wadi Mukheiris,the scale bar is 100µm

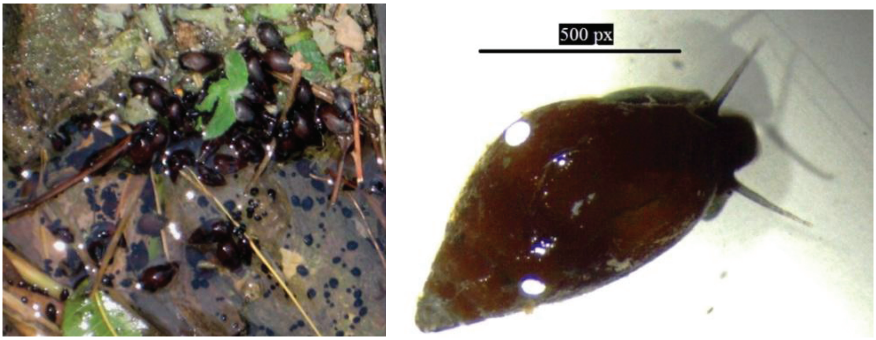


Figure 8.5: Living *Melanopsis buccinoidea* from Wadi Hisban.

Melanoides in contrast to **Melanopsis** prefers muddy ground and standing water. Melanoides tolerates higher salinity than is the case in any of the varieties of Melanopsis. It may tolerate an increase in salinity and used to occur in huge numbers in Karama Reservoir, but from 2012 to 2013 the salinity in Karama Reservoir increase so much that it became extinct here. Melanoides has a slender elongate shell that can grow up to 5 cm in length with high and slender spire and of to 15 whorls. Often even juvenile shells are decollated. Transverse and spiral ribs are generally present, commonly forming tubercles with each other.

Melanoides tuberculata lived in the 80s in the brackish pools in Azraq but due to the destruction of that environment it has become extinct. It occurs now near Hemma at the Yarmouk and from here along the Jordan Valley to the Dead Sea and to its southernmost feeding creeks as well as pools with soft bottom substrate next to wadi Al Hasa. It may be found anywhere in Jordan at places with muddy ground covered by clean fresh to slightly brackish water. It also occurs commonly in the muddy substrate on the bottom of King Abdullah Canal (Fig. 8.6) and is thus spread over large areas in the Jordan Valley.

Muddy substrates in Zarqa River are obviously not sufficiently clean for Melanoides to live on, and thus the species can be used as a good indicator for strong pollution on muddy river substrates as in Zarqa River and for salinity rising as much as in the reservoir of Karama dam (Fig. 8.7).

The youngs of a Melanoides tuberculata develop within the brood pouch of their mother. Such brood chambers are present also in individuals with a shell size of less than 2 cm in length. Of the hatching young the initial 1.5 to 1.7 whorls have an irregularly wrinkled surface representing a sculptural pattern that develops due to retarded calcification during early ontogeny. On subsequent whorls ornament appears and is regular and the youngs hatch from the brood pouch often with about five whorls completed.

Its success in rapidly settling all available fresh water substrates in ponds, lakes and channels is connected to its parthenogenetic mode of reproduction.

Melanoides populations usually consist of only females. With only one masculine individual a whole population can be started. The shelter of the brood pouch of the mother is left with four of five whorls of well calcified shell. The youngs released to the environment are thus well protected from attack, and the- tiny juvenile can easily be transported on the feet or on feathers of water birds and can thus be spread easily over long distances.

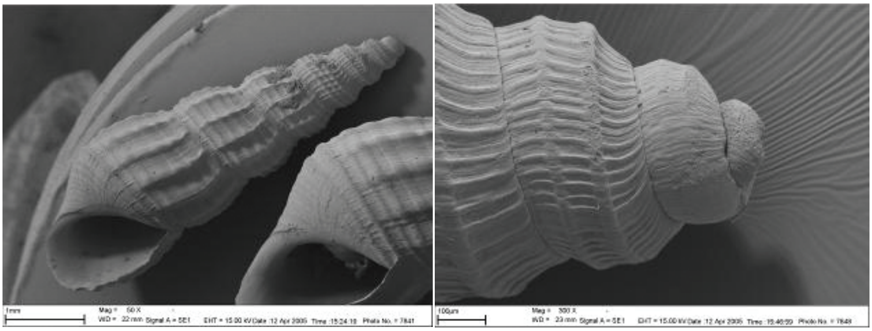


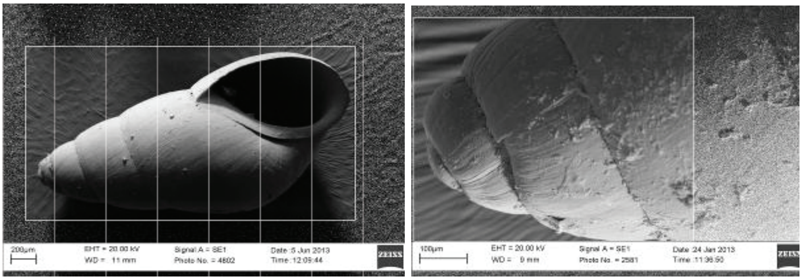
Figure 8.6: a. Shell of Melanoides (King Abdullah canal), the scale bar is 200µm, b. Juvenile shell of Melanoides collected in 2012 from King Abdullah Canal,the scale bar is 100µm

Figure 8.7: *Melanoides tuberculata* from Karama Lake

Hydrobia together with species resembling ***Hydrobia acuta*** occur only sporadically in Jordanian waters and it is thus not very useful as a water quality indicator species. It apparently prefers flowing water with a lot of vegetation in it. Hyrobia differs from Pseudamnicola by having a larger and higher shell with more whorls when fully grown. Its shell is about 3.3 mm high and 2 mm wide, consisting of about 5 whorls and is ovoid elongated, smooth with slightly convex whorls.

The aperture is of oval shape and can be closed with an organic operculum that has few whorls with eccentric nucleus. The embryonic shell consists of a little more than one whorl and is connected to a young leaving the egg case crawling on its foot.

Along with shells of all stages of growth including the minute shells of freshly hatched young were washed from the sediments of a small creek with brackish water near the northeastern end of the Dead Sea. Thus Hydrobia was breeding here with the youngs hatching from the numerous small hemispherical egg capsules attached to hard substrates in the water. The gastropod feeds on growths present on stones, much of which consists of diatoms. From the same creek at the Dead Sea the very similar ***Semisalsa contempta*** was found (Fig. 8.8). Both species are from a slightly brackish pond south of the Dead Sea.



(Scale bar is 200μm) (Scale bar is 100μm)

Figure 8.8: Semisalsa with shallow sutures from a creek Northeast of Dead Sea, with juvenile part of the shell, embryonic stage ends after one whorl is formed.

Hydrobia is studied to enable the description of several gastropods with similar shells encountered in different localities in Jordan. Similar species collected from a small creek belong to at least three species living in brackish water with increasing degree of salinity.

Pseudamnicola has circum-Mediterranean distribution with species which are difficult to distinguish by shell features alone. Species within the genus differ only slightly regarding their shell shape and can be distinguished from each other only by anatomical characterization, especially such of the morphology of the sexual organs. *Pseudamnicola* occurs commonly in Wadi Atun (Fig. 8.9a). It is small with more than 2 mm high hydrobiid shell and only about 4 whorls and of these the last one increase in size more rapidly than the ones before and thus compose more than two thirds of shell height.

The apertural margin, in the fully grown shell, is thickened and continuous. In the creek egg, capsules of ***Pseudamnicola*** were observed in large numbers, especially on the lower side of stones. They consist of small cupula-like structures which are white at first but rapidly become settled by cyanobacteria coloring them greenish. From these egg-capsules the hatching youngs have a little more than one whorl of shell. The same or a similar species was found in a spring at the NE end of the Dead Sea (1978) (Fig. 8.9b), which since has been covered up by building construction. Since we found *Pseudamnicola* only in creeks stemming from springs with mineral water such as Wadi Atun (Fig. 8.10) or in such with brackish water, the small snail can be regarded an indicator for water with higher salt content than fresh water.

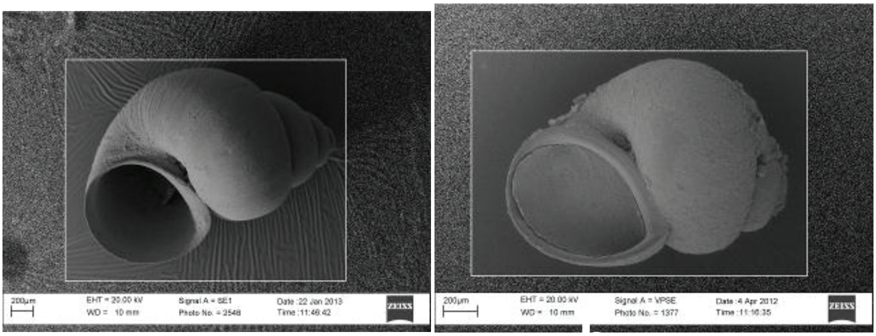
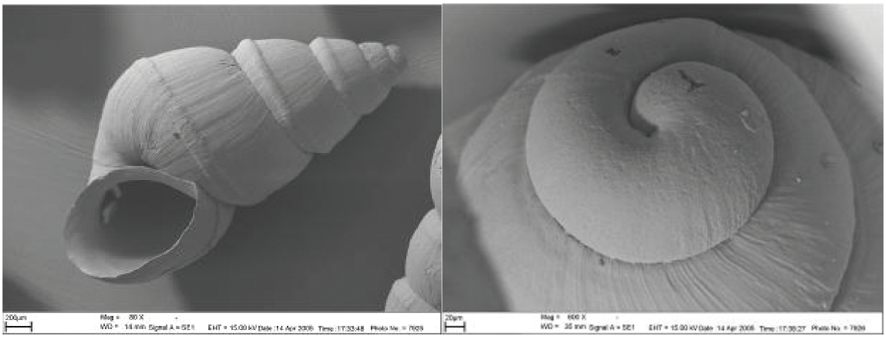


Figure 8.9: a. Shell of *Pseudamnicola* from Wadi Atun (2012), b. *Pseudamnicola* gastropod from a small creek at NE edge of the Dead Sea (1978), they may very well represent different species of *Pseudamnicola*, the scale bars are200µm

Figure 8.10: Pseudamnicola from Wadi Atun.

Falsipyrgula barroisi lives along the northern part of King Abdullah Canal, but also in a vegetated irrigation canal near Abu Habil and next to Sharhabil Mosque (Fig. 8.11). The small, 2.5 – 3 mm long elongate shell is characterized by having ornament of a distinct keel on its whorls, and of having the size and general shape of *Hydrobia*.

The first whorl of the shell belongs to the freshly hatched juvenile and on the third whorl of the shell a keel appears and the fourth whorl (or a little more) the shell is fully grown. The aperture is around 1mm high and the total shell measures around 3 mm in height. *Falsipyrgula* was found common in the bottom mud of the canal west of Abu Habil in spring 2001 and was extracted a life from a canal surrounding Sharhabil Mosque in the Jordan Valley.



(The scale bar is 100µm) (The scale bar is 20µm)

Figure 8.11: a. Shells of *Falsipyrgula* from King Abdullah Canal, b. Fully grown shell with the shell of the young hatching from the egg capsule noted well at the growth increment present just after the first whorl (from a canal near Abu Habil area).

Ovatella is a member of Basommatophora, family Ellobiidae which actually is a representative of the marine pulmonates. Its ovoid shell with large last whorl and short spire has a narrow elongate aperture with a columellar fold on the inner lip. The ornament consists of incised spiral lirae. The animals live amphibious. ***Ovatella (Myosotella) myosotis*** is a common Mediterranean and east Atlantic species that lives in salt marshes. Individuals of *Ovatella* were first noted in 1978 at the NE end of the Dead Sea in a small creek below a brackish water spring (Fig. 8.12a). 2002 it was again collected next to the branching off of the road to Madaba from the main road along the Dead Sea.

Individuals of *Ovatellamyosotis* lived with many individuals on the wet zone of the small creek which emerges from a little spring with brackish water. At the beginning of this creek with brackish water the salt content was not sufficiently high, while only some ten meters below, *Ovatella* was found on the moist sand among *Salicornia* plants and their roots. Stones, plastic junk and wood were the substrate for numerous individuals of all sizes. Below these objects in the shade also the gelatinous egg masses were attached.

The accompanying fauna consists of *Hydrobia* and *Pseudamnicola* living under water on hard substrates in the creek alongside with *Melanoides* in their different stages of growth. 2012 the spring was destroyed due to the construction of appartment blocks and only dead shells of *Ovatella* were found near a creek of irrigation return flows and spring water further north of the houses.

Ovatella also lives on the coasts of the North-See and Baltic-See within the supratidal regime and in the creeks near the Dead Sea between the spring and the salty Dead See indicating a salinity that is about comparable to that of oceanics water. ***Ovatella myosotis*** complets its embryonic and larval development within the shelter of its egg mass and hatches from the egg mass as crawling young. In later stages it resorbs the inner walls of its shell.

Tiny young of ***Ovatella*** can easily be transported on the muddy feet of some shore birds which come from the Mediterranean Sea to collect food near the creek. In case the amphibious snail finds a place with salinal conditions, coming close to those of the sea, they survive and feed on the algal growths here including many diatom algae.

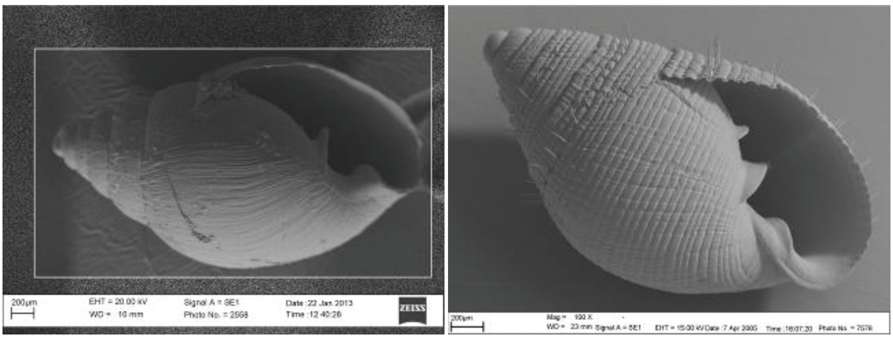


Figure 8.12: a, *Ovatella myosotis* from the salt creek near the NE end of the Dead Sea, the scale bar is 100µm, b. *Ovatella myosotis* from Aqaba, the scale bar is 200µm

Among the pulmonate gastropods especially ***Physa*** is a good indicator species for moderately polluted fresh water. *Physa* tolerates some degree of house sewage added to streams, but is no longer present when the water becomes salty. Additions of chemical pollutants such as mineral oils kill it.

In Jordan, *Physa acuta* is now common while 1978 it was found only in a ditch near Deir Alla.

Living individuals appear reddish brown with the soft body of the snail seen through the semi-transparent shell. ***Physa*** extends finger-like appendages of the mantle onto the outside of its shell, which probably are involved in the gas exchange. Its presence in a creek or river can also be seen on the occurrence of its characteristic spawn. It consists of a clear gelantinous mass that has 10 or more eggs, each in a rounded transparent capsule.

It glues to any hard substrate, commonly the underside of stones, and since it is transparent the young snail can be detected on it with magnifying glass. The youngs hatch crawling and rapidly grow to become mature within a relatively short time. Since the environment with polluted water holds a lot of nutrients for algal growth Physa can find ample food for growth and multiplication.

Physa acuta is now (2011-2013) present not only in quite strongly and in all weakly polluted creeks, but in clean rivers such as the Mujib (Fig. 8.13a). It lives in Shueib creek up and downstream of the treatment plant (Fig. 8.13b) and even lived in the Zarqa River shortly below its spring at Khirbet Es Samra treatment plant in spring 2013 (Fig. 8.14), while in fall 2011 it was only in the lower Zarqa River downstream of King Talal Revervoir.

Physa acuta can be regarded as character species to moderately polluted water in Jordan, while the similar *Bulinus* which also has a shell that is coiled to the left prefers pond water and slow flowing creeks. It also does not tolerate the degree of pollution as is tolerated by *Physa*. The shell of Physa resembles that of *Bulinus* but has a more pointed apex and a shinier smooth surface of it periostracum.

Figure 8.13: a. *Physa acuta* eggs from Mujib Lake., b. *Physa acuta* with eggs in Wadi Shueib.

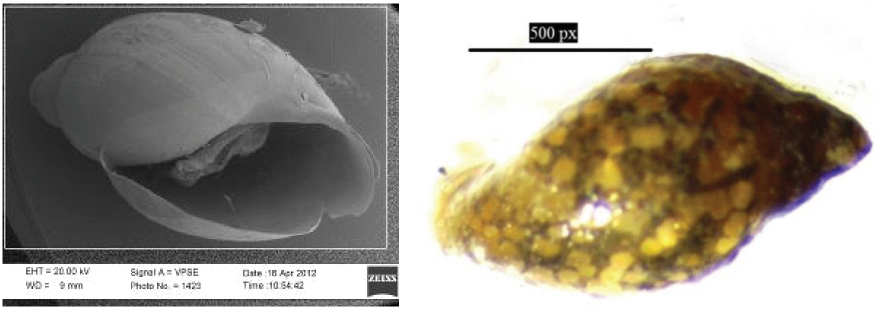


Figure 8.14: *Physa acuta* from Zarqa River collected in 2012, the scale bar is 200µm

Bulinus has a sinistral shell resembling that of ***Physa***. The shell consists of rounded whorls with the aperture wide and higher than the spire. Growth lines can be strong and a fine spiral pattern of lines may cover the gray periostracum. The living animals appear grey while the *Physa* is brown and when crawling the mantle is not expanded across the shell margin, as is the case in *Physa*.

Bulinus truncatus is a transmitter of ***Schistosoma***, but occurs only rarely in Jordan. *Bulinus truncatus* was found 1978 living in the pool formed by the ancient water collection basin built by the Romans at Jerash. This is now dry and puddles in it contain no gastropods. *Bulinus* was also discovered in springs and puddles formed near Nimra spring next to Zarqa River (2013) together with *Melanopsis*. *Bulinus* entered pools with mixed water of springs and Zarqa River not populated by *Melanopsis* living in a clear small creek issuing from the spring (Fig. 8.15).

Both species do not enter Zarqa River proper, but disappear before any contact with the actual river; its water is obviously not healthy enough to either one. In 2014 *Bulinus* was no longer found in that water, but now *Theodoxus* has become common, thus indicating an improvement in the quality of the water of the spring. In the frame of our study *Bulinus* was found only occasionally and thus it is of little value as indicator species.

It appears that it tolerates some more pollution than *Melanopsis* but less than *Physa* and it is present in Jordan and can appear with rapidly increasing number of individuals wherever moderately polluted water of creeks form puddles in slow moving fresh water.

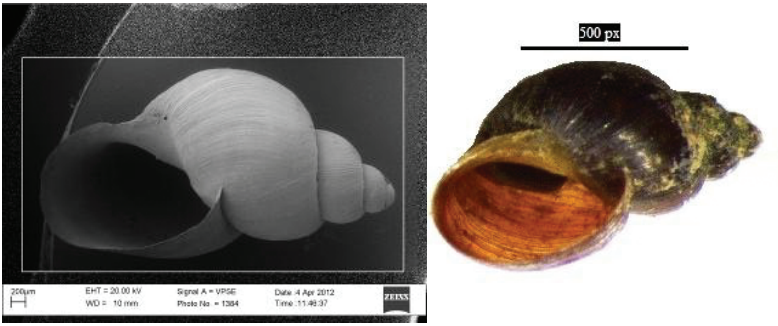
Figure 8.15: Bulinus from a small pool near Nimra spring in the upper ZarqaValley, March 2013

Galba of the Lymnaeidae resembles in its shell shape *Bulinus*, but in contrast to the later it is dextrally coiled. Physidae and Lymnaeidae have no gill but transport a bubble of air in their pallial cavity. They can thus also live in badly oxygenated water by taking their oxygen with them underneath the shell in the mantle cavity.

The bubble is actively sucked into the cavity guided by the muscular opening, the pneumostom, and is expelled that way by being pressed out by muscular contraction of the walls of the lung. Oxygen bubbles can also be collected from plants or cyanobacterial growths under water, where they are continuously produced when sun light is available.

Galba truncatula is up to 10 mm high and 5 mm wide shell with pointed spire of conical shape and deep sutures between whorls. ***Galba truncatula*** was found near the spring of Hisban in small canals leading to fields (Figs.

8.16&8.17) and near the spring of Wadi Shita. It was collected from Wadi Musa (Petra) in 1978 and was also found in a creek that issues into the Zarqa River just downstream of Zarqa Bridge on the road Amman-Jerash in 1983. Its spawn resembles that of *Bulinus* and consists of a gelatinous mass attached to hard substrates and from which after about 10 days of development small crawling snails hatch with a shell of a little more than one whorl as reported from Druze and Shishan marshes of Azraq Oasis by NELSON (1973).



(Scale bar is 200µm**)** (Scale bar is 500 px)

Figure 8.16: *Galba truncatula* from Wadi Hisban (2012) scanned and as in the field

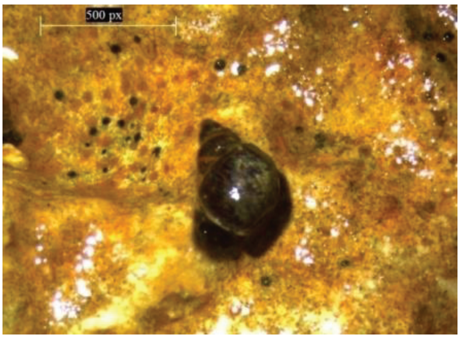


Figure 8.17: *Galba truncatula* with eggs (Wadi Hisban 2012).

Bivalves with species of the genera *Unio*, *Pisidium*, and *Corbicula* live in Jordan. Of these *Unio* and *Corbicula* prefer flowing water that contains much phytoplankton. They are only found in King Abdullah Canal. The bivalves *Pisidium* occur only rarely in Jordanian waters as for example in the clean water of ditches in the Jordan Valley and can thus not be used for pollution assessment.

Unio has a distinct and characteristic mode of development of its off-springs which includes a parasitic phase of its juveniles mostly in the gill of fishes. The eggs are held in large brood pouches which are connected to the gills. When youngs have evolved to be ready for hatching (Glochidia-Stage) they have a bivalved shell that is mineralized with the two valves connected to each other by elastic ligament. This elastic ribbon holds the shell apart, while closing the valves is accomplished by muscles. The Glochidia are expelled into the water by the mother-clam often when it senses the contact to a fish.

Larvae at this stage have secreted a long byssus thread and the valves of their shell are wide open. Thus several individuals are usually connected with each other by their mucus threads and form groups of individuals. When the fish sucks in water through the mouth to expell it along the slits of the gill for breathing, the ***Unio*** larva can come in contact with the tissue of the gill and may get attached to it with its gluy byssus thread.

As soon as the sensory cilia of the mantle margin of the larva comes in contact with the tissue of the fish, the strong shell muscle of the larva contracts and pulls the valves together. They have at their margin a strong thorn, which can penetrate the tissue of the gill of the fish. This irritation of tissue results in its reaction to encapsule the penetrating bivalve larva and include it in a blister. This is what is needed by the bivalve in order to successfully continue its life. The parasitic larva can now continue life while all larvae which are not sufficiently lucky to get hooked to fish tissue die.

The parasitic ***Unio***, the species from King Abdullah Canal, is hosted by a fish that lives here over an extended period sufficient for the bivalve to reach a stage of development inside of the cyst and feed on the body liquid of the fish until it has grown to a size that allows it to continue its life as a free living bivalve. For the change over, it opens the cyst, drops to the bottom of the canal and continues life as a normal bivalve. *Unio* thus reaches all regions which are visited by the fish in which it is hosted.

To continue life after leaving its host *Unio* pumps water over its gills by current produced by cilia, catching organisms of the phytoplankton with it and channeling that food wrapped in mucus to the mouth along the branches of the gill. By that way of life individuals of *Unio* can live for many years, as long as the water is sufficiently clean and contains enough nutrients for a rich development of phytoplankton. Many cells of algae usually turn the water of King Abdullah Canal green, thus creating a perfect environment for feeding *Unio*. Since the bivalves grow to a large size, the water of the canal has relatively good quality that keeps the bivalve going and alive for several years.

Unio terminalis (Fig 8.18) and the ***Unio semirugatus*** (Fig 8.19) rhomboidal shell shape were found alive in 1999 near Mashara. ***Unio terminalis*** lives in King Abdullah Canal also which at times in its northern section hold predominantly water that is derived from the Yarmouk River (Figs. 8.18& 8.19).

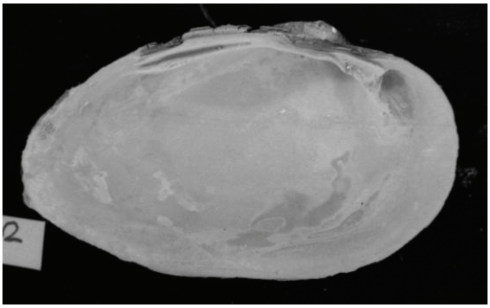


Figure 8.18: *Unio terminalis* from King Abdallah Canal.

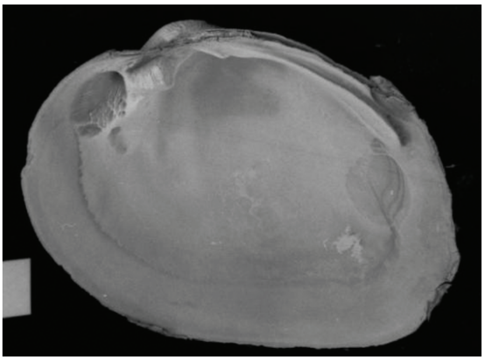


Figure 8.19:*Uniosemirugata* from King Abdullah Canal.

The shell structure of *Unio* consists of an outer prismatic layer with the large prisms composed of fine needles arranged as bundles. The transition to the thick inner layer of nacre is well developed, and the nacre is in brick-layer mode. It is more regular in the shell than in pearls which have also been formed by the *Unio* and can be found in the bottom mud of KAC.

Corbicula, in contrast to *Unio*, releases juveniles after a period of brooding in a special brood pouch of the mother. The miniature adults are released directly without intermediate parasitic stage as in *Unio* and also without a planktotrophic stage as is found in most bivalve species that live in the Gulf of Aqaba. The number of youngs released by *Corbicula* is much smaller than that released by *Unio*, but their chances of survival are much better.

The shape of the shell differs strongly from that of *Unio*, and also its composition is different. The shell of ***Corbicula*** consists also of aragonitic material but in a crossed lamellar structure. The origin of *Corbicula*is south-eastern Asia and it has been introduced to Jordan by transportation (ships etc.) quite some time ago. ***Corbicula fluminalis*** was found alive near Mashara in 1999. It was also found in 2013 in the sediment of KAC and it is still living in it in large numbers (Fig. 8.20). Since it would react to increased pollution its presence in the bottom sediment of the canal is an indication of continous flow of relatively good quality water.

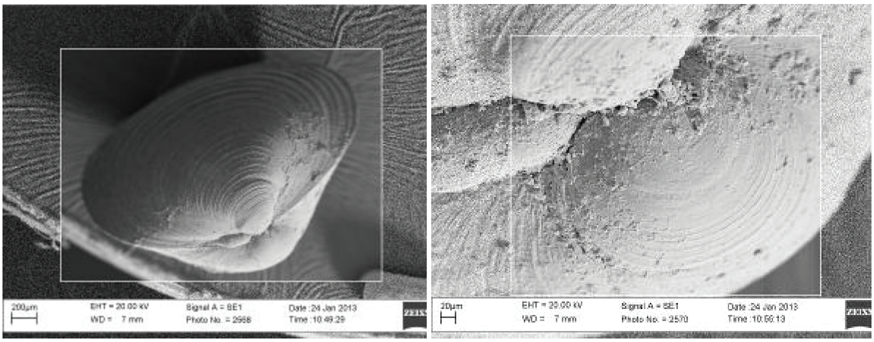


Figure 8.20: a. *Corbicula fluminalis* with juvenile shell, the scale bar is 200µm, b. detail of the *Corbicula fluminalis* embryonic shell that consists of a straight hinge veliger-shell and an added juvenile shell that grows within the brood pouch of the female (From King Abdullah Canal), the scale bar is 20µm

The juveniles of *Corbicula* are crawling and have a shell thickness of 200 µm. From hatching to death, after several years, the bivalve filters phytoplankton from the water with its gill. The shell is thick and solid and can grow to a size of approximately 2 cm.

In the case of the tiny ***Pisidium***, with shells of similar shape and construction as ***Corbicula*** but much smaller (up to 2mm), the female broods the youngs in a pouch and releases them when they are ready far developed. This brood pouch can hold only a few individuals, but their chances of survival are very high when they hatch, due to their relatively large size. They then reach maturity quite rapidly, so that a settlement of a body of water with *Pisidium* can occur in short time. ***Pisidium*** was collected from the spring in Wadi Hisban in 1978, in a spring near the Jarash Bridge at the Zarqa River and in the Roman Pool on the highway Amman- Jarash. Quite a number of individuals were found living in the King Abdullah Canal next to Abu Habil Mosque together with ***Hydrobia,*** different types of ***Melanopsis*** and with ***Falsipyrgula***.

Chapter 9

FLORA AS BIO-INDICATORS

9.1 Introduction

Four different localities in which plants were found to grow on salty ground were intensively studied and it was found that each of them presents quite distinct charactertics. Plants which tolerate salty ground for their growth have a quite distinct character in different localities. In the Jordan Valley such plants surround the Karama Reservoire that contains salty water, even though most of the water entering it comes from the surrounding mountains farther east and northeast and which is somewhat polluted but not salty.

Most of the salt in that lake is of local origin, stemming from salt present near the ground surface. Thus from small springs near the Reservoir the water is brackish, and the ground near the reservoir and next to it is quite salty. The reason for that can easily be detected by the exposed gypsiferous rocks. The structures seen in the surrounding hills indicate that diapiric salt is being pressed up.

In Wadi Araba the sabkha of Taba represents an environment in which evaporation is high leaving the salt in the soil with little soil moisture. The springs which issue into the flat at the margins bring water that has its origin to the east, probably seeping through the mountain range that separates Wadi Araba from the Disi flats. Near the shore of the Gulf of Aqaba moist salty flats a specific community of plants was studied between the hotel complex and the Royal Diving Center.

Here salt has come predominantly by spray of sea water from the Gulf of Aqaba. In winter times often strong winds from the NW pick up the top of waves splashing against the shore and its hard beach rocks and blow it landwards. The flood waters of rare rains dissolve the surface salt on the ground of the hill base to the East and wash it back to the sea.

The salty moist flats in the north-eastern part of Azraq sabkha have their own character. Here water is basically derived from the extensive hilly and in the North mountainous areas occupied by volcanic rocks. Also local springs, such as Garandal and Zerqa Ma'in are considered. Especially because the later is thermal and the chemistry of its water is probably quite distinct from that of other salty waters.

9.2 General view about flora along the water bodies in Jordan

Within the plants the spore plant, Sporophyta, falls into two groups, the Bryphyta (mosses) and the Pteridophyta (fern plants). In the case of the mosses the spore part (Sporangium) grows from the Gametophyte. The spore producing part grows from the fertilized egg-cell of the moss and consists of a stem with a capsule in which the spores form. The growing part of the moss is haploid, the stem and capsule are diploid, and within the capsule spores grow which are haploid again.

Bryophytes including the mosses and liverworts are small and attached to the substrate by rhizoids only for anchoring and not for absorbing water or nutrients from the substrate. Bryophytes absorb minerals from dust, rainfall, and water running over their surface.

Bryophytes are unique among plants in that the dominant, conspicuous generation is the haploid gametophyte. In all other plants, the dominant stage is the diploid sporophyte. Mosses are often connected to the formation of tufa, at places of springs which issue from limestone. Here calcium carbonate is precipitated from water rich in dissolved calcium.

Mosses and algae extract carbon-dioxide from the water used for their photosynthesis and thus calcium-bicarbonate that is more soluble in water than calcium-carbonate under high pH-values is deposited as thin films on the plants as encrustation of lime-tufa. The mosses may in their lower parts be encased by tufa "cement" and the growing points lie constantly above the increasing tufa layer. Such a characteristic tufa production is found for example in Wadi Atun (Fig. 9.1a). In Jordan tufa formation is also commonly promoted by films of cyanobacteria, especially when thermal water issues from springs as in Wadi Zarqa-Ma'in.

The fern ***Adiantum capillus-veneris*** grows in Jordan next to springs with cold fresh water on shady rock face (Zohary 1966, pl. 6). Its leaves are light green, arising from a short-creeping root with dense cover of brown scales (Fig. 9.1b). The leave-blade is two-pinnate and near the base, ovate or triangular. The margins of the leaves may have attached brown spore capsules. Shaded rock cliffs with water seeping through a cleft usually have pillows of dark green mosses and next to them the delicate Adiantum fern is usually present, as is the case in all mountainous parts of Jordan.

Figure 9.1: a. Wadi Hisban- spring with moss and fern, b. Close up of *Adiantum capillus veneris* plants covering the wet limestone cliff

Equisetum, horse tail, of the Equisetaceae, is also a spore-plant and Equisetum ramosissimum lives on the banks of running water in Jordan as annual above ground and perennial below in its rhizome. The upright stem is cylindrical consisting of a hollow tube interrupted by nodes. Its surface contains silex particles and has elongate grooves. Each node has a leaf-sheath with short triangular scales.

Spores are produced in a cone with a surface of hexagonal scales. These are the outer ends of short stalks that have the spore case at their base. When the spores are ripe the armor of scales opens and wind blows out the spores. Coniferopsidae (naked seed plants) contain the Gnetales, with Ephedra. It is bush-like growing in the desert in Jordan and has scale like leaves, and at the end of the branches, minute flowers that are either male or female. The male flower can be transferred by insects but also by wind and were recognized by Litt et al 2012 as indicator of influence of semiarid steppe vegetation, together with pollen of wild grasses (Poaceae), and Artemisia Ephedra alata which occurs for example in the area of Azraq.

The conifers occurring in Jordan belong to Pinus, Juniperus and Cupressus. The leaves of Pinus are long, thin and have a needle-like appearance, but others as in the case of the Juniperus, have flat, triangular scale-like leaves. The leaves are evergreen and remain on the plant for several years before falling.

Pinus seeds develop inside a protective cone. The male cones produce yellowish pollen which are carried by wind to a female cone and are here caught by a drop of water and drawn into a tiny opening on the ovule. From the water drop and after it has entered the female cone a pollen tube grows and seeks out the female gametophyte. Pinus halepensis- forests are characteristic to higher altitudes in northern Jordan between 600 and 1000 m of calcareous soil, especially in the area of Jebel Ajlun and the region south of River Zarqa in the Dibbin forest near Jarash. Its pollen may fly far and their number in sediment samples for example from the Dead Sea can be used for the interpretation of changes in land use during deposition, indicating a decrease in agricultural use (Litt et al 2012).

Juniperus phoenica, Juniper, grows as a small tree in the mountains of southern Jordan. Leaves are needle to scale like and are arranged in pairs or whorls. Plants may be either male or female some individual plants have both sexes in one. The cones are berries which contain 3-8 seeds. The male cones of approximately 3 mm in length shed their pollen in early spring (Zohary 1966, pl.19).

Gymnospermplants in Jordan are growing far from running water. Angiosperms are split into 2 groups which can be distinguished by their seedlings. Those of the monocots (monocotyledons) have one seed-leaf only. Also leaves of most monocot plants have parallel veins. The seedlings of the dicots (dicotyledons) have two seed-leaves. The leaves of the dicots are usually net-veined. Trees are usually dicots, but most species grouped in about 250 families are herbs.

Classification order of the genera encountered during our study are listed according to modern phylogeny, although that is primarily based on classical order, by morphology of the plants, which include more recent data of molecular analysis, as is presented by Stevens (2001 onwards) in: Angiosperm Phylogeny Website. Version 12, July 2012.

Monocotyledones with the suborder Arecales, palms, are represented by Phoenix found near springs and moist spots in the hot regions of Jordan, not avoiding slightly salty water. The order Alismatales has Vallisneria and Potamogeton in clean rivers but almost absent in modern Jordan, and Ruppia that is common in salty creeks near Karama Reservoir.

Order Arales has members of the family Araceae and species of Arum, which occur on shady places along creeks, especially near gardens. Members of the family Lemanceae with the characteristic Lemna consisting of floating leaves attached to roots that extend into the water occur rarely in ponds with good fresh water quality.

Order Liliales is richly represented in Jordan with members of the family Liliaceae of which Allium occurs in gardens along creeks while species of other genera, among them Bellevalia, Colchicum, Fritillaria, Gagea, Leopoldia, Muscari, Ornithogalum, Tulipa, Urginea, and Asphodelus prefer drier grounds (Figs. 9.2a&b). Of the family Smilacaceae, Smilax is found climbing on bushes and near creeks.

Figure 9.2: a. Allium neapolitanum spring 2013 from Um ed Dananir, b. Ornitogalum montanum, near ACOR end of March 2013

Order Asparagales has Asparagaceae such as Asparagus with thorny climbers commonly. Climbing are Tamus, rare in Jordan (Fig 9.3a). In the family, Iridaceae, species of Crocus, Gladiolus, Iris, Romulea, and the Amaryllidaceae species of Narcissus, Pancratium, Ixiolirion, Sternbergia occur and flower in areas usually not close to running water. Among the Orchidaceae, Epipactis was noticed within the moss rich calcareous spring deposits of the mineral water in Wadi Atun, while orchid occurs on drier ground (Fig 9.3b).

Figure 9.3: a. *Asparagus aphyllus* from King Talal Reservoir area 2014, b. Epipactis (Family Orchidaceae) Wadi Atun 2011

The order Scitamineae is represented in Jordan by Musa, banana, planted in the Jordan Valley.

Order Poales, grasses, with members of the family Poaceae is well represented also along creeks and rivers. Some genera represent the agriculturally important forms such as Triticum, wheat, Hordeum, barley, Zea, corn, Oryza, rice, Saccharum, sucre cane. Among the grasses the reeds Phragmites, and Arundo are the largest and the most obvious visible ones connected to running and standing water, Saccarum, Desmostachya are also quite visible in the lower parts of rivers and creeks forming large dense clumps. Among the smaller grasses Aerulopus, Stipa, Polypogon, Schoenus, Scirpus, Eleocharis, the sedges (Cyperaceae) Cyperus, Carex, Fibristylis, and the Juncaceae Juncus are present, along with Phragmites and Arundo. Typha of Typhaceae (order Pandanales) is one of the larger grass-like plants common along rivers and creeks.

Eudicots of the super-order Ranunculales, (order Ranunculales have the family Papaveraceaea with genera such as *Papaver*, *Roemeria*, *Glaucium*, and *Fumaria* and the family Ranunculaceae) which lives with genera such as *Ranunculus*, *Clematis* (Fig. 9.4a), *Adonis*, and *Nigella* (Fig. 9.4b). Most of these genera have species in Jordan.

Papaver, *Roemeria* and *Glaucium* grow on barren grounds as well as among the grassy thickets along Zarqa River and the tributary creeks, while *Fumaria* prefers to grow within the denser meadows along rivers and creeks, and the margin of small irrigation canals (Figs. 9.5a&b). The red flowers of *Papaver* and *Glaucium*, as well as the purple *Roemeria* and the pink *Fumaria* are found around fields on the highland as well as in the Jordan Valley. Among Ranunculaceae most species grow in several localities in Jordan and are not restricted to the margins of water ways, and only ***Ranunculus aquatilis*** grows exclusively in clean water. *Ranunculus* has the flower with five leaves on its outer parts, screw-like numerous pollen leaves and many seeds in the inner portion.

Ranunculus asiaticus with conspicuous yellow flower which is one of the most common flowers in Jordan during spring, time at the slopes of Wadi Wala near the Kings Highway, flowering in spring. The red variety differs from the red *Adonis* by the central part of their flower. No species belonging to either family in Jordan grows when soil becomes salty.

Of the order Laurales the bush-like Laurus nobilis used to grow on the banks of the Yarmouk and nearby the Jordan River in the past, and has since disappeared from near water environments in Jordan.

Figure 9.4: a. Clematis cirrosa from Ajlun 2011, b. Nigella from a spring near King Talal Lake 2014

Figure 9.5: a. *Fumaria officinalis* from Wadi Shueib spring, 2013, b. *Fumaria capreolata*, lower Wadi Shueib (end of March 2013).

The super-order Caryophyllales includes the family Chenopodiaceae-Amaranthacea with genera such as Chenopodium, Salicornia, Salsola, Anabasis, Suaeda, Arthrocnemum, Atriplex, Amaranthus and the family Aizoaceae with Mesembryanthemum, Aizoon. Many of them are important Jordanian halophytes and have leaves and flowers reduced in size but similar to each other among the different species, so that they are nor easy to determin and distinguish from each other.

Anabasis grows along the slightly salty creek of Wadi Atun, Salicornia settles at the margins of brackish creeks, at Karama, Suaeda grows in dry stream beds of the desert as well as on salty ground next to Karama Reservoir and Arthrocnemum grows as small bushes along the creek with brackish water that flows from Karama Reservoir next to the Jordan River. Atriplex is common as small sage-bush in dry and saline places in the Jordan Valley.

Chenopodium and Amaranthus are among the plant on the Zarqa River margin and are common weeds on Jordan Valley fields, and Rumex of the Polygonaceae may grow here as well as in quite dry environments. Polygonum is also found near water or not far from it in the Jodan Valley.

Mesembryanthemum represents a plant that serves as an indicator for salty ground, as is the case around Karama Revervoir, and Aizoon indicates the same on moist ground near the shore of the Gulf of Aqaba.

The family Tamaricaceae of the Caryophyllales includes the bush like Tamarix and Reaumuria, of which Tamarix trees grow right next to the outlet of the Khirbet-es Samra sewage plant that represents the spring of Zarqa River in summer time and bushes belonging to the genus are found where the River Mujib joins the Dead Sea and along the salty Karama Reservoir and at other places in Jordan with salty soils.

In the family, Caryophyllaceae Spergularia and Limonium enter the salt rich environment, one near creeks, the other on mud flats. The herbs of the Caryophyllacea such as those belonging to Silene, Minuartia and Stellaria are found in moist meadows near streams, but occur also in other environments, such as the margins of fields away from running water. Gymnocarpus and Sclerocephalus grow in the bed of dry desert beds and the first also on salty soil near the Gulf of Aqaba. Paronychia and Pteranthus grow among rocks, also next to River Zarqa.

The family Cactaceae with Opuntia may grow near rivers and creeks but also elsewhere on dry ground. The plant with its characteristic thick spiny segments is found in Jordan in the area extending near Amman to the Jordan Valley and was introduced to the Mediterranean Region after the discovery of America. It is thought to native to Mexico. The flowers may be white, yellow and red and the tasty but spiny fruits ripen in late summer.

The super-order Saxifragales in its order Gentianales contains the families Apocynaceae with Nerium and Vinca (Fig. 9.6a), the Asclepiadaceae with Periploca, Cynanchum, Pentatropis, Calotropis, Pergularia (Fig. 9.6b), and the Meliaceae with Melia. Nerium oleander is the most important plant along almost all streams in Jordan, also such which flow for only a short period within the year. Vinca is a related herb representing an escaped garden plant. Calotropis, the apple of Sodom is a very characteristic bush-like plant of the hot environment found in the Jordan Valley near streams, and here also members of the other Asclepiadacea are growing. Among the Saxifragales, the family Halagoraceae is contained with the water plant Myriophyllum that was found only in Azraq pool.

The order Santalales of this super order holds the members of the family Loranthaceae Loranthus and Viscum which are parasitizing on bushes growing in northern Jordan in river and creek valleys, but also elsewhere.

In the order Oleales the genus Olea is an important culture plant not found along creeks but may be very close to them growing on dryier ground.

Figure 9.6: a. Vinca herbacea as grows in gardens in the upper Wadi Shueib, b. Pergularia from downstream of Mujib dam (end of March 2014)

Super-order eurosids of Rosales holds genera such as Prunus, Rubus, Pyrus, Amygdala, Crataegus and Sarcopoterium. Old fruit trees of Pyrus and Amygdala (Prunus) are found in the gardens of Um ed Dananir and the upper Wadi Shueib. Bushes of Crataegus and the low Sarcopoterium may be encountered on the slopes next to creeks, but also away from them. The spiny semi-shrub Sarcopoterium may have invaded the abandoned olive groves since the Early Islamic Period and the appearance of its pollen in lake deposits are important indicators on that (Litt et al 2012).

Sarcopoterium spinosum characterizes the vegetation transitional zone between the Mediterranean and the desert (Danin 1988, Baruch 1990). In the order Rhamnales and family the Rhamnaceae are represented by the spiny bush-like Rhamnus, growing usually far from running water on mountains and Ziziphus that grows commonly along creeks, especially in the hot zones. In the family Moraceae, Morus and Ficus with fruit bearing bushes and trees are found near running fresh water avoiding polluted water.

Order Urticales with the family Urticaceae holds Parietalia and Urtica, of which the nettles prefer nitrate rich soil and occurs along polluted streams from the mountains to the Jordan Valley, but is also found in less humid environments, as long as the soil is rich in nutrients. Parietaria in contrast grows on pebble bed of wadi Yutum after flooding.

Order Vitales with the family Vitaceae has Vitis that has been introduced to Jordan as culture plant to produce wine. It is still grown, now and wine from Vitis from Madaba and Ajlun is available, as it used to be with short interruptions, since Hellenistic times.

Order Zygophyllales contains species of Zygophyllum, Nitraria, and Fagonia and includes some good indictors for saline environment

Order Fabales includes a large number of species grwing in Jordan such a the trees of Acacia, Prosopis, the bushes Retama, Calycotoma, Ceratonia, Cercis, Cassia, and the herbs Cicer, Anagyris, Astragalus, Glycyrrhiza, Lathyrus, Lens (Fig. 9.7a), Lotus, Lupinus, Medigago, Ononis (Fig. 9.7b), Pisum, Trigonella, Trifolium (Figs. 9.8a&b), Vicia. Acacia usually grows distant to creeks, but may be present on dry slopes near them in the hot Jordan Valley. Near creeks the similar Prosopis with spiny branches covers the beaches of creeks in the hot parts of Wadi Shueib and Wadi Kafrein. Retama bushes may come close to the Zarqa River, but grow also in dry areas.

In the old gardens of the upper Wadi Shueib or near Um ed Dananir trees of Ceratonia as well as bushes of the broom Calycotoma grow. Ceratonia is a relict of former use as fruit tree. Here also Pisum, Cicer and Glycorhiza are grown or present as relicts of former garden growths.

The moist meadows next to creeks hold Lathyrus, Trifolium, Trigonella, and sometimes Lupinus, all of which also grow outside of that environment. Melilotus and Lotus live along shores and in moist places, as do two species of Trifolium. The same is the case with the yellow and pink blooming trees of Cassia and Cercis which are planted along the roads. Thus the only plant of the Fabales noted to be attached to the margin of creeks is Prosopis, and this only in the hot region next to the Jordan Valley. Mostly dry wadis in the south after a flood have Astragalus and Ononis. Trigonella also grows and salty grounds.

Figure 9.7: a. Lens culinaris Zarqa King Talal Dam area, b. Ononis spinosa from near Shita spring

Figure 9.8: a. *Trifolium purpureum* from Wadi Zarqa, b. *Trifolium resupinatum* from Wadi Wala

The order Malpighiales has the family Euphorbiaceae, with Mercurialis, Euphorbia, Ricinus, and the family Linaceae, with Linum (Fig. 9.9a). Malpighiales, as very diverse order, also contains the willows (Salicaceae) with Salix and Populus and similarities which are hard to recognize except with molecular phylogenetic evidence.

Salix prefers a wet base and grows only next to creeks. It tolerates only distinct types of water pollution, not for example, that of the Zarqa River, but that of dirty creeks such as the sewage loaded one coming from Baqaa or from the Wadi Sir Treatment plants. Mercurialis is an invasive herb that may mix with the plants of the nitrate rich ground near Zarqa River and Euphorbia which prefers drier ground. Oxalidaceae are represented by Oxalis with a single species that used to grow in former gardens (Fig. 9.9b).

Order Fagales is represented by Quercus with the two species in Jordan, Quercus calliprinus as in Ajlun is evergreen and Quercus ithaburensis which produces new leaves every spring and grows to a larger tree. Quercus pollen is transported by wind and are important indicators for the shift of vegetation with time. Oak trees can be encountered next to creeks or springs but they prefer mountains and their slopes. Order Juglandales with the family Juglandaceae, Juglans, walnut, which were introduced to Jordan by the Greeks in Hellenistic times is no longer found outside of gardens.

Figure 9.9: a. *Linum mucronatum* from Sarcopoterium zone 2013 ACOR field, b. Oxalis pes-caprae from Um Ed-Dananir near the creek.

Order Geraniales and family Geraniaceae have Erodium which is a common herb with two species along creeks and the canal in the highland as well as in the Jordan Valley (Fig. 9.10a). It also has distinct species which grow in mostly dry desert valleys right after one of the rare floods as in Wadi Yutum. Individuals belonging to this genus are easily recognized by their narrow bird-beak-like fruits.

Malva, Alcea and Malvella (Malvales) are herbs which may occur along creeks, but are also found elsewhere (Fig. 9.10b). Species belonging here may have large colorful flowers and may characterize the flora of hillsides as well as higher margins of creeks and rivers. The family Cistaceae of that group with Helianthemum, can be found next to or in the bed of periodical streams, and Cistus grows among oaks and pines in the mountain forests.

Figure 9.10: a. *Erodium malacoides* from Wadi Kafrein below the dam, b. *Alcea setosa* near Rumeimin, spring 2013.

The orders Geraniales and Malvales are related to Brassicales and Myrtales according to molecular data, while they differ distinctly by morphology. Order Brassicales with its family Cruciferaceae, is represented in Jordan with Cardaria, Nasturtium, Lepidium, Sinapsis, Capsella, Critmum, Anastatica, Hirschfeldia, Sisymbrium, Salvadora, Sinapis, Brassica, Erucaria, Zilla, Notoceras, the related family Resedaceae with Reseda, Ochradenus, the family Capparidaceae with Capparis, Maerua, and the family Salvadoracea, with Salvadora.

The characteristic Cruciferaceae have a flower with four leaves with yellow, pink and white colors: Yellow in case of Sinapis, Hirschfeldia and Sisybium, white flowers in Nasturtium, Lepidium, Neotorularia and Cardaria. Nasturtium is characteristic to clean creeks with the plant entering the water, but it occurs also along the lower Zarqa River. Lepidium is also found here, forming meadows with its broad leaves next to Zarqa River. Cardaria occurs in the upper Zarqa forming dense populations along the river bank but it actually represents and usual plant of field-margins, present around Amman and many places in Jordan. Neotorularia grows on salty mud in Azraq (Fig. 9.11a).

Zilla with pink flowers is a characteristic spiny plant that grows in the hot areas along creeks, such as Wadi Shueib and also when the soil in salty. Among the Resedaceae, Reseda occurs along the shore of the river from the highland to the Jordan Valley, and in the hot area also the bush-like Ochradenus is found at the margin of creeks such as that leaving Kafrein Reservoir (Fig. 9.11b). Salvadoria grows as bushes near springs on Tall el Hamman next to Kafrein creek. Anastatica (rose off Jericho) is a plant of the extremely dry and not salty region with rare rain found in the mountains over looking the Dead Sea and those in the SE desert of Jordan.

Figure 9.11: a. *Neotorularia torulosa* Cruciferan Azraq 2014, b. *Ochradenus*from a creek downstream of Kafrein Reservoir.

Order Apiales, family Umbelliferae has species of Hedera, Ferula, Conium, Ainsworthia, Lagoecia, Malabaila, and Apium. The large and poisonous Conium grows in shaded abandoned gardens along creeks, and here also Ammi and Orlaya may grow. The large Ferula approaches creeks, but is common away from them as well, and near the creeks in warm places near the Jordan Valley Ainsworthia occurs is found. Hedera is found as climbing bush on rocky slopes or walls of ruins, often in abandoned gardens.

Many culture plants such as parrots (Daucus carota), fennel (Foeniculum), anis (Pimpinella anisum), parsley (Petroselinum crispum), coriander (Coriandrum sativum), and dill (Anethum graveolens) belong here and may be found in the gardens along creeks. The only plant closely connected to water is Apium, the fool’s water cress, growing only in or next to streams when water is not strongly polluted.

The order Lamiales is seen within the group of the asterids and is interpreted to be related with Solanales and Boraginales in addition also to Plantaginaceae and Scrophulariaceae.

Among the Boraginaceae and Lamiaceae numerous species grow in Jordan, but only few of them are closely connected to running water avoiding salty ground. Mentha is always found near clean springs and small creeks, but it may also grow at places near the water along the lower Zarqa River. Different species of Anchusa may grow next to creeks, but are also found elsewhere not near the water flowering in spring time. Similar species of Arnebia and Echium (Fig. 9.12a) may be present in the meadows which accompany creeks, but are more commonly found elsewhere, and in shaded gardens next to wadis Shueib, Sir and Shita and here Lamium, Salvia (Fig. 9.12b) and Ballota are also common.

Examples of common fresh water Lamiaceae species such as Lamium moschatum and Lamium amplexicaule are described here (Fig. 9. 13a&b).

Lamium moschatum has a 4-angled stem and leaves similar and opposite. The flowers are almost totally white and stand one circle below the leaves. The plant grows, among other herbs in meadows on the valley slopes, for example in Wadi Wala, but was not found close to the margins of rivers or creeks. ***Lamium amplexicaule*** grows from a taproot with stem and leaves similar to ***Lamium moschatum*** but flowers pale pink but also bilabiate and tube like. The ovary is 4-parted and develope from its brown nutlets. The plant grows on moist places near Hisban creek, and is also found in old gardens in shady environment in Ajlun area.

Figure 9.12: a. *Echium judaeum* Lacaita near Zarqa River, b. *Salvia viridis* occurs downstream of Kafrein dam.

Figure 9.13:a. *Lamium moschatum* in Wadi Wala (2014) growing together with Silene and Sinapis, b. *Lamium amplexicaule* from Wadi Hisban growing on a wet place near the creek 2012

In the order Gentianales and family Rubiaceae Asperula, Galium, and Rubia are present n Jordan. Asperula arvensis grows along the Nitrate rich moist soil on River Zarqa as well as around fields in spring times in Jordan, Galium with the climbing sticky Galium aparine grows among moist vegetation margins as well and non sticky Galium also in the Zarqa River and Rubia is represented by a large climbing plant that has yellow flowers.

The Scrophulariaceae with Verbascum grows in dry environments and was flowering on the hills north of Iraq al Amir (March 2013), as described by Feinbrun Dothan (1978 pl.294). Cistanche (Figs. 9.14a&b) and Orobranche, broomrape, of the parasitic Orobranchaceae are related to the Scrophulariaceae.

The broomrape has yellowish stems and completely lacks chlorophyll. When not flowering, no part of the plant is visible above the surface of the soil. Orobranche and Cistanche are holoparasitic genera with their species related to each other. In the case of the Orobanche from King Abdullah Canal the host was a Malvella and on the field near Al Qarn in the Jordan Valley they parasitized on soya (pig) beans.

Figure 9.14: a. *Cistanche salsa* encountered in the Al Qarn area with the host as pigbean, b. *Cistanche tubulosa* from Jordan Valley.

Plantago and Plantaginaceae according to molecular charactrization include Scrophulariaceae and Veronicaceae. Plantago is an inconspicuous herb with broad to narrow leaves and flowers are arranged on the median stalk in a cone. Single flowers are numerous, tiny and wind-pollinated. Plantago grows on the margins of rivers and creeks, and in the highland in the upstream area of Zarqa River or the lowland in the Jordan Valley downstream of Kafrein and Shueib revervoirs.

Order Ericales has in Jordan the small strawberry tree Arbutus that has characteristic red bark. The bell shaped flowere of the order is white during spring and red berries later on. It grows among the oak trees in Ajlun Mountains (Figs. 9.15a&b). The order Ebenales, family Styracaceae is representd by Styrax with bushes growing in mountainous areas distant from creeks and streams**.**

Figure 9.15: Arbutus flowering in March in the oak forest of Ajlun

Order Primulales family Primulaceae, have Anagallis, with blue flowers on a small herb often growing near creeks and near clean water. Cyclamen may be found in gardens and is common on mountains formed by limestones. It begins to bloom with its pink flowers in winter (Fig. 9.16a).

The order Myrtales is represented by the tree Eucalyptus, the bush Lawsonia, and the herb Epilobium (Fig. 9.16b). The common tree Eucalyptus grows along rivers and creeks (Fig.). Lawsonia (henna) is a relict garden bush and Epilobium has pink flowers and occurs rarely along creeks, for example the upper Wadi Shueib. Punica of the subfamily Punicaceae is a fruit tree that has come to Jordan in ancient times and is found as relict in gardens and is also still planted here and there.

Figure 9.16: a. *Cyclamen persicum* in Ajlun 2011, b. *Epilobium hirsutum*with flowers from Wadi Shita, spring (2012)

The order Solanales with its family Solanceae is represented by Solanum, Hyoscyamus, Lycium, Physalia, Mandragora, and Nicotiana. Among those plants that can serve as biomonitors Nicotiana trees as they grow along the Zarqa River were found at places with fresh water seeping through the ground but apparently they also prefer some water rich with nitrates. Lycium bushes grow along the creek near Kafrein Dam in Jordan Valley near and also in the bed of Wadi Yutum.

In the hot Jordan Valley also the shrub-like Whitania grows with its characteristic lampion-like fruits. Hyoscyamus, Lycium, Solanum, Datura, Withania were found to grow and flower in spring time 2013 along the creeks downstream of Shueib and Kafrein reservoirs.

Order Cucurbitales is represented by Cucumis, Bryonia, Citrullus, Ecballium, all of which have species in Jordan, but only Bryonia was found climbing on oleander bushes and rocks on the margions of Zarqa River (Fig. 9.17a) and on stome walls in Ajlun. Very conspicuous Citrullus grows in the desert and has a watermelon-like fruit that is yellow and hard when dry. Cucumis has been grown in Jordan since ancient times (cucumber and melon). ***Ecballium elaterium*** as in ***Feinbrun Dothan*** (1978 pl 469) is found in Amman growing on rubble piles near the Univerity of Jordan (Fig. 9.17b). Ecballium has no tendrils thus differing from Bryonia.

Figure 9.17: a. *Bryonia cretica from* Zarqa River 2014 climbing on rock and Oleander, b. *Ecballium elaterium* from near ACOR end of March 2013.

The order Dipsacales is represented by the herb Scabiosa and the climbing Lonicera. Scabiosa as in Feinbrun-Dothan (1978 pl 462) grows on the dry slopes to Zarqa River with the white flower head at the end of the branches. Lonicera is an erect climbing shrub with scented flowers of pale yellow color that have the stamens excerted. The berries are orange red. Other climbers in Jordan are Rubia, Tamus, Smilax, Hedera, Asparagus and Convolvulus (Fig. 9.18a). Family Convolvulaceae include Convolvulus, and Cressa. Convolvulus may grow near streams, and is also common on irregated land as weed. Cressa cretica tolerates salty ground but was encountered at Shita spring without salty soil near it.

Order Campanulales with Campanula is found with several species in Jordan (Al-Eisawy 1998), all of which have blue bell-shaped flowers, none of them grows near creeks or streams and all of them avoid salty ground (Fig. 9.18b).


Figure 9.18: a. *Convolvulus althaeoides* from ACOR, b. *Campanula strigosa* from the slopes to Wadi Zarqa

Within the order Asterales the large family Asteraceae (daisy family) can be divided into several groups according to the shape of their flowers. These are composed of numerous single flowers and consist of a specialized head in which numerous individuals of non-stalked, sessile flowers are attached to the same basal disk. Thus this flower head of Asteraceae looks like a single flower.

The fruit of several species of the Asteraceae has a pappus and wind dispersal is assisted by ths hairy pappus. Many members of the Asteraceae are pollinated by insects, but wind pollination is found for example in Artemisia. But commonly the flower head is showy with the outer individuals flowere leaf like and inner ones tubular, as is the case of species of Achillea, Anthemis, Asteriscus, Calendula (Fig. 9.19a), Chrysanthemum (Fig. 9.19b), Cichorium, Crepis, Leontodon, Pulicaria, Rhagadiolus, Scorzonera, Senecio, Sonchus, Taraxacum, and Tragopogon which all grow in Jordan.

They may be composed predominantly of much tube like small single flowers as in Aaronsohnia, Achillea, Ageratum, Centaurea, Cirsium, Cousinia, Matricaria, Onopordon, and Silybium. The plant may be a thistle with many thorns, as present in species of Carthamus, Centaurea, Cirsium, Cnicus, Cousinia, Gundelia (Fig. 9.20a), Notobasis, Onopordon (Fig. 9.20b), Picnomon, Scolymus, and Silybum (Fig.). In others the flowers are small and indistinctly developed as in Artemisia, Dittrichia, Inula, Lactuca, and Varthemia. Only few grow to form bushes with woody base such as Ageratum, Artemisia, Ditrichia, and Inula, while most of them grow as herbs.

Figure 9.19: a. Close up of *Calendula arvensis* golden flower from Wadi Shueib (March, 2012), b. *Chrysanthemum coronarium* from Wadi Hemme near Masharia.

Figure 9.20: a. *Gundelia* from Wadi Huni 2014, b. *Onopordum macrocephalum* from lower Zarqa River March 2013

Aaronsohnia grows in hot environments on dry river beds and on salty ground. Achillea grow on field margins, the shrub Ageratum grows in hot conditionsnear water, Anthemis (with a species found next to Zarqa River) appears to thrive well on ground moisted by the polluted water, and o1thers Anthemis grow on salty ground near the shore of the Gulf of Aqaba. Asteriscus is found on salty soil in Karama. Cichorium with its characteristic blue flowers grows along the margin of King Abdulla Canal, but otherwise prefers dryer localities. Inula grows next to springs as at Shita, Hisban and Wadi Atun with its mineral water.

Matricaria forms dense growths along the uppermost Zarqa River and enters salty ground, as well as Crepis and Senecio. Scorzonera species which grow along water courses in the desert as at Amra or in the wadi bed on the gravels after floods as that of Wadi Yutum together with Pulicaria. Matricaria also enters salty ground, as does Senecio and Crepis. Many areas are rich in spiny plant such as thistles which dominate here, suggesting the adaptive value of being spiny when grazing pressure is high (Zohary 1983, Sternberg et al. 2000).

The vegetation encountered in rivers and creeks in Jordan was also characterized by Zohary (1962), Kürschner (1986), Al-Eisawy (1996) and Albert et al (2004). According to the assembled data the shore of running water is usually the place for the shrubs *Tamarix jordanis* and *Tamarix nilotica* and a rim of small bushes of *Nerium oleander* is present as well as creeks with water running most of the year and within valleys that have no water during drier part of the year. Moist margins are taken by the reeds *Arundo donax*, *Phragmites australis*, and *Typha domingensis*. Less common are willow bushes of Salix acmophyllum.

Higher trees on the shore, the poplar Populus euphraticus, now often are replaced by Eucalyptus. Rivers and creeks often have their origin in the highlands and close to the desert with transition to the desert flora with bushes of *Retama raetam* and *Atriplex halimus*. At their end in the Wadi Araba, the Dead Sea or the Jordan Valley the palm tree *Phoenix dactylifera* is accompanied by grasses such as *Desmostachya bipinnata* and Saccharum ravennae. Swampy places near springs, creeks and rivers have *Nasturtium officinale*, *Apium nodiflorum*, *Berula erecta*, *Mentha* *longifolia*, *Veronica anagalis-aquatica*, and the grasses *Juncus arabicus*, *Polypogon monspeliensis*, *Cyperus laevigatus*, *Schoenus nigricans*, *Scirpus holoschoenus* as well as thistles (Centaurea spec.).

The vegetation of springs flowing all year resembles that of creeks at the same altitude. Water that issues from shaded rock walls is surrounded by *Adiantum capillis-veneris*.In the hot region of rivers and creeks subtropical or Sudanian flora is present with Acacia species, *Salvadora persica*. Commonly also, near springs, grows the palm tree Phoenix dactylifera that can also grow near brackish springs.

Historical biodiversity surveys regarding the flora that accompanies the lower Jordan River were carried out by Lynch (1848), and Zohary (1962). They registered a dense vegetation including willows and poplar trees and Tamarix shading the river channel. Bank vegetation also included reeds such as Phragmites, bulrush (***Typha domingensis***), Oleander shrub (***Nerium oleander***) and various species of the grass Cyperus.

Laurel trees (Laurus) fringed the banks where the Yarmouk flows into the Jordan. Nowadays only Tamarix and Phragmites grow along the Jordan River downstream of Lake Tiberias due to pollution and the rise of salinity of its water. It has been stated that only occasionally the ***Tamarix jordanis*** bushes come into contact with such of ***Salix acmophyllum*** in areas above 1000 m above sea level and ***Vitex agnus-castus*** (Lamiales) was found to grow here.

But Vitex was not encountered during our study and Salix was found growing on the margins of creeks from the highlands to the Jordan Valley, in case the water has the quality needed for its growth. The transition to the dry desert plants is taken by the Juniper ***Retama raetam*** (Juniper bush) and ***Atriplex halimus*** (Chenopodiaceae) (as may be documented along the upper Zarqa River).

Chapter 10

FLORA OF ZARQA RIVER AND THEIR INDICATOR VALUES FOR WATER QUALTY

Zarqa River has the source of its water in the Amman Region. In former times its discharge depended very much on the time of the year. In winter, during the rainy periods the discharge was high and turbulent, while during the remaining of the year the sources were the numerous springs and the River discharge was small. In its middle part, at the bridge of the highway Amman-Jerash- the River flew all over the year. At Its discharge into the Jordan Valley the water has always been used for irrigation.

The actual Zarqa River has its main origin at the es Samra sewage treatment plant east of Suchna, discharging constant volumes all year around and the water composition depends mainly on the functioning of the treatment plant. Khirbet es Samra effluent has a brown color and is relatively clear, but foam forms when it washes across larger rocks (Fig. 10.1). It has waste water smell, but not a foul smell as the water leaving the Wadi Sir or Baqaa treatment plants (2013 and 2014). Right next to the concrete wash-over from the treatment plant the River enters a natural ground with normal pebble strewn bottom and relatively strong slope and thus rapid flow.

The water is thus well mixed with air in its upper reaches and remains so over much of its long course, with a drop in altitude of about 800m. The chemistry of the water clearly deviates from that which of ancient times, when the water issued from springs. The water observed in 2013 and 2014 showed a better quality, than the water 30 years ago (1978, Bandel & Salameh 1981).

Much organic material is found dissolved and colors it brown. Phosphate compounds are present which cause the water to foam when running across turbulent areas. The water is nourishing a rich live of bacteria visible by the growth of thick crusts of cyanobacteria and other microbes on all surfaces covered by water.

Thus from the beginning of its flow the chemistry of the water is influenced by rich autotrophic production of organic material, first predominantly of bacterial origin. The intense light that affects the River during the day will also cause a rapid growth of free swimming Plankton organisms, predominantly belonging to the Phytoplankton. The intensity of light and the proportion of ultra-violet light in it changes with times of the year as well as temperatures between summer and winter. Both have influence on the biological processes which occur in the water of the River, but such effects have not yet been studied.

Figure 10.1: Zarqa River origin at Khirbet es Samra

From the beginnig of the River and along its upper course the margins of the River are covered with dense growth of plants. *Tamarix* and *Phragmites* are the larger and most conspicuous (Fig. 10.2) plants accompanying the River from its spring to its end in Deir Alla. During the dry season the water is channeled for further use in the Jordan Valley. During the wet season the level of the River rises and continues as creek reaching there Jordan River.

Figure 10.2: a. Heavy occurrence of pollution tolerant plants, Tamarix and Phragmites reeds, at the exit of the treatment plant, b. Phragmites australis and Tamarix are growing right next to the spring of the River and both are present all along the River down to the Jordan Valley.

Bushes and trees of ***Tamarix*** (salt cedar) live in Jordan with 4-5 species and grow under quite differing conditions. Species are difficult to distinguish from each other and they may also hybridize, which would make their determination even more problematic. The evergreen flowering shrubs or trees grow to a maximum of 18 m in height and may also grow close to each other forming dense thickets.

The bushes have slender branches and grey-green foliage with leaves of scale-like shape, 1–2 mm long. They overlap each other along the stem as is the case in a cedar. The pink to white flowers form on 5–10 cm long spikes resembling catkins, but including both sexes at branch tips (Fig. 10.3a). *Tamarix* can spread both in vegetative mode, by roots or submerged stems, and sexually by seeds. Each flower produces thousands of tiny (1 mm diameter) seeds that are usually provided with a tuft of hair. Wind disperses them over long distances. *Tamarix* can grow on high salinity soils tolerating up to 15,000 ppm soluble salt, tolerates alkali conditions and may grow under quite adverse conditions.

Phragmites australis represents a common grass (reed) along Rivers and creeks. *Phragmites* seeds are brown and thin with long, narrow bristles, attached to each seed (Fig. 10.3b) transported by wind and birds. Once established the reed multiplies through rhizomes below and above the soil from which new plants grow. The reeds form fence-like growths on River banks and may out-compete with other vegetation with stems standing close to each other and up to 4 m in height.

The leaves are stiff elongate and smooth and alternate from the stem which terminates in a feathery flowering panicle. Its stout rhizome is deeply embedded in the soil and the roots represent a good protection against erosion. *Phragmites* tolerates higher salinity than the similar reed *Arundo* and also differs from it by having long hairs between the florets. Both reeds have alternate leaves but in *Phragmites* leaves are narrower than in *Arundo.*

Phragmites australis is a bio-indicator in Jordan indicating wet soil, and when in pure monospecific form of growth it often indicates that water is relatively brackish. The reed also surrounds the thermal mineral springs in Zarqa Ma'in.

Figure 10.3: a. Whitish flowers of *Tamarix* in Zarqa River, b. *Phragmites australis* with goldenflowers at the same site (March, 2012)

Only a few kilometers downRiver from the source of Zarqa River larger organisms appeared in the water in spring 2013. Frogs appear as seen when they escape into the water. Their larvae are visible in more quiet places swimming in small pools formed on the margin of the River. Insect larvae, especially the agglutinated tubes of Chironomidae,begin to cover stones and fish is common with their off springs seen in the shallow water. All hard surfaces are here covered by dense crusts of cyanobacteria and after only a short way downRiver also fine filamentous algae appear.

Thus after a short distance of flow numerous insect larvae are present and feed on the rich growths of autotrophic organisms. Alongside appears fish which feed on insects. Also the presence of the character organism to this type of water in Jordan, the gastropod *Physa* is found. It can be detected by the presence of its characteristic gelatinous spawn found on many surfaces of stones in the River.

Between pebbles and at places with slow current the remnants of the organic films and cover are washed together and assemble in soft mud. Within it bacteria rapidly use all oxygen and conditions become anaerobic. Specialists such as chironomid insect larvae with blood rich oxygen absorb haemoglobin and *Tubifex* worms with similar blood feed on that mud.

They keep the posterior part of their body in the water while feeding in the oxygen free mud, thus digesting organic material and remineralizing it.

They also form pellets which are held together by mucus and can be transported by currents more easily than the sticky mud. Since Zarqa River in most of its bed has relatively rapid current the water is turbulent and is continuously recharged with oxygen from the air. The water is usually shallow and thus well penetrated by light.

All chlorophyll bearing organisms continuously produce oxygen released into the water of the River, hence, the use of the rich mineral load of the water for the production of organic substances by autotrophic life. But in general, the composition of life within in the River does not change much along its way down to the Jordan Valley, and the gastropod *Physa* continues to represent the character organism along the River. Its disappearance from the River as for example during once of our observations in fall represents a distinct sign of change of water quality to the worse.

On the margins of the River with moist ground a rich flora is established. It consists predominantly of plants of which many may also be found near cultured fields. These plants are predominantly herbs and most of them when growing next to the River are very well developed and grow to a large size compared with individuals further away from the water.
Here the pepperwort *Lepidium draba* forms dense growth next to the creek and often separated from it by a rim of grasses, *Rumex* and *Amaranthus* grow directly at the water edge and at places which are commonly flooded. The purplish white Cruciferen species *Eruca*, and the yellow *Sinapisalba* of the same group of plants, are common as well. *Malva* and *Plantago* like places of growth near the creeks.
Matricaria with characteristic composite flowers without a rim of sterile flower forms dense growths next to the water. The yellow *Sonchus* and the white *Anthemis* of the same composite group with its yellow and white petals is present in the beach flora. Here also *Urtica urens* and *Urtica pilulifera* grow as well as *Calendula* marigold.
Asperula with tiny blue flowers is part of dense green growths here as well as the desert plant *Anabasis*. This has entered the rim of the River while the desert lily *Asphodelus* blooms nearby on dry ground. Here in the upper part of Zarqa River the dry land with the basalt of NE Jordan is close and

is touched by the River margin. Grounds that were moist shortly before are covered by the colorful species of *Papaver*, *Ranunclus*, *Adonis* and *Roemeria* (Figs.10.4a&b).

Figure 10.4: a. *Adonis palaestina* in the upper stream of Zarqa River (March 2013), b. *Roemeria hybrida* upper Zarqa River, 2013.

Lepidium draba (syn. *Cardaria draba*) (pepper-cress) is annual or perennial and occurs from dry margins of fields (Zohary 1966, pl.448) as present from northern Jordan to the margin of the Zarqa River. The plant can tolerate a wide variety of environments. It prefers water holding a lot of nutrients such as is the case in the Zarqa River, especially its upper part (Figs. 10.5a&b). It is thus a biomonitor of humidity and can live with water rich with minerals.We noted it to grow all over Jordan from near Azraq as well as the region of Amman and it tolerates a wide variety of environments with nutrient rich soils.

The peppercress establishes large stands that exclude and compete with all other plant species. It persists in its roots and when spring rains come grows to produce a dense cluster of white flowers.

Figure 10.5: a. *Lepidium draba* (= *Cardaria* draba) floweringis growing on the Zarqa River banks, b.Rim of *Lepidium draba* along the River (spring 2013).

Rumex cyprius of the Polygoniaceae is found next to Rivers and creeks but can grow also on rather dry places during even very short wet periods. Its leaves are ovate triangular with pointed apex and entire margin and have a pleasant sour taste when young. Flowers are small and the red fruits have broad wings. Rumex cyprius lives near Zarqa River just as well as on rocks or rocky places (Fig. 10.6a) and it was described from Jordan (Al-Eisawy 1998, fig. 243) and Zohary (1966), who had noted that several more species of the genus occur here.

Rumex dentatus grows also on moist places in the Jordan Valley, as well as almost any place in Jordan when it receives some water. It preferably grows in moist areas, such as the edges of cultivated fields.

Amaranthus of the Amaranthaceae occurs with several species, among them ***Amaranthus palmeri***, (red root pigweed) that is native to tropical Americas, but is widespread as an introduced species to most continents in a great number of habitats (Zohary 1966, pl. 264, 265, 267). This is an erect, annual herb reaching a maximum height near 3 m. The leaves are nearly 15 cm long on large individuals, the ones higher on the stem have a lance shape and those lower on the plant are of oval shape (Fig.10.6b).

Individuals of the plant bear both male and female flowers in dense clusters. The fruit is a capsule less than 2 mm long with a lid which, when ripe, opens and releases a tiny black seed. Similar is ***Chenopodium murale*** of the Chenopodiaceae as described by Zohary (1966 pl. 202) from Jordan to live on waste places, former gardens and on irrigated fields. It is an annual plant with erected branching stem up to 70 cm tall. Its leaves

alternate and have broadly triangular shape with toothed margin and a powdery lower surface.
The flowers are densely clustered and have their position in the leaf axils. The black fruits are small, and flowers were present at the end of March 2013 and 2014 along Zarqa River, and also on the margin of grain fields.

Figure 10.6: a. *Rumex cyprius* from Zarqa River (spring 2013), b. *Amaranthus* next to the River March 2013

Malva sylvestris grows to 50 cm in height with its broad leaves differentiated in 5 to 7 lobes with the large pink flowers having darker veins. It grows from the highlands next to Rivers and creeks down to the Jordan Valley and in the vicinity of irrigated fields. When provided with much water the plants are large, and when growing in the shade the plant grows high.
Malva parviflora has small white or pink flowers and stems are covered with stiff hairs. The leaves are circular with heart-shaped base and margins with shallow, rounded teeth. The leaf stalk can be quite long. The dry fruit splits into individual carpels. ***Malva parviflora*** was described by Zohary (1972, pl. 467). The characteristic leaves of both species of *Malva* often compose much of the vegetation along river margins, here along Zarqa River as well as near other Rivers and creeks from the highlands to the Jordan Valley.
In the dense cover of herbs on the margin of Rivers and creeks ***Plantago*** is usually encountered, regardless of whether in the highland near the origin of Zarqa River or the lowland in the Jordan Valley below Kafrein and Shueib Dam reservoirs (Fig. 10.7a). It needs humidity in the ground and

appears to be less sensitive to chemical additions, but avoids increased salinity.

Eruca sativa occurs (Zohary 1966, pl. 462) along the River Zarqa near its shore, tolerating the polluted water (Fig. 10.7b). It has formerly been used as salad plant. *Eruca sativa* or*Brassica eruca* is commonly known as Rucula. *Eruca sativa* grows 20–100 cm in height. The leaves are deeply lobed with four to ten small lateral lobes and a large terminal lobe. The flowers are 2–4 cm in diameter, arranged in a form that is typical of Brassicaceae in general. The petals are creamy white veined with purple, and with yellow stamens. The sepals are shed soon after the flower opens. The fruit contains edible seeds. The plant also covers after spring rains slopes of the Zor near the Jordan River.

Figure 10.7:a. *Plantagolanceolata* from Zarqa River, b. *Eruca sativa* next to the upper Zarqa River 2013

Sinapis alba carries bright yellow flowers in a large number on a long median stalk that rises from a basal rosette of leaves which are covered by hairs. The fruits grow while plants are still blooming and their shape is dagger-like (Zohary 1966, pl 459; Al Eisawy 1998). White mustard seeds are mostly used for the preparation of mustard pastes. It may form dense growths along Zarqa River (Fig.10.8a), but also occurs elsewhere on the margins of fields.

***Matricaria aurea*is** an aromatic herb with yellow globular head of only the central flowers without sterile ones surrounding them. The leaves are slit and narrow. It accompanies the Zarqa River in case the River margin is formed by soil (Fig.10.8b), as is the case in the uppermost part downstream of the treatment plant, in some smaller portions downstream of King Talal Reservoir and in Wadi Huni. The plant also grows on marginal land as suggested by Al-Eisawy (1998, fig.189).

Figure 10.8: a. *Sinapsis alba* from areas next to Zarqa River, end of March 2013, b. Dense growth of *Matricariaaurea* in the upper Zarqa River

Sonchusmaritimus grows near fresh water creeks, and *Sonchus oleraceus* is common along River margins, such as Zarqa River (Fig. 10.9a), and is also found near irrigated fields (Al Eisawy 1998, figs.218, 219). We noticed *Sonchusoleraceus* on moist soil along the upper and middle Zarqa River, and near watered fields throughout the country.

Anthemis occurs in Jordan with 4 species described by Al-Eisawy (1998, figs. 129-132). Two of them with white flowers living in the hot regions ***Anthemis palaestina*** is found next to Zarqa River (Fig. 10.9b) and appears to thrive well on ground moisted by the polluted water of the River. It is present everywhere next to water in Jordan and differs from the very similar ***Anthemis bornmuelleri*** by having hairy leaves in a later stage.

Figure10.9: a. *Sonchus oleraceeaus* at characteristic environment next toZarqa River at WadiHuni 2014, b. *Anthemis palaestina* from moist ground at upper Zarqa River spring above Suchna 2013, growing together with *Rumex* as well as *Tamarix*

Nettles prefer nutrient rich soils especially rich in Nitrogen. ***Urtica urens*** has stinging leaves with poison injected through hollow silicified spines (Fig. 10.10a). Its pollen are spread by wind. *Urtica* is very common next to the River, since its water is enriched with nutrients. But it is also found in other places, especially were sheep or goats are common and the ground is moist. *Urtica pilulifera* has stinging hairs on its leaves (Fig. 10.10b). Flowers of male and female lie on the same plant and are arranged in clusters. The fruits are ball-like (Zohary 1966 pl.36,38, Al-Eisawy 1998, fig. 482). Along the wet region of Zarqa River *Urtica* is a member of the vegetation of herbs. It is not found in the central part, where soil of the River margin is washed away by spring floods.

Figure10.10: a. Urtica urens from Tall Zira'a, end of March 2013, b. Urtica pilulifera from Wadi Al Qarn, March 2013

Anagallisarvensis (pimpernel) occurs among the plants surrounding the fields in the region of the Jordan University as well as next to creeks in the Jordan Valley, and along the King Abdullah Canal. *Anagallis* thus is present everywhere in Jordan at places with sufficient humidity (Fig. 10.11a). The small pimpernel is an annual plant that usually has deep blue flowers, in the case of *Asperula arvensis*, that grows along the margin of herbs in Zarqa River

Asperula arvensis is an annual plant with small blue flowers and 4 angled stem that is up to 50 cm long with the leaves in whorls 10-25 mm long, each with one vein and with rounded apex. The flowers are deep blue, have 5 leaves and the fruit is a round 2-3 mm long and smooth. It occurs in relatively shady and moist environment near watering canals in Wadi Shueib next to the Jordan Valley as well as in the recently flooded ground of upper Zarqa River together with a number of plants that occur on margins of fields, as observed near the University of Jordan in Amman (Fig. 10.11b), and in the bushy area of Ajlun.

Figure 10.11: a. *Anagallis arvensis* from Zarqa River, b. *Asperula arvensis* from field close to the Jordan University 2013

From Suchna to King Talal Dam large trees bordering the River are predominantly represented by ***Eucalyptus***. The tree is less common in the mountainous part of the River and reappears more commonly in its lower course and in the Jordan Valley (Fig. 10.12).
This was introduced to Jordan from Australia. The tree is sufficiently massive to withstand strong water waves, while oleander bushes are not. Thus the periodical floods coming down the original valley from Amman

and joining the River near Suchna destroy much of the flora of the River side by floating junk becoming entangled in the plants. *Eucalyptus* usually has its branches above high water stand and is thus not affected.

Eucalyptus globulus has become quite common in Jordan since as is extensively planted. It grows rapidly and can adapt to a range of site conditions. The bark sheds often, peeling in large strips. The broad leaves when young are about 6 to 15 cm long and are covered with a blue-grey, waxy bloom, which is the origin of the common name "blue gum". The flower buds are top-shaped, ribbed and warty with flattened cap on the bud bearing a central knob. The cream-colored flowers grow singly in the leaf axils and produce much nectar that yields a strongly flavored honey.

The approximately 2 cm large fruits are woody, and from them small seeds are shed through valves which open on the top of the fruit. The roots of *Eucapyptus* trees reach deep into the soil. The tree is adapted to seasonal drought stress associated with dry summers. Transpiration rates remain high even when water supply from the soil dwindles and thus the plant threatens native vegetation. Below Eucalyptus trees along Zarqa River no other plants survive, and only its dry leaves are assembled.

Figure 10.12: *Eucalyptus globules* tree with the mature leaves are long, narrow and curved. The flower buds single, from Zarqa River 2012

Floods of the River causes the absence of ***Nerium oleander*** on the River banks, while downstream of King Talal Reservoir that keeps back floating material in the lake, *Nerium* is growing on the River margins. Oleander is a characteristic bush that grows along almost all Jordanian creeks with wet grounds even when the water is not running.

The plant reaches the water by deep roots. *Nerium oleander* is a perennial shrub that may grow 2-4 m tall with erect stems and branches. The big evergreen leaves, from whorls of three, can be 10 cm long and have simple shape with pointed end and a median vein that is very prominent underneath. The large red flowers grow in terminal bunches (Fig. 10.13a). The fruit is cylindrical and when it opens it exposes seeds, each with hairy cotton like part (pappus) (Fig. 10.13b).

The hairy attachment to the seed helps distribution by wind. Seeds can also float and are thus transported far downstream to form colonization of banks and dense stands. *Nerium* grows only along creeks with water having normal salinity and it thus does not grow, for example, in Wadi Atun with its mineral water. Polluted and treated wastewater as that of Zarqa River is sufficient for growth. The gallery of *Nerium* bushes in the upper Zarqa River had largely been destroyed in 2013, while downstream of King Talal dam it remained in good condition.

Figure 10.13: a. Flowers of *Nerium oleander*, b. The fruit with flying seeds from lower Zarqa River 2013

One major change regarding the quality of Zarqa River occurs when it joins its old valley coming from its former origin in the area of Amman City. In ancient time Zarqa River had its spring there. When we studied its course in 1979 it arose from the old waste water treatment plant near Ayn

Ghazal, but at present, it here discharges only flood water in winter after rain events.
Such events of short term strong rains cause strong floods, for example that in winter 2013. From below the town of Suchna, the floods become so turbulent and carry pebbles in the River bed capable to scrape off whatever may have grown on them.
The strong water currents also remove all finer sediment that may have deposited near the margins of the River including its vegetation. Thus beaches are eroded and fine sediment is washed from them leaving pebbles without soil and where finer material could be deposited it commonly consists of well sorted sand. These floods also flush out all debris consisting mainly of plastic materials that had assembled throughout the year in the mostly dry valley from Amman to Suchna. Thus trees and reeds at River margins have to withstand that load or they become destroyed by it. The scenery of the River banks has also not been changed for the better. Thus the periodical floods coming down the original valley from Amman and joining the River near Suchna do not only change the composition of the River bed by increased transport of pebbles and erosion, but also by destroying much of the flora of the River side by the floating junk becoming entangled in the plants.
In the section of the River between Suchna and King Talal Lake several small springs and creeks join the River, and their fauna and flora represent the original situation of River and its side creeks.
There may still be *Melanopsis* present here as in Nimra spring a few km downriver of Suchna, where *Bulinus* was also present, 2013. Both do not enter the actual Zarqa River but survive in the water of the small springs and shallow pools next to them. In the pools rich population of the drifting water plant *Lemna* is found. This is the only place in Jordan in which we observed this plant. It may easily have reached the place attached to the feathers of water birds, but in Jordanian waters it obviously has little chance to survive, with the exception of this isolated pool next to the spring.
In 2014 the flood created by winter rains in Zarqa River between Amman and Suchna was less strong. Thus the ponds and creeks coming from Nimra spring were not flooded by water from Zarqa River. Within the year that has passed the number of individuals of gastropods in the clean water exploded and also the composition of the fauna changed. *Melanopsis* of all sizes are everywhere with a sharp boundary of occurrence when in contact

with the water of Zarqa River. No gastropod survives the transition into River water.
This is also the case with two further species, ***Theodoxus jordanis*** and ***Melanoides tuberculatus***. *Theodoxus* was only present with large numbers of juvenile individuals while *Melanoides* grew to median size. The contact to Zarqa River means to all these gastropods life or death. All smaller or larger run-offs of the Nimra spring water into the River represent sharp boundaries and kill the gastropods.

Lemna minor (Duck weed) is a small floating water plant found world-wide. It is extremely rare in Jordan, but in the small pond formed next to Zarqa River by Nimra spring *Lemna* was found floating (2013) (Fig. 10.14a).
Lemna consists of one to three leaves which contain cavities filled with air. It can thus swim at the surface of the water. From that position roots extend into the water and collect minerals as well as stabilize the plant on the water surfaces. Some cells are filled with oxalate-needles which protect them from being eaten by snails. Spreading from one pond to the next, most probably occurs, by attachment to the feet of water fowl. The water of Zarqa River in spring 2013 was obviously polluted to such a degree that *Lemna* could not grow, except on the surfaces of pools filled by clean water.
Interesting is the appearance of trees of *Nicotiana* and *Salix* where the fresh water of Nimra spring seeps through the ground. Larger *Phragmites* growths and continuous growths of *Nerium* are found in a few side creeks.
One of these marginal spring water, a few km upstream of the bridge of the highway from Amman to Jerash, is collected in ponds, which even contained water turtles. Thus, in case the quality of the water of Zarqa River would improve, a relatively rich fauna and flora is still surviving next to it and could settle it again. Obviously, the present quality of the water of Zarqa River does not allow that.

Nicotiana glauca (tobacco tree) avoids salty ground and sheds its leaves every winter. The smooth leaves are arranged alternating, one leaf on each node on the small tree. *Nicotiana glauca* contains in its yellow flowers both sexes. It has seed-fruits. Tobacco tree is native to South America but it is now widespread as an introduced species in Jordan. The bush appeared to avoid contact to the water of Zarqa River 2013 (Fig. 10.14b), and it was interpreted that the plant may be used as indicator species (biomonitor) for relatively clean fresh water in the soil. While it was encountered only close to Nimra spring 2013, it was found growing along the River on gravel with soil between the pebbles also downstream of the bridge near Jerash.

Figure 10.14: a. Large number of *Lemna minor* occurs in a pond near to Zarqa River, b. *Nicotiana glauca* tree with flowers near to Zarqa River.

Usually bush-like trees of Salix, willow, grow on the Zarqa River only where fresh water seeps through the ground and near clean springs such as Nimra. Two species of willows were recognized from Jordan (Zohary 1972, pls. 26-28). Of these *Salix alba* is also common throughout Europe. It flowers in the spring (March or April) and has leaves which are hairy above and below and thus appear white. Leaves are ovoid-elongate in shape and finely serrated along their margin. *Salixalba* grows only in non-saline soils and near fresh water.

Salix acmophylla has comparatively longer leaves, similar to the other species but has reddish branches and remains smaller. The willows shed their leaves in fall and are either male or female with male and female catkins (flowers) on different individuals of the plant.

The male catkin consists of many flowers predominantly of pollen bearing leaves which are accompanied by nectar secreting glands. Male catkins are yellow when ripe and dull pale brown when pollen is spend. Pollen reaches the female catkin by wind or transported by insects. The female flowers are naked and green and carry many two-lobed styles each on one of the numerous ovules.

The many seeds when ripen each equipped with hairs, are light and can be spread far away by the wind like parachutes. The wood of willows is soft and usually pliant, tough and twigs are used for making baskets. The roots are tough, large, and from them new plants can grow. Along Zarqa River *Salix* grows only at places in which spring water seeps from the River bank. But some side creeks of the Zarqa (even such with strongly polluted and bad smelling water coming from Baqaa) have willows growing from their stream beds.

Also in the small heavily polluted creek in Wadi Kafrein near its issuing into the Jordan Valley and at altitude below sea-level willows are still growing in its bed with the root in the dirty water. In Wadi Shueib *Salix* grows downstream of the treatment plant of Es-Salt (Fig. 10.15). Thus obviously strongly polluted water can be tolerated by *Salix,* while the chemical load of the Zarqa River prohibits its growth. *Salix* grows from the highland to the Jordan River when water quality allows.

The median portion of Zarqa River until it joins King Talal Reservoir is marked by plastic junk found entangled in the vegetation and covering all parts of the Rivers sides. In places where water flows slow the junk is washed to the beach.

The landscape between Suchna and King Talal Reservoir actually presents a scenic and pleasant area that is spoiled by heavy pollution with plastic material that may get entangled high up on trees and bushes and also covers all beaches in bends of the River as thick layer of plastic bags and bottles.

This pollution by junk washed down-river was less evident one year later (spring 2014) and the River also flooded its margins with less erosive power (quite in contrast to Mujib and Wala river in that same year 2014).

Figure 10.15: *Salix* downstream of the treatment plant at Wadi Shueib 2013. Polinating male and next to it tree female catkins and Salix femal and male flowers.

Near the bridge Amman to Jerash a spring issues from the southern margin of the River bed that has, at least since Roman times, been used as spa. The water could be used both internally and externally. While the Romans founded the spring so solidly that its stone walls have survived in good condition. Only recently it has been destroyed by modern ignorant people by filling it with junk.

The lake of King Talal Reservoir is dark and the water is brown in winter while it seasonally changes to a pea green color due to plankton blooms (Figs. 10.16a&b). Oxygen concentration of the water must be a problem- since bottom sediments are free of oxygen. Within the whole course of the river to the lake a large amount of organic matter is being continuously produced.

This is especially due to the influence of cyanobacteria but also algae growing in profusion due to the shallow, well- lightened, water and the presence of nutrients in the water. This material is changed into a fine muddy substrate by the activity of numerous insect larvae, worms, some frog larvae, some *Physa* and some fish.

It becomes deposited wherever water flows a little more slowly, also below stones. Here oxygen is consumed rapidly and non oxygen using (non-aerobic) microbes take over turning the mud black and free of oxygen. Such puddles and ponds are the preferred places of settlement for the red oligochaete worms (*Tubifex*) and red larvae of chironomids, which transform mud into pellets after passing their digestive system.

Figure 10.16: a. the stony slopes of Wadi Zarqa next to King Talal Dam with spring time plant cover and green margins of the River, b. Zarqa River downstream of King Talal Dam with Typha and, Nasturtium thickets forming the margin to the water following the belt of Cyperus laevigatus

Whenever there is a flood or even a small increase of currents this fine and light material is washed down-River affecting all more quiet places of water flow and turning them into areas of deposition with depleted oxygen in the sediment. Finally, all the fine particles, mud and pellet alike, are collected in King Talal Reservoir to form its bottom sediment. The water of this lake is, in the deeper parts, free of oxygen.

The chemical processes involved in the transition from oxygen bearing to oxygen free water and sediment causes changes in the solubility of metals and in general transforms organic and non-organic substances. Thus the chemistry of the water leaving the lake differs from that entering it. It would be interesting to know the difference regarding the content of heavy metals. Also no studies have been carried out so far regarding the composition of the mud that forms the bottom of the lake.

King Talal Reservoir has not only an influence on the quality of the water but it also serves as a filter to collect flooding debris. The reservoir may be considered to represent the third and distinct part of the River. Sometimes large parts of the lake are covered by swimming debris (Fig. 10.17a&b).

Figure 10.17: *Tamarix* as barrier to plastic junk near Nimra spring.

A creek entering the lake from the south does not improve the quality of the water since it consists of water leaving Baqaa Treatment plant with concentrated pollutants. But even here a few springs which issue from the limestones exposed in the side of the valleys may provide very clear water that has besides *Melanopsis* and *Theodoxus,* indicating high quality of the water, but only until it mixes with the water of the main creek. A new addition to the runoff into King Talal Reservoir is derived from the purification plant at Zai (Fig. 10.18a).

In spring 2013, the water quality of the River downstream of King Talal Dam appeared to be basically the same as in the River in Suchna- eventhough the water has given nourishment to a rich growth of photosynthetic organisms, and many invertebrates lived along its course.

The water that leaves King Talal reservoir is rapidly oxygenated due to the rapid and turbulent flow of the River. First, thick bacterial crusts cover hard surfaces, but only at about 100 m below the outflow of the dam filamentous algae appear and a rich larval insect fauna can be present as was observed in spring 2011.

In winter 2012 no higher life was observed and the water from the dam to the end of the River at the Deir All Triangle contained neither insect larvae nor *Physa*. Here larger particles such as plastic bags are no longer present since they were collected in King Talal dam. That influence on the River is evidenced by the presence of *Nerium*-bush galleries along the River (Fig. 10.18b). This lower and fourth part of the Zarqa River may improve in water quality.

In this lower part of River Zarqa with the gallery of oleander bushes on River margins, green meadows with the reeds *Juncus* and *Cyperus* occur directly at the margin of the River. Where beach regions have less rapid currents and where some finer sediments are deposited or preserved also

Nasturtium officinale and ***Mentha longifolia*** are found, often many individuals together forming thickets of herbs. The meadows near these growths provide the living place for a dense flora, for example of thistles such as *Centaurea* and *Onopordon* and also for not spiny members of the Compositae such as *Arthemis.* Both thistles are also present along the upper Zarqa.

Plantago and the nettle *Urtica* have settled on all moist grounds as does *Anagallis*. All of which occur in the highland near the river uppermost part. In the shallow water of the River *Typha* reeds form dense thickets and on the beach next to the large grass *Saccharum* may grow. Among the obvious species of Poaceae along creeks species of the genera *Saccharum* and *Imperata*, as high reed with long leaves, *Phragmites* and *Arundo* as high reeds with alternating leaves, broader in *Arundo* and narrower in *Phragmites* are found.

Figure 10.18: a. Waste water from the Zai purification plant with thick black suspension joins King Talal reserve, b. *Nerium oleander* and Juncus next to the Lower Zarqa in spring 2013

Typha domingensis, (Rat tail), Typha occurs in Jordan along Rivers, such as Mujib and Hasa, but is not found along the Zarqa. Both Typha latifolia and Typha domingensis were noted to occur in Jordan by Feinbrun Dothan (1986, pl. 450, 451). Both were also noticed by us in 2013, ***Typha domingensis*** growing along Hasa River in its canyon, and ***Typha latifolia*** next to River Mujib. During spring 2014 all Typha reeds at the margin of the River Mujib were flushed out by a strong flood.

Typha has erect shoots which are more than a meter in height. Leaves alternate, are mostly attached near the base and the joint-less stem eventually bears the characteristic flowering spikes. Flowers, when fresh, are cinnamon-brown and consist of numerous male flowers which form a narrow spike at the top of the vertical stem. Male flowers consist of stamens and hairs, and wither once the pollen is shed and has been carried off by the wind.

The very large numbers of tiny female flowers form a dense, sausage shaped spike on the stem below the male portion, may be up to 30 cm long and 4 cm thick (Fig. 10.19a). Seeds are minute, 0.2 millimeter long, and attached to fine hairs. One spike may contain up to 250 000 seeds.

When ripe the heads disintegrate and seeds are dispersed by wind carried by their cotton hairs. The plant grows in fresh water and may grow more abundantly in clean water as well as in nutrient rich treated waste water. It is not found on salty ground.

Typha can grow on mud rich with organic material since it is provided with a well-developed air containing tube system that provides oxygen for root growth also in anaerobic sediments.

Typha occurs in Jordan along Rivers, such as Mujib and Hasa with normal salinity, is not found along the Zarqa River upstream of King Talal Dam, and not near Karama Reservoir. That indicates that the polluting substances of the upper Zarqa River as well as the high salinity at Karama reservoir are not tolerated. Typha is common in Wadi Atun and Himara (2000-2500 μS/cm salinity).

From the situation observed for example in Wadi Al-Hasa, Wadi Mujib and lower Zarqa River, *Typha* growth occurs in shallow water, while ***Saccharum ravennae***, Ravenna grass, grows from between pebbles next to the River. Ravenna grass is native to the Mediterranean and Africa. It is a perennial grass that grows in large, dense clumps from a network of rhizomes. The serrated leaves are up to a meter long, 3 cm wide and green. The flower stand is plume-like and reaches far above the clumps of basal leaves. It forms silvery seeds.

Saccharum ravennae is found on the highland as well as in the hot Jordan Valley. It prefers the higher temperatures. It grows along the banks of running water with normal salinity (less than 3000 μS/cm), along the Zarqa River observed below the dam with high content of nutrient salts (Fig. 10.19b) and along a creek with cleaner water of Wadi Sir, Wadi Hasa, dry

Wadi Numeiri, Wadi Atun and it can survive and grow with approximately 4000 µS/cm salinity as noted in Wadi Himara.
It is not present near brackish water as along the Karama reservoir. On the banks of Zarqa River it grows jointly with ***Phragmites australis***, ***Juncus maritimes arabicus*** and ***Tamarix*****.** The grasses growing in the region including *Saccharum* were described by Feinbrun-Dothan (1986).

Figure 10.19: a. Typha with mature seed-heads from Zarqa River in spring 2012). b. *Saccharum ravennae* found downstream of King Talal Dam, Zarqa River (spring 2012)

Juncus maritimus arabicus is characterized by nude leaves, which are either thin, more or less flattened or round and contain spongy internal material. Musselman-list of Juncaceae from Jordan (internet) suggests that several species of *Juncus* grow in Jordan, such as *Juncus acutus*, *Juncus bufonius*, *Juncus effusus,Juncus fontanesii*, *Juncus inflexus*, *Juncus littoralis*, *Juncus punctorius*, *Juncus rigidus (=maritimus)*, *Juncus subulatus*. All resemble each other and bear inflorescens near the tip. Many species are exceptionally hard.

Juncus maritimus arabicus among them has its flowers about 60 cm high with very acute leaf apices, lives in salt marshes and salt water pools by oases, and is commonly found around springs in Jordan. It also grows in not salty environments. It is found along Zarqa River (Fig. 10.20a) as well as around the western pool in Azraq Oasis. *Juncus* differs from other grasses by the round smooth simple leaves. It is not easy to distinguish the different species of the genus.

Cyperus (sedge) is grass-like with solid, sharply three-angled stems and leaves with closed sheaths. The flowers are often aggregated into spikes or heads. In Jordan ***Cyperus rotundus***, ***Cyperus schimperianus***, and the similar ***Carex divisa***, often occur together with *Juncus maritimus*. Cyperus prefers dry conditions, but tolerates moist soils and is found near river and creek margins.

The flowering stems of Cyperus have a triangular cross-section which distinguishes it from Juncus with round stems. *Cyperus laevigatus* grows up to 60 cm forming clumps interconnected on a horizontal rhizome. It grows in wet areas, especially in brackish water, wet alkaline soils, mineral-rich hot springs, and other moist saline and alkaline habitats. It is found in Zarqa Ma'in growing together with Tamarix trees near springs of mineral water with up to 60°C.

Cyperus laevigatus was found with the other reeds such as *Phragmites australis*, *Saccharus ravennae*, *Typha domingensis*, *Juncus maritimus arabicus*, and *Imperata cylindrica* along the sides of the lower Zarqa River (Fig. 10.20b).

Figure 10.20: Juncus from Zarqa River, spring 2013. Cyperus from the moist ground next to Zarqa River in Wadi Huni 2014

Scirpus maritimus grows here and was also noted in the lower Wadi Hasa near the Dead Sea. The grass as illustrated by Aichele & Schwegeler (2011) is very close to the one seen in the lower Zarqa River. Also other species of Scirpus have been noted to grow in Jordan.

Cynodon dactylon, the Bermuda grass, has been introduced to the Jordan Valley and was seen to grow along the edge of lower Zarqa River**.** The blades of the leaves aregrey-green and short, with rough edges. The erect stems can grow 1–30 cm and are slightly flattened, often tinged purple in color. The seed heads are produced in a cluster at the top of the stem and the root system can reach deep into the ground. The grass creeps along the ground and roots wherever a node touches the ground, forming a dense mat. ***Cynodon dactylon*** reproduces through seeds, runners, and rhizomes and also tolerates some salt. Also present is ***Desmostachya bipinnata***, Halfa grass, with narrow, tough, leaves and may be rolled up. It is a drought and salt-tolerant grass of desert or semi-desert conditions. It is regarded a common and widespread species growing along irrigation channels, in orchards, and associated with cultivation for example in the Jordan Valley.

Carex with several species were described by Feinbrun-Dothan 1986. All species of Carex are perennial and typically have rhizomes and short rootstocks. The flower bearing stalk is not branched and usually erect and triangular in section. The leaves are blade-like and extend away from the stalk with a sheath which encloses part of the stalk.

The blade is normally long and flat and the leaves have parallel veins. The flowers of Carex are small and combined into spikes, which are themselves combined into a larger flower stand. Almost all Carex species are monoecious, that is each flower is either male or female. *Carex divisa* prefers wet ground but not salty environment, and Feinbrun Dothan 1986 mentions its occurrence from the Dead Sea region as well as from the Azraq Oasis, and here associated with Poa sinaica.

Downstream of King Talal Dam, on muddy ground in the lower Zarqa River ***Nasturtium officinale,*** water cress, grows. It is a fast-growing, aquatic or semi-aquatic, perennial plant. It represents one of the oldest known leaf vegetables consumed by human beings.

The plant has a root system by which it can grow to form a larger number of individuals. The stems lie in the water or extend erect in emergent plants which are branched above and have roots at nodes. Leaves are heart shaped at their base and a rounded main leaf has margin entire or lobed. Flowers are white or pink with long anthers and the resulting fruit have cylindrical shape with reddish brown seeds arranged in two rows.

The watercress lives in streams in Jordan as recorded by (Zohary 1966 pl. 408). Al-Eisawy (1998) noticed that it occurs all over the country wherever fresh water stands or flows. This can be confirmed, but the plant avoids the strongly polluted water of Zarqa River upstream of King Talal Lake (Fig. 10.21a).

***Menthalongifolia*, **mint**,** is closely connected to running water. It is found at almost every spring and creek close to them. But the mint can also grow at places near the water in the lower Zarqa River- here documenting a better quality of the water than further upstream, but still only of *Physa* quality. Very commonly mint grows in the spring regions for example in the clean water that flows from the spring at Wadi Hisban (Fig. 10.21b).

Figure 10.21: *a. Nasturtium offincinale* near King Talal dam, b. *Mentha longifolia* from Zarqa River

Berulaerecta is an aquatic herb with white flowers occurring in Ammon (Zohary 1962, pl 620) in swamps and ditches and was also noted by Kürschner (1986) and Albert et al (2004) to grow along Jordanian creeks. The plant is weakly poisonous and approximately half a meter high and lives several years. The plant can have leaves below water with different shape than the leaves above the water. The stem has grooves and leaves are split with fine side branches and serrated margin. The white flowers are on short stalks and are arranged in groups of 10-20. Fruits are egg-shaped and brownish and are spread by floating on the water. The plant resembles ***Apium nodiflorum*** (Sellerie).

The thistle Notobasis syriaca, Syrian thistle, grows on the margins of Zarqa River, and is also found along the creek in the lower part of Wadi Kafrein (Fig. 10.22a). It can obviously get along with nutrient rich water because it is especially large near the origin of Zarqa River. The large purple head is surrounded by a circle of very long spines. The basal leaves are large and have a pattern of green with white or purplish veins (Feinbrun-Dothan 1978, pl.635, Al- Eisawy 1998, fig.190). This thistle is very common on watered fields in the upper Jordan Valley.

Also the thistle ***Onopordum macrocephalum*** grows near the lower Zarqa (Fig. 10.22b). Seven species of *Onopordum* were recognized in Jordan by Al-Eisawy (1998, fig.191-197), while Feinbrun-Dothan (1978) noticed only three species to occur in Jordan. ***Onopordon macrocephalus*** of these has a single branch or a few branches from the base, and at the end of the branch is the large purplish-red flower-head resting on long gutter-like spines. It forms thickets along the shore of the lower Zarqa River. Legumens such as *Glycorhiza*, *Pisum* and *Trifolium* and others are found near the beach of lower Zarqa River and along the margins of the fields near the River.

Figure 10.22: a. *Notobasis syriaca* in Zarqa River, b. *Onopordon macrosephalum* from Zarqa River 2014

Sarcopoterium spinosum, thorny burnet, is a small thorny bush of the Mediterranean region that grows on dry land with its pollen spread by the wind. The much-branched shrub is usually only 30-60 cm high with wooly hairy shoots. Lateral branches form spines, and leaves are 9-15 cm small, ovate with hairy leaflets. The flowers are in spikes of 3 cm and are round and elongate. The upper flowers are females and the lower males. Pollen are carried by wind and thus wide spread. They were noticed to appear in the Dead Sea deposits. The small fruit consists of 2 carpels which are enclosed in a berry-like structure, which becomes red and fleshy.

Zohary (1972, pl. 23) noticed that this dwarf shrub represents the leading species of various batha communities. It usually grows next to abandoned fields, but also reaches Zarqa River growing on its margins at places with steep stony slopes next to the River (Fig. 10.23a). Here, it may grow next to *Juncus* and *Nerium oleander* which both represent plants which are exclusively growing along River margins.

Sarcopoterium spinosum as element of the batha or semi-steppe characterizes the vegetation transitional zone between the Mediterranean territories toward the desert. The more or less simultaneous expansion of evergreen *Quercus calliprinus* and *Sarcopoterium* is also documented in Lake Hula and Lake Tiberias indicating that the Mediterranean maquis and bathas, as known today, have lived in the Levant since 1000 years.

Pteranthus dichotomus with indistinct green flowers can grow nearby on the rocky shore of the lower Zarqa River (Fig. 10.23b) and here also Paronychia argentea with small, yellow-white flowers that are hidden within the paired bracts grows on small pockets of soil in dry rocky environment. Pteranthus dichotomus is a small herb that has several times branched fleshy stem (Zohary (1966, pl. 195).

The triangularly rounded and elongate leaves are fleshy with smooth margins and nodular surface. Flowers are small and green and three lie together in a thickened part of the stem. The fruit has one 2 mm long seed with spiny surface. Al Eisawy (1998, fig.81) noted the occurrence of this species in dry hot places.

Figure 10.23: a. Sarcopoterium from Zarqa River, b. Pteranthus dichotomus growing in community with the thistle Centaurea procurrens.

Asteriscus has a characteristic yellow flower Asteriscus pygmaeus found on salty soil in Karama. It has a rosette of leaves with soft hairy surface and its yellow flowers on a short stalk (Figs. 10.24 a&b). The plant prefers dry ground and is also encountered in salty ground, but not restricted to it (Al-Eisawy 1998, fig. 139).

Asteriscus graveolens grows on desert ground with a woody base and longer branches than in Asteriscus pygmaeus and it was also found on somewhat salty ground. The flowers are a little smaller and their stalks are a little longer (Al-Eisawy 1998, fig. 138).

Feinbrun-Dothan (1978 pls. 538, 539) documented the main differences between the short ***Asteriscus pygmaeus*** and the higher branched ***Asteriscus graveolens*** and described a third ***Asteriscus aquaticus*** which is higher, not branched and is said to grow near water, but was not recognized by us.

Figure 10.24: Two species of Asteriscus, a. Asteriscus from Zarqa River, b. Asteriscus downstream of Kafrein Dam

In comparison to the Rivers Mujib and Wala similar vegetation can be noticed in years without flood in Zarqa River. Similar margin vegetation is found Mujib below the dam site. In smaller creeks the winter floods are not as destructive as is the case along much of Zarqa River and vegetation comes close to the margin of the running water or may even enter it especially regarding *Mentha* and *Nasturtium*. Both Rivers in spring (March

2014) were totally washed out by strong floods which filled their reservoirs and overflew their dams.

These flash floods set into motion all larger pebbles and even big boulders in the River beds. All animal life and plant growths in the River and next to it in the intermediate beach region were washed away except in protected niches.

WADI SHUEIB PLANTS

Olea europaea is a tree that rarely exceeds 8–15 m in height with silvery green leaves and a trunk that is typically gnarled and twisted. The small white flowers arise from the wood grown in the previous year and flowers spring from the axils of the leaves. The olive fruit is smaller in wild plants than among those trees fond in orchards. Olives are harvested in the green to purple stage. The olive tree may reach an age of over 2000 years and grows slowly. Olives prefer loose soil and penetrate deep with their roots.

Olea europaea has been cultivated for olive fruit, its oil, and for fine wood. The earliest evidence for the domestication of olives comes from the Chalcolithic Period for example from of the archaeological site of Teleilat Ghassul north of the Dead Sea in Jordan. From that ancient settlement, based on olive stones, evidence of olive cultivation and dating were obtained.

According to the pollen spectrum at Lake Hula the olive was present in the region for the last 10000 years. The olive in Jordan is eaten as fruit and oil is extracted since begin of agriculture in the region. Ancient olive oil presses are known for example from Chalcolithic Age in the town of Pella. At the end of the Iron Age, ca 2.600 years ago, moderate increase of the evergreen and deciduous oak pollen as well as the olive pollen curves were observed. From that time onwards the occurrence of Vitis vinifera (vine grape) pollen is documented (Fig. 11.1a).

Since that time Ficus carica, fig tree, has been cultivated and probably grown here (Fig. 11.1b). It requires well-drained soil. The edible fig is one of the first plants cultivated by humans. Remains of figs dating to about 9400–9200 BD were found in the early Neolithic villages in the Jordan Valley, 13 km north of Jericho (Rollefson 2008). The find even predates the domestication of wheat, barley, and legumes (beans, pies).

Figs are sweet, ready to eat when ripe, and easily planted. Figs were also a common food source for Greeks and Romans, in Jordan. The plant can tolerate seasonal drought, and old specimens when mature, can reach a considerable size and form a large dense shade tree. They live in areas with standing or running water, grow well in the valleys of rivers with much water available in the ground. The tree can grow right next to creeks and may even have its roots within the creek.

Figure 11.1: a Vitis from the Ajlun 2014, b. Ficus tree with the leaves and fruits from the Ajlun.

Populus euphratica (Poplar tree) grows as a tree and can reach 15 m in height more than 2 m in width when grown to old age. It was found on river banks and near springs in the Dead Sea area as well as the Jordan Valley and along valleys up to Amman (Zohary 1966, pl.29). The tree is shallowly rooted with the roots spreading widely. Leaves on mature shoots are of very variable shape and usually broader than long, broadly ovate to lanceolate.

The polymorphic leaves differ in shape even on the same tree or branch. The tree is male or female (dioecious) with slender flowers (catkins) which are 2 to 3 cm long and in the male with purple red pollen. The female flowers measure 2.5 cm and grow to 9 cm when seeds are mature. Flowering occurs during May. The nut- fruit measures about 1 cm and liberates minute seeds bearing silky hairs that allow them to be carried farway by wind.

Poplars are not growing along Zerqa River, probably due to the low quality of its water, while they occur along many smaller streams, as for example Wadi Shueib. On slightly salty soil poplars are not found.

Pyrus syriaca, pear tree, is a low tree that loses its leaves in winter-time. Its crown is spherical and dense on a trunk and somewhat thorny. Syrian Pear is prominent during March-April, when it is entirely covered with white flowers. It grows among the bushes of Ajlun and is also present at margins of olive groves near Rumeimin and in the old gardens of Wadi Shueib. Blossoming occurs together with the sprouting of the leaves or even before.

The flower is similar to that of the almond, hawthorn, apple and plum, but not pink as that of the almond or with pink rim as in case of the apple. Pollination is performed by insects, especially bees. At the end of the summer fruits ripen and change color from green to yellow. Pear wood is good for carving. Domesticated varieties were developed from the wild species already during antiquity, and Syrian Pear is considered to be one of the progenitors of domesticated pear.

Amygdalus communis, almond tree (Fig. 11.2a), is native to the Mediterranean region. It is considered to be one of the earliest domesticated tree nuts. Wild almonds are bitter, its kernel produces cyanide and eating them in larger numbers can be fatal. Selection of the sweet type from the many bitter in the wild marked the beginning of almond domestication. Domestication of almond tree could well have been in the vicinity of Jordan (Zohary 1972, pl. 33 and 34).

Morus alba, mulberry tree, with females and males in separate trees grow in the old gardens of Wadi Shueib in the area below Es Salt and above the modern wastewater treatment plant (Fig 11.2b). ***Morus alba*** with fresh green color is also commonly planted in gardens in the city of Amman. The tree originated from China and was introduced as food for butterfly caterpillars ("silkworms"), and nowadays serves as a fruit tree, but more commonly as ornamental tree in gardens.

Birds frequently disperse ***Morus alba*** by shedding seeds from eaten fruits and thus new plants can grow near the preferred resting places of birds. The tree may well have been introduced to Jordan in antiquity. The plant was noticed by the Babylonians and was later incorporated into Greek and Roman mythology, for the reddish purple color of the white mulberry fruits. Mulberry leaves serve as the sole food source of the silkworm (Bombax mori), the pupa/cocoon of which is used to make silk. Trade of silk was already carried out in ancient times along the Silk Road from China, and it could be possible that in antiquity it was tried to produce silk also in Jordan.

Figure 11.2: a. *Amygdalus almond* tree from Wadi Hisban, b. *Morus Alba* from the upper Wadi Shueib end of March 2013

Rubus saguineus (blackberry) is a thorny bush that grows well along humid habitats and is common in many shady places in Jordan. Blackberries live many years and typically bear biennial stems arising from the root system. First and second year shoots usually have numerous short curved very sharp thorns and a tangle of dense arching stems.

The berries are good to eat. In Wadi Shueib it represents a common plant in its upper part (Fig. 11.3a) and appears to be absent in the lower hot portions of the valley. Rubus does not grow in places with raised salinity and it also avoids polluted water as in River Zarqa.

Citrus (lemon) (Fig. 11.3b) originally comes from the Himalaya region and arrived in the Mediterranean during antiquity. Lemons entered Europe during the time of the Roman Empire. They probably were also grown in gardens in Jordan, during that time. The lemon was recorded in literature in a 10th century Arabic treatise on farming, and was also used as an ornamental plant in early Islamic gardens. It was distributed widely throughout the Arab and Mediterranean world between 1000 and 1150. The gardens along Wadi Shueib below Es-Salt have many relict trees documenting that lemon once grew here well.

Figure 11.3: a. *Rubus saguineus* with reddish dark berries (Wadi Hisban, 2012), b. Citrus flowers at Um ed Dananir spring 2013

Punica granatum (pomegranate) is commonly encountered near creeks, and also in Wadi Shueib (Fig. 11.4a). The pomegranate was cultured by people living near Petra even before the Nabateans and it was grown near the Stone Age settlement Sha'ar Hagolan near Lake Tiberias and belonged to the diet of the Yarmukians together with vegetables and olives. The pomegranate was also a fruit used in ancient Egypt, and it is mentioned in the bible. The city of Granada was named for it as well as the mineral garnet.

Characteristic are the bright red flowers. The edible fruit is of round shape and has a thick reddish skin. There are many seeds in a pomegranate berry and each seed has an edible surrounding juicy pulp. Punica is one of the trees which survived from time of intensive horticulture in Jordan, and there are still a few gardens from which Punica is still harvested, for example the Wadi Shita area west of Amman and in gardens north of Ajlun Mountains. The tree grows also on irrigated lots in Wadi Araba near Gharandal and here it tolerates the slightly raised salinity of the water.

Ceratonia siliqua is a heat and dryness resisting tree with foliage present throughout the year and it can grow to 10 to 20 m in height. The tree grows on lime rich soil as in the gardens in upper Wadi Shueib (Fig. 11.4b). Similar to other Fabales its roots live in symbiosis with nitrogen fixing bacteria (Rhizobium) and thus it increases soil fertility. The original tree may have come from Arabia and was cultivated in the 2nd millennium BD in Egypt as documented by reports of Thutmosis II and Ramses II. The wood of the tree was used during their time for construction. The Romans imported the tree to Greece and Italy and its spreading further west was done by Arabs.

Figure 11.4: a. Punica from Wadi Shueib, spring 2013, b.Ceratonia, spring 2013 Wadi Shueib garden.

Melia azedarach, bead-tree, of the mahogany family is native to India. It has pinnate leaves and small flowers present in clusters. The fruits are round and yellow at maturity and remain on the tree for a long time. The hard seeds were widely used for making rosaries. Leaves are shed with the begin of the winter and they grow again together with the flowers, as observed in the gardens of Wadi Shueib, end of March 2013 (Fig. 11.5b). At that time the flowers were not opened.

Lawsonia inermis (henna) may grow to a small tree with many branches and small branches ending in a spine. The elongate leaves are opposite with depressed veins on their surface and the flowers are with pairs of white or red stamens on the rim of their tube. Fruits are small and open irregularly into four splits. The fresh branches were cut, pulverized to produce red color. Lawsonia inermis can be considered as one of the plants that has survived in gardens as that below Um ed Dananir since antiquity and was probably common at similar places in Jordan. Henna has been used since the Bronze Age to dye skin, hair, fingernails, leather, silk and wool.

The climbers *Clematis cirrhosa*, *Rubia tenuifolia*, Lonicera etrusca, *Smilax aspera* and *Tamus communis* are found in Shueib Valley using bushes and trees as holdfasts. In gardens on the northern flank of Ajlun these climbing plants are also present often climbing on oak trees, while in the old garden below Um Ed Dananir west of the town of Baqaa mostly diverse fruit trees serve as holdfests. ***Lonicera etrusca,*** honeysuccle, has tubular funnel-shaped flowers and the fruit is a berry (Fig. 11.5b).

Clematis cirrhosa of the Ranunculus-family has large flowers and seeds with long appendages that can be spread by wind. The many fruits formed in each flower with long silky cotton-like appendages resemble not only the seeds produced by the related Anemone which is herb-like, but also the unrelated Salix and Populus. Also the Oleander and many Compositae such a Sonchus or the thistles have pappus bearing seeds.

Figure 11.5: a. *Melia azedarach*from Wadi Shueib in spring 2013, b.*Lonicera etrusca* flowering at Um ed Dananir end of March 2013

Helix hedera (ivy) is an evergreen climbing plant, growing in shady places on rocks and walls in Wadi Shueib. It climbs by means of aerial rootlets with matted pads which cling strongly to the substrate. The leaves are alternate with two types of shapes, either five-lobed juvenile leaves or leaves with entire margin on fertile flowering stems exposed to full sun, usually high in the crowns of trees or the top of rock faces. The flowers are produced from late summer until late autumn, individually small, 3–5 cm diameter umbels, greenish-yellow, and very rich in nectar.

The fruits are purple-black to orange-yellow and berries ripen in late winter. One to five seeds are in each berry, which are dispersed by birds eating the berries. *Hedera helix* was observed only in the upper part of Wadi Shueib.

Epilobium hirsutum was encountered on damp ground in gardens next to Shueib with flowers in October 2012. The perennial herb is up to 2 m tall and has a robust stem with leaves arranged opposite to each other and attached without stalks. Leaf margins are deeply serrated and their shape is lance like. The stem is densely covered by hairs along its entire length.

The flowers have a rich purplish color and a diameter of approximately 2 cm. The plant lives for only one year, but may come again from its rhizome that survives.

The plant sheds a large number of seeds from its elongate fruits, provided with a hairy cover for transport by wind. It was also encountered close to the spring at Wadi Shita together with *Nasturtium officinale* (watercress), *Anagallis arvensis* (pimpernel), the composite *Dittrichia viscosa* (yellowhead), and *Sisymbrium septulatum* (yellow cruciferan herb). *Epilobium hirsutum* apparently avoids grounds with raised salinity, and also polluted water as along Zarqa River. *Epilobium hirsutum* can be considered a plant that is salinity, drought and pollution intolerant.

Smilax aspera is a perennial, evergreen shrub with a flexible and delicate stem, with sharp climbing thorns. The leaves are 8–10 cm long, alternate, tough and leathery, heart-shaped, with toothed and spiny margins and spiny middle ribs of the underside. The flowers are small, yellowish or greenish, gathered in axial branches and occur in fall. The fruits are round berries of 1 cm in diameter found in clusters and are noticed in spring time when they are red. Later they turn black and contain one to three tiny round seeds. Smilax climbs on oak bushes in Ajlun 2014 and was also found in the old gardens of Wadi Shueib.

Tamus communis is a climbing plant growing to 2-4 m in height, with twining stems. The leaves are spirally arranged, heart-shaped, up to 10 cm long and 8 cm broad and with an up to 5 cm long stalk. It has separate male and female plants. The flowers are individually inconspicuous, greenish-yellow, 3-6 mm in diameter, with six petals. The male flowers are on slender side branches, the female flowers occur in shorter clusters. The fruit is a red berry 1 cm wide. The plant is poisonous. Tamus was found in the old gardens of Wadi Shueib below Es Salt in spring time 2013.

Ranunculus aquaticus, white water-buttercup, unlike its terrestrial cousins, is found in ponds, lake margins, ditches and streams. The herb occurs rarely in Jordan and was observed only in the upper water of Wadi Shueib, in fall and before winter rains (Fig. 11.6a). The small white flowers with yellow centers rise above the water surface. The leaves are of two distinct types one with very finely divided, thread-like, fan-shaped under water, and the other type appearing scalloped floating or extending over water surface. The leaf form is variable depending on the season and growing conditions, but the leaves are always alternately arranged on the stem.

Leaves growing above water are more compact than the submersed ones which are more segmented. Fibrous roots often emerge from nodes on the lower portions of the stems. New plants grow from seeds as well as from stem fragments. In Jordan *Ranunculus aquaticus* is rare and was found growing in quite clean water below Es-Salt in Wadi Shueib in fall 2012.

Veronica anagallis-aquatica, the brook pimpernel, with blue flowers grows in moist and wet habitat. The plant was found growing in creeks with fresh water in the Zor area of the Jordan Valley and thus occurs in the hot Jordan Valley along creeks, along the margin of King Abdullah Canal in Al Qarn, below Kafrein and Shueib dam (Fig. 11.6b), as well as in the highlands, and here accompanied by other herbs such as Asperula, Galium and Rubia, for example along margins of upper Zerqa River before it joins the old river bed. It also grows along irrigation ditches branching off from Shueib creek in its lower part.

Figure 11.6: a. *Ranunculus aquaticus* from Wadi Shueib, b. *Veronica anagallis aquatica* from Wadi Shueib

Cressa was noticed to grow on somewhat salty grounds (Feinbrun-Dothan (1978, pl. 46, repeated by Al-Eisawy, 1998, fig.233). But ***Cressa cretica*** (alkali weed) was encountered to grow next to lower Wadi Shita. Here it grows as bushes. The leaves are minute, sessile with the blades ovate-lanceolate to ovate and small with pointed end and grey-green color.

The small pink flowers are arranged close together at the end of the stem. The outer and inner sepals are ovate with silky surface, and the corolla is white to pink, forming a tube with five lobes and the stamens extending above them. Fruits are capsular.

The leaves may exude salt on their lower surface, which we could not confirm since we found that they preferred growth not in salty soil, but next to fresh water in the lower Wadi Shueib.

Sisymbrium septulatum is an annual herb with stems branching above and flowers of greenish yellow or bluish color. The leaves are attached on a stalk and have deeply lobed shape. The fruits are narrow and slender. Yellow flowers occur among other species of Sisymbrium all of which grow on fields in Jordan (Zohary 1966). ***Sisymbrium septulatum*** cannot tolerate salty water and is absent where water is polluted. It grows in profusion in the lower Wadi Shueib and Kafrein below the dams, both localities near the Jordan Valley (Fig. 11.7a).

Hirschfeldia incana, Mediterranean mustard, occurs in spring time, grows to 30- 80 cm in size and has usually a densely hairy stem with branches (Fig. 11.7b). The lower leaves are long and have divided shape with an enlarged terminal lobe and smaller lateral lobes. The yellow flowers are about 1 cm in diameters. The fruits are narrow 1-2 cm long.

The yellow plant occurs in large numbers along Wadi Shita, Wadi Shueib, and Wadi Hisban, and is absent in the mineral water of Wadi Atun and brackish to salty water of Karama area. It is also absent from the humid margin of Zarqa River, thus it avoids chemically polluted water. The similar yellow ***Sinapsis Alba***, in contrast forms dense growths along Zarqa River and is not restricted to the river, but also grows in fields distant from rivers or creeks. The fruits may already be ripe while the plant is still blooming (Al-Eisawy 1998), and the plant grows in humid conditions, also in Wadi Shueib.

Albert et al (2004) noticed in similar environment, among other, also the spring flowers *Anemone coronaria* and *Cyclamen persicum*, wild barley (Hordeum bulbosum), Asteriscus as *Pallenis spinosa*, *Asparagus aphyllus*, which we encountered as climbing into bushes in Wadi Um ed Dananir, in addition to spotted Arum which is comparatively rare but was noticed by us in Ajlun.

Figure 11.7: a.*Sisymbrium* at margins of ACOR spring 2013 next to sewage seep, b. *Hirschfeldia incana* from the Zarqa River spring 2013.

Arum hygrophilum grows next to the creeks of Um ed Dananir. It is also present in similar conditions in Wadi Shueib, grows on red soils covering limestone in Ajlun near water seeping from the ground, as well as below bushes in the old gardens along creeks. Arum is a herb with tall root-stock, arrowhead - shaped leaves and flowers are contained in a funnel like leave, which may be white, yellow, brown or purple. The fruit is a cluster of bright orange or red berries. All parts of the plant are poisonous, and they avoid salty ground.

Urginea maritima (sea squill) is a common plant that stands out in the landscape. It blooms at the end of summer and in autumn. Its globose bulb is renewed progessively during the period of several years. The sea squill has two annual stages. In November it grows leaves and this vegetative stage continues throughout the winter and early spring. In April the leaves wilt and all parts of the plant which are above ground die. At the end of the summer the stalk with the flower begins to grow with the generative stage lasting several weeks.

The flowering plant, of approximately 1 m in height, is not branched and carries dozens of flowers (50 to 250) which are arranged along its length, each attached to a short pedicle. Blooming begins from the bottom, and every day another group of flowers, each 1 cm across, opens above the previous ones, and the flowers that opened the day before wilt. The plant is described by Feinbrun Dothan (1986, pl. 69) to occur in Jordan and was noticed by Al-Eisawy (1998, fig.400) to grow everywhere.

The bulb may have a diameter of 25 cm and is the largest of all bulbs of wild flowers in Jordan. It consists of underground leaf bases which store food and water. In November the green sea squill leaves are prominent as fresh islands in a landscape of wilted plants. Growing near water, Urginea is an exception.

Asparagus aphyllus is climbing and grows to 100–150 cm in height, with stout stems and much-branched feathery foliage. The leaves are needle-like modified stems in the axils of scale leaves. The flowers are bell-shaped, greenish-white to yellowish, approximately 5 mm long, with six petals partially fused together at the base. They are produced singly or in clusters of two or three in the junctions of the branchlets. Male and female flowers grow on separate plants, but sometimes hermaphrodite flowers are found.

The fruit is a small red berry 6–10 mm in diameter, and is poisonous to humans (Dothan-Feinbrun 1986 pl 139, Al-Eisawy 1998). Asparagus aphyllus was noticed to climb on bush oaks in Ajlun and among bushes and trees near King Talal dam. Asparagus has been used as a vegetable and medicine, and in ancient times, it was known in Syria and Spain. Greeks and Romans ate it fresh when in season and dried the vegetable for use in winter.

Arundo donax is a large perennial reed with erect or arching shape, quite tall and branched or, not-branched. It grows in Jordan only near fresh water and avoids salty water. The reed rises from thick, scaly rhizomes of 2 to 4 cm in diameter. Leaves alternate and are distributed rather uniformly along the stem except on old stems with blades which are up to 60 cm long and 6 cm wide with leaf bases broader than sheaths.

The flower and seed stand are ovoid and up to 70 cm long with stiffly ascending branches (Fig. 11.9a). Arundo donax may also reproduce by budding from underground rhizomes and stems. Also stem fragments washed by floods or becoming isolated due to human activities can grow a new plant. Feinbrun Dothan (1986, pl 351) noticed that the grass is found near water in Jordan.

The largest colonies occur along rivers from wet sites to dry river banks far from permanent water. Scattered colonies of *Arundo donax* occur in moist sites or near springs which issue on steeper slopes and it is also often found along drainage ditches. It is the largest reed in Jordan and only found where the ground is not salty. It accompanies the lower margins of Shueib creek for longer stretches and is here more common than Phragmites (Fig. 11.9b). Arundo has alternating side leaves attached to a stem, in contrast to Saccharum. Leaves are broader than those of Phragmites. Arundo donax is a bio-indicator of wet ground produced by fresh water, but it tolerates other additions to the water and thus sewage tolerant to some degrees.

Figure 11.9: a. Flowers of *Arundo donax* and, b. Large *Arundo donax* downstream of Salt treatment plant in Wadi Shueib (March 2012)

Hordeum bulbosum (Fig. 11.10b), wild barley, and other grasses are found especially along Wadi Shueib in parts not covered by oleander bushes and Arundo reeds. ***Ricinus communis***, (castror oil plant) has as seed the castor bean which, despite its name, is not a true bean. Castor is indigenous to the southeastern Mediterranean. The plant is large and grows in the Jordan Valley (Zohary 1972).

The leaves are broad, alternate, simple, and split into 5-12 lobes. They have various colors during their growth from dark reddish young ones to dark green older ones. The flowers are quite characteristic by forming large conical inflorescence at the end of a branch. Here the top flowers are red with the males below in yellowish green, and fruits may be below (formed by spiny capsules) all seen in one inflorenscence.

The fruit capsules hold flattened bean-like seed which can be used for medical treatment. The plant was found growing in the Ghor area in humid conditions with clean to polluted water near creeks, consisting of fresh to slightly salty water. Ricinus communis was found growing on the banks of Wadi Shueib next to the outflow of the relatively well treated water of Es Salt Treatment Plant (Fig. 11.10b). Here the water has the quality approaching that of the Physa stage. Here also Salix grows next to Rhizinus.

Figure 11.10: a. Hordeumfrom Al Qarn area, Jordan Valley (spring, 2014), b. Rizinus from Wadi Shueib 2013

Allium, garlic and onions with a number of species are represented in Jordan, especially in and near former gardens (Feinbrun Dothan 1986). The different species are similar to each other (Al Eisawy, 1998 figs. 355-362). Allium, as in the garden at Um ed Dananir, was also present in similar surrounding in the gardens next to Wadi Shueib and Ajlun, near creeeks and also far from them. The white flowers arranged in hemispherical flower stand are characteristic, as is the onion smell. The plant is common along creeks but also far from them, and it was not noticed anywhere on salty ground**.**

Many culture plants such as parrots (Daucus carota), fennel (Foeniculum), anis (Pimpinella anisum), parsley (Petroselinum crispum), coriander (Coriandrum sativum), and dill (Anethum graveolens) may be found in the gardens along creeks. Among the legumens the cuture plants *Cicer arietinum* (chickpea) and *Vicia faba* (broad bean- saubohne) are present. These were cultured in the area since about 9000 years as was documented in Ayn Ghazal and Jericho.

They represent founder crops which also include the reeds Triticum and Hordeum (wheat and barley) as well as *Lens culinaris* or *Lens esculenta lentil* and *Pisum sativum* (pea).

Pisum syriacum or ***Pisum sativum*** is the original one for the common pea and it may well had been first cultivated in the Levant by Neolithic farmers. The wild pea is restricted to the Mediterranean basin and the Near East. The earliest archaeological finds of peas date from the neolithic era of current Syria, Turkey and Jordan. In Egypt, early finds date from ca. 4800–4400 BD in the Nile delta area. The wild pea is encountered here (Zohary 1972, pl. 316) and it may be the original one of the common pea. It was also grown in Spain around that time.

Cicer arietinum, chickpea, has also been cultured by the early argriculture inventing people which lived near Amman. It, as well as pig-bean (Vicia faba), are found in the gardens, as relict of former culture and are still planted and grown. In Jordan several species of the group are used as culture plants of which some have been grown here since Neolithic times at the begin of agriculture. ***Vicia palaestina*** and ***Vicia ervilia*** is documented by (Zohary 1972, pl. 278 and 285) are found on cultured grounds.

Figure 11.11: Pisum(pea),Wadi Huni, spring 2012.

The lentil (Lens culinaris) was grown supposedly first in Iran and represented a food source during the prehistory of Jordan. It was used also for soil improvement by the Romans (Graham & Vance, 2003), since many legumes form root nodules to fix atmospheric nitrogen in a symbiotic relationship with soil bacteria. This Lens culinaris is documented by Zohary (1972, pl. 299). The plants in total or plant products like leaves and pods can be tilled into the soil as a nitrogen source or legume crops and can be rotated with other crops for soil improvement, as was known to the Romans.

A number of other Fabaceae are important agricultural and food plants such as *Medicago sativa* (alfalfa), *Ceratonia siliqua* (carob), and *Glycorrhiza glabra* (liquorice). Liquorice as stated by Zohary (1972, pl. 121) lives near river banks, but it was also noticed to grow in fruit gardens in Ajlun. From the root of *Glycyrrhiza glabra* a sweet flavor can be extracted. The herb can grow to considerable length with large pinnate leaves divided into up to 17 leaflets and flowers of purple to pale whitish blue arranged in a loose inflorescence. The fruit is an oblong pod that contains several seeds. The liquorice is extracted1 from the root and contains a compound that is sweeter than sugar.

In the lower reaches of Wadi Shueib and in similar surroundings in Wadi Kafrein and Wadi Hisban some characteristic plants are encountered. Bushes and trees among these include Christ's thorn Jujube *(*Ziziphus spina-christi). In Jordan it is found in the Jordan Valley and next to the Dead Sea and also on the hills, for example, near Iraq al Emir. The tree and its parts appear to have been in use in Pharaonic industry (carpentry), diet, and in medicine. The fruits were sometimes made into bread. Egyptian peasants made similar bread as late as the beginning of the 20 th century.

Zizyphus spina Christiis frequently mentioned in Christian as well as Muslim traditions, and was also recorded by pilgrims who visited the Holy Land during centuries. The Christ's thorn Jujube is mentioned in the Qur'an. The custom of washing the dead with leaves of the Christ's thorn Jujube seems unique to this species and to Islam. The holiness of the tree originated with the citation in the Qur'an, and the sacredness arose from events in the lives of saints, heroes, and holy men living near the trees (Dafni & al. 2005).

The evergreen bush grows on wet places in Wadi Araba, in the the Jordan Valley and along Kafrein and Shueib creeks. It also grows in Wadi Atun. The small greenish yellow fruits are nice to eat. Zohary (1972) described it and noticed the presence of Ziziphus lotus in the Lower Jordan Valley (pl 452).

Acacia usually grows distant to creeks, but may be present on dry slopes near them in the hot Jordan Valley. Near the creeks the similar Prosopis with spiny branches covers the beaches of creeks in the hot parts of Wadi Shueib and Wadi Kafrein.

Prosopis farcta is a shrub-tree of 2–3 m or taller. It is a common bush in the hot Jordan Valley (Zohary 1972, pl. 43). Although not eaten by livestock (because of its spines), other herbivores eat the fruits, thus most likely aiding seed dispersal. It settles also on salty ground. In the Jordan Valley slightly salty water produces salty soil on which a hydrophytic vegetation grades into one of halophytic character with plants such as *Atriplex halimus*, *Prosopis farcta*, Zygophyllum- species and species of Tamarix, living on both types of soil- just moist or moist and salty (Zohary 1973).

Prosopis farcta and ***Prosopis juliflora*** species were introduced to Jordan, particularly, *Prosopis juliflora*, which are little demanding as regards water, and can thrive with annual rainfall as low as 150 mm. Prosopis are phreatophytes with a root system of mixed type, able to tap moisture as deep as 15 m into the soil.

Figure 11.12: a.Ziziphus tress posses edible small rounded fruit from Wadi Shueib, 2013, b. Prosopis tree with flowers and fruit in Shueib reservoir area, spring 2013

Calotropis procera, apple of Sodom, is a shrub or small tree up to 2.5 m high with simple stem that is rarely branched. It is woody at its base and covered with a fissured, corky bark. The branches are succulent, dense, white, with glandular hairs. Leaves are opposite, attached directly to the stem, and of ovoid blade-like shape. Flowers are in groups with five partly purple leaves and 5-lobed calyx. The fruit is a simple ovoid and fleshy follicle of up to 10 cm in diameter. It contains numerous flat seeds silky white pappus that is 3 cm or more long, and seed are dispersed by wind.

Calotropis is native to Jordan. The green globes are hollow but the flesh contains toxic extremely bitter milky sap that turns into a gluey coating resistant to soap. The milky sap contains a complex mix of chemicals, some of which are poisons. Calotropis and Acacia are the character plants for the Sudanian region that extends from the area around Aqaba to the north of the Jordan Rift south of Lake Tiberias in Jordan.

The area has been called the Sudanian penetration zone in which the hot loving flora penetrates far to the North (Baierle 1993, Albert et al 2004). Calotropis procera documents the reaches of this hot area far into the Jordan Rift, and brings it into the neighborhood to the Mediterranean Flora. It does not grow on moist salty soil.

Figure 11.13: a. Apple of Sodom occurs at the exit of Wadi Shueib to the Jordan Valley, b. Flowers of Calotropis from Wadi Shueib, 2013.

Lactuca orientalis (oriental lettuce) is found in Wadi Shueib as small spiny bush 10- 30 cm tall. According to Al- Eisawi (1998) Lactuca orientalis is a non succulent, annual shrub with creeping rootstalks and dark green appearance. The leaves are simple and alternate with a single leaf at each node. They have elongated shape with serrated margin. The multi branched stems end with a spine at the end of each branch.

This species inhabits the dry and freshwater habitats and is present along the margins of streams with slowly running water, such as that of Wadi Shueib at the reservoir where it occurs together with Acacia (Fig. 11.14a). ***Lactuca orientalis*** shows high drought tolerance but in Jordan it cannot survive raised salinity.

In the Jordan Valley, among the Solanaceae also ***Lycium shawii*** bushes grow along creeks, and the shrub-like Whitania somnifera, with its characteristic lampion-like fruits, and Hyoscyamus aureus, grew and flowered in spring 2013 along the creeks downstream of Shueib and Kafrein reservoirs. Non of them enter moist salty ground as is present around Karama reservoir lake.
Lycium shawi, the Arabian boxthorn, grows also in the desert and has its flowers at different times of the year. They are solitary and pale violet from the outside and funnel like tubular at base (Al-Eisawy 1998). It was noticed to occur under saline conditions near the Dead Sea. We did not find the plant on salty ground but found the small bush growing and flowering along the creek that issues from Kafrein Reservoir (Fig. 11.14b). Here the ground is not salty.

Figure 11.14: a. *Lactuca orientalis* as it grows on the banks of Shueib stream, b. Lycium shawni with flowers and fruites in spring 2013 downstream of Kafrein reservoirs

Solanum incanum is a small shrub that was found growing along the middle course of the Zerqa River near the bridge to Jerash, grows near irrigation water in the Jordan Valley, and along the lower Shueib and Kafrein creeks (Fig.11.15a). Its leaves are ovate and covered by fine prickes or hairs and the flowers are white, or violett. The others are consicuously yellow, and the fruits are globular green berries (Feinbrun-Dothan 1978, pl. 275, Al-Eisawy 1998, fig.473).

Solanum incanum is a possible ancestor of the modern eggplant Solanum melongena, also known as aubergine. It is also closely related to tomato and potato. Interpretation goes that Solanum melongena was domesticated in India from the Solanum incanum. The numerous Arabic names for it, along with the lack of the ancient Greek and Roman names indicate it was introduced throughout the Mediterranean area by the Arabs in the early Middle Ages. Wild potato species occur in America in the area of southern Peru, where they were domesticated 7,000–10,000 years ago, but the exact date of domestication is unknown.

Tomato originated in Mesoamerica and is the ancestor of some modern cultivated tomatoes. Both plants are intensively planted in the Jordan Valley.

Whitania somnifera is a shrub with branches covered with minute star-shaped hairs. Leaves are simple and the small greenish or yellow flowers grow in clusters arising from short branches. The round fruits are losely contained in a green lampion like cover. The plant grew along the creek below Kafrein dam in spring 2013 and is quite characteristic with its lampion like fruits in an inflated and membranous calyx (Feinbrun Dothan 1978, pl. 272). The roots are a source of a drug which might have been used by ancient Egyptions since the berries were placed on the mummy of Tutenchamun.

Hyoscyamus aureus, golden henbane, lives on cliffs and old walls of ruins, as well as next to Kafrein creek. The flower is a bell-like tube and the stem is gluey. The plant is poisonous. Hyoscyamus aureus also grew on the limestone cliffs of Wadi Wala 2014 and River Zerqa 2013 (Fig. 11.15b). The golden henbane was used by the Greek as was documented by Plinius to aid in oracles by the priestesses of Apollo, even though it can be toxic.

Figure 11.15: a. *Solanum incanum* next to Zarqa River, Jerash bridge, b. *Hyoscyamus aureus* from Wadi Wala 2013.

Convolvulus arvensis (Bindweed, Acker-Winde) is a climbing or creeping herb that may form up to 2 m long branches. Its leaves are spirally arranged, and elongate to arrow-head like in shape. The flowers are about 2 cm across and trumpet-shaped, white, with five pink radial stripes. The fruit contains 2 seeds and is eaten by birds, with the seeds spread with their droppings and surviving for a long time until conditions are ready so that they can grow into a new plant. Convolvulus is not connected closely to running water in Jordan, but occurs near it, as it is also common on irrigated land as weed and it avoids salty grounds.

Convolvulus arvensis with flowers occurred in March 2013 in the lower Wadi Kafrein at the margins of the creek and it also grows in gardens and along field margins in Jordan together with some other species of the genus (Al Eisawy 1998).

Ageratum conyzoides grows originally in Mexico, and has been introduced to Jordan. In contrast to most other members of the Compositae found in Jordan it grows to the size of a shrub. It has ovoid leaves with serrated margins and flowers in heads in which the single pink to purple flower is 5-8 mm in diameter. The bush grows along the creeks below Kafrein and Shueib dams next to the water- preferring hot climate and wet base (Fig 11.16a). Al- Eisawy (1998) characterized the mode of life of this plant as growing in wet and hot conditions as found in Wadi Shueib. The simple large leaves of the plant have an aromatic smell.

Periploca aphylla is characterized by its many naked branches and was found under hot and wet conditions, it the lower Wadi Al-Hasa and grows in shady gardens on the slopes of Ajlun and within the bush-oak forests of that region. It grows as dense and dark green climbing bush which uses trees as support, Tamarix in Shueib creek According to Al-Eisawy (1998 fig.32) Periploca produces an abundance of hairy seeds dispersed by wind.

Cynanchum acutum is a hardy plant with rose and purple flowers arranged in groups which have a good smell and appear in July (Feinbrun-Dothan 1978, pl.38, Al-Eisawy 1998, fig.28). Seeds are spread by wind due to their cotton-like, parachute-like hairy pappi. The plant prefers a hot environment and we noticed its characteristic tough leaves, which are shaped like an arrow-head, on twines at the mouth of Wadi Shueib and below the dam in Wadi Kafrein. The climbing plant prefers humid habitats but avoids salty environment.

Salvadora persica is a small shrub or tree with a crooked trunk, seldom more than one foot in diameter. The flowering branches frequently hang vertically for up to 1 m (Fig. 11.16b). The leaves are long, oval with long stem and are fleshy. It sheds its leaves in winter. The flowers are small with four green to white leaves and each flower has two fruit leaves and a short pistil. The pea- shaped narrow round fruits are red or dark, violet when mature and each holds one seed. ***Salvadora persica*** are found on moist and salty place in the Dead Sea area.

Figure 11.16: *Salvadora persica* form Tel Hamman, 2014, b. Ageratum flowers from Wadi Kafrein downstream of the dam, spring 2013.

SALT PLANTS IN JORDAN

12.1 Introduction

Four different localities in which plants were found to grow on salty grounds were analysed. It was found that each of them represents a distinct character and thus a unique assemblage of plants. In the Jordan Valley, populations of such plants surround the lake of Karama Reservoir with its salinity range of 16000 to 35000 µS/cm. Most of the salt in that lake is of local origin, coming from the rocks underlying the reservoir and stemming from salt near the ground surface. This salt has basically the same composition as the salt of the Dead Sea. Thus the small springs near the reservoir issue brackish water, and the ground near the reservoir and next to it is quite salty.

The reason for the presence of salt can easily be recognized by the exposed gypsiferous rocks at different localities along the shores of the lake representing the relict materials of saline deposits from which the more soluble salts are washed out into the lake. Also the tectonic structures that can be seen in the surrounding hills indicate that diapiric salt has been pressed up by sediment load and by structural movements of the Dead Sea Rift.

In Wadi Araba the Sabkha of Taba represents an environment in which evaporation is much higher than the water that is added to the shallow depression during the rare winter floods. Also the springs which issue onto the flat from its eastern margin, bring water that has its origin in the eastern mountains. Water is probably seeping through the mountain range that separates Wadi Araba and Taba dry lake from the Disi flats. Here the possible former connection between Disi and Wadi al Hiswa lay north west of the town of Quweira ending in Wadi Araba near the location of Taba Swamp dry lake. It was closed by the rising mountain chain that accompanies the eastern margin of southern Wadi Araba. But there are obviously still under ground ways for the ground water to reach the Araba Valley.

The springs at the margin of the Sabkha thus may have their origin in Disi. Near the shore of the Gulf of Aqaba moist salty flats present the locality for the growth of a specific community which we studied in the area between the hotel complex and the Royal Diving Center. Here salt has probably predominantly been derived from the spray of sea water.

The northwesterly strong winds often pick up the top of water waves splash it against the shore and its hard beach rocks and blow the spray landwards. The rare rains dissolve the surface salt on the ground of the hill base and wash it back towards the sea shore. In case that water does not flow into the Gulf of Aqaba directly, but remains standing near the shore line for some time plants grow here, most of which complete their life time rapidly, as is the case for many plants growing in desert environment.

The salty moist flats in the North-Eastern part of the Azraq Sabkha have their own character. Here water is basically derived from the extensive hilly area, which further to the North joins the mountainous area of Jebel Druz and is occupied by volcanic rocks. Water issuing from the NE margin of the Azraq flat consists for most of the time of groundwater that has moved for a long distance through the volcanic rocks.

It emerges at the margin of volcanic rocks forming the edge of Azraq basin, and evaporates leaving behind crusts of salt. When rains are added during the moist period of the year that salt becomes dissolved and shallow brackish lakes form, which relatively rapidly evaporate again. The margins have water with low salinity, while when shrinking the water turns salty. Along the shores of short lived lakes flora develops, while further from the shores no higher plant can grow and the dried out surface is simply mud cracked.

12.2 Karama dam reservoir area in the Jordan Valley

Salicorniaeuropaea of the Chenopodiaceae occurs near brackish water on sabkhas, salt marches, as for example at the margins of Karama salt lake (Fig. 12.1a). As noted by Zohary (1966 pl.227) *Salicornia* grows on marshes in the Dead Sea area. Leaves and stems of *Salicornia* store surplus salt and often acquire a sausage-like form. Therefore, in the plant that lives only one year the salt concentration increases as a whole and the color of the plant changes from green to brown or red within the growth period, documenting at the end a near lethal concentration (Albert et al 2004). The fresh green leaves can be eaten and taste only a little salty since they have not stored much salt at that stage of growth. The salt concentration increases within the growth period of the individual plant that it would be fatal in case the plants had a longer life span than one year.

Salicornia grows jointly with ***Phragmites*** in brackish creeks and on drier ground it joins ***Tamarix***, also *Suaeda* may grow next to it. Closer to Lake Karama, where the ground becomes saltier *Salicornia* is replaced by ***Suaeda*** and ***Mesembryanthemum*.** The creek contains below its water surface *Ruppia* and on its margin *Spergularia*. *Phragmites* and *Salicornia* also surround the small Qurein pool in which a brackish spring issues from the ground.

Suaeda vermiculata belongs to a taxonomically complicated complex of several closely related subspecies or species of Suaeda as they occur in Jordan (Fig. 12.1b) and neighboring countries. The fleshy, cylindrical leaves are much longer than among other Jordanian halophytes such as the genera Salsola and Salicornia. The succulent plant concentrates the surplus salt in special cells in the leaves, as is the case of chlorid-halophytes.

Zohary (1966, pl. 230-233) found ***Suaeda vermiculata*** and ***Suaeda monoica*** to grow near the Dead Sea on saline grounds. Surrounding the Karama lake Suaeda grows on saltier and drier ground than Salicornia. On dry grounds it grows close to Tamarix and closer to the salty lake it becomes replaced by *Mesembryanthemum*.

Figure 12.1: a. Salicornia in the small creek and form the margins downstream of a Karama dam, b. Suaeda salt- tolerat plants of Karama area (March 2013)

Spergularia salina and ***Spergularia media*** occur on salty ground (Zohary 1966, pl. 171, 172). It was found to grow during spring-time in the small brackish creek next to *Salicornia* and *Ruppia* at Karama. Its flowers are small and inconspicuous.

Ruppia maritima, wigeongrass, grows in a brackish creek which discharges into the Karama reservoir, and it forms dense thickets in the creek leaving Lake Karama towards the River Jordan (Fig. 12.2a). It is a thread-thin, grass-like annual or perennial herb which grows from a rhizome anchored shallowly in the wet substrate. It develops a flowering point tipped with tiny flowers which usually extend above water.

The seeds can be spread in the water and can be transported inside the guts of fish and waterbirds which eat the fruits. The plant also reproduces by sprouting from its rhizome to form new colonies. ***Ruppia maritima*** has a wide salinity tolerance but was not seen in fresh water in Jordan, but only in places with brackish water, here also in shallow pools next to Karama Lake, but not in the lake itself.

Mesembryanthemum covers the stony, sandy and fine grained ground close to the lake, as well as quite on dry salty ground at places which are saltier than those covered with *Salicornia*, and *Suaeda*. Here it only grows when the ground is moistend by rain. This succulent plant is a chlorid-halophyte which concentrates the salt in special cells. Stress produced by salt can also be overcome by reduced evaporation during photosynthesis. This reduction allows life with less water and thus less salt is introduced into the plant (Albert et al 2004).
These authors reported that according to studies carried out with the growth of ***Mesembryanthemum nodiflorum***, as compared to those of ***Suaedamaritime***; found that the first is more sensible to higher concentrations of NaCl than the latter, which aggrees with field observations. It hat *Suaeda maritima* is found in all four locations with salt tolerating flora. *Mesembyanthemum* was noticed to occur only near Karama Lake (Fig. 12.2b). . *Mesembryanthemum* was also noticed to open its flowers only around noon, thus the flats covered by it near Karama Lake look quite different in the morning than in the afternoon.

Figure 12.2: a. *Ruppia maritima* grass in Karama creek (March, 2012), b. *Mesembrynthemum* from the flats of Karama

Limonium lobatum, sea-lavender, grows more than 10 cm tall from a rhizome. This opportunistic halophyte lives on the salty soil of the northern flats of Karama area which are periodically inundated by the salty Karama Lake (Fig. 12.3a). From a basal rosette of wavy, lobed leaves rise broadly winged stems with one sided clusters of purple and white, papery flowers. Its leaves clustered at the base have glands which excrete salts from the tissue of the plant. This excretion removes the salts out of the plant onto the surface of the leaves where they crystallize and could be washed away by rain or wind. The small fruit is retained in the papery calyx and has one seed.

Limonium tolerates moderately salty soil and was found next to *Mesembryanthemum* on the salty flat that was flooded in winter 2013 by Karama reservoir. On that same flat in spring 2014 no plant was encountered. *Limonium* also grows in environments which are not salty, and it was also seen on the slope or Zarqa River near King Talal Lake in dry lands eroded by rain water.

Atriplex halimus lives near saline meadows and marsh edges, as was noticed by Zohary (1966, pl.214). The plant has a fine film of hairs on its leaves and thus appears to be of gray color. Through these they extrude salt and are specialized to actively transport ions to the surface of the leaf. Thus the plant can extract salt from the ground, but the salt remains in the vicinity. The hollow hairs usually consist of two cells and are totally filled with the vacuoles which are attached to a special cell that extracts the salts from body liquids and enables the transport of sodium-chloride. As soon as the hair is filled it detaches by a preformed brake off, either by its own, or when hit by rain drops (Albert et al 2004). Salinification of soil occurs also due to irrigation and subsequent evaporation in the Jordan Valley and here *Atriplex halimus, Prosopis farcta, Tamarix* also find fitting conditions for growth.

Closer to the non salty area next to Karama Lake the spiny bush ***Prosopis farcta***is encounteredwhich according to Zohary (1972) is a component of the saline and riparian vegetation in the Dead Sea area and along the banks of the Jordan River. *Prosopis* in Jordan also grows on soils without salt as is the case near the end of creeks in the Jordan Valley and along the lower reaches of Zarqa River.
Arthrocnemum macrostachyum *grows* in an opposite direction regarding the salinity of the groundwater and in the salty environment of the creek that leaves it towards the Jordan River (Fig. 12.3b).This green prickely bush ischaracteristic for salt loving plant communities found on Jordanian salt flats (Zohary 1966, pl. 226). *Ruppia* is often found next to it growing submerged of salty creek.

Arthrocnemum macrostachyum is accompanied by *Salicorniaeuropaea* as yearly herb on the margins of salty ponds and creeks. On dry grounds, next to it, ***Mesembryanthemumi*** is found and***Salsola jordanicola***, ***Suaedaver miculata***, and the grass ***Aeluropus littoralis*** are growing.

Figure 12.3: a. *Limonium lobatum* growing together with Suaeda on the muddy sandy flat of norther Karama, b. Arthrocnemum grows on salty soil near Karama dam

Asteriscus pygmaeus grows among salt loving plants such as *Mesembryophyllum* on the fine grained sils of the flats surrounding

Karama Lake as well as at the margin of King Abdallah Canal near Al Qarn. ***Asteriscus pygmaeus*** has a rosette of leaves with soft hairy surface and yellow flowers on a short stalk, one of which may have ripe seeds, while the others next to it are just budding.

The plant prefers dry ground and is encountered in salty ground, but not restricted to it (Al-Eisawy 1998, fig. 139). The seeds are connected to a wooly pappus and can spread by wind. Feinbrun-Dothan (1978 pls. 538, 539) documented the main differences between the short ***Asteriscus pygmaeus*** and the higher branched ***Asteriscus graveolens*** that grows on non salty ground in dry river beds.

Trigonella stellatum also grows on the salty ground in the northern mud flat of Karama reservoir and clearly tolerates some salinity. This small plant can also be found on salty grounds with clay and sand in the Azraq flat as well as on fine sand near Aqaba shore. These mud flats with salty soil water have also ***Pteranthus dichtotomus*** (Zohary 1966, pl.195) and ***Betavulgaris*** which also grow next to grain fields around Amman. It is thus not an indicator species for saline environment, but can tolerate it and grow on it.

Aeluropus littoralis as grass of the Poaceae can live on salty ground has alternate leaves on its stem and grows from an elongated rhizome (Fig. 12.4a). Its central stem is 5–30 cm long and leaves are branching with the leaf-sheaths longer than the adjacent internodes of the stem. The flower stand is 1-4 cm long with crowded flowers in two rows. The grass secretes salt with its roots. Many members of the Poaceae have a leaf structure that protects them against collapse when internal sap pressure gets low. Brackish and saline grounds allow the small size *Aeluropus*, as well as the high grass ***Phragmites australis*** to grow.

Capparis spinosa prefers dry heat and intense sunlight (Zohary 1966, pl.358). Capers are salt-tolerant and the plant consists of creeping branches up to 3 m long. Leaves have elliptical shape and long duration on the plant. The plant bears curving thorns and its flowers are large and solitary with numerous and long stamens. Capparis was found to grow next to Karama dam on stones. *Capparis spinosa* has been studied by Aronson (1989) who noticed that it represents a salt tolerant shrub. Its occurrence on the rocks of the Karama dam confirms that (Fig. 12.4b). It is also growing on stone walls in the surrounding of a Citrus plantation in the Jordan Valley and on rocks surrounding Kafrein reservoir, it thus tolerates some salt but is not restricted to growth on salty ground.

Figure 12.4: a. *Aeluropus littoralis* from Azarq salty ground, b. *Capparis* of Karama dam 2013.

12.3 Taba in Wadi Araba

Taba in Wadi Araba is a typical Sabhka having a characteristic succession of its vegetation as was noticed by Albert et al. (2004). Own observations confirm these data. The Taba swamp dry Lake can be considered the outflow of groundwater coming from Disi basin (Bandel & Salameh 2013).

Cress acretica, alkali weed, grows at the margin of the dry lake near the road. *Cress acretica* of the Convolvulaceae has been indicated by Zohary (1973) to live in a dry salty environment, as was also stated by Feinbrun-Dothan (1978, pl. 46) and repeated by Al-Eisawy (1998, fig.233). *Cressacretica* was encountered to also grow and flower in the lower Wadi Shita on salt-free ground (Fig. 12.5a). But near Taba the ground contains some salt. The leaves of the small bushes are minute, of ovate pointed shape and grey-green color. The small pink flowers are arranged close together in the cylindrical end of the stem.

The outer flower leaves have a silky surface the corolla is white and pink forming a tube with five lobes and the stamens extending above them. Fruits are capsular. The leaves may exude salt on their lower surface.***Cressa cretica*** with rose colored flowers was also found along the dry margin of Mujib River together with ***Atriplex halimus***, ***Suaeda aegyptiaca***, ***Alhagi maurorum*** and the grasses ***Aeluropus littoralis***,

Desmostachya bipinnata. Among the halophytes recorded from the shore of the Red Sea of Saudi Arabia *Cressa cretica* has also usually been determined.

Next to the Cressa belt, at the base of fans coming from the mountains, bushes of Acacia grow and on the other side of this grow the zone, towards the Sabkha ***Phoenix dactylifera*** is the dominant tree. Albert et al (2004) noticed that Acacia (near the salty ground) sometime stores salt in their leaves. Small leaves and folding of leave, when the sun is intensive, help Acacia against becoming to hot as does a thick cover of hairs that reflects the sun light. Acacia is present on dry slopes in wadi Araba and it also occurs near streams in the hot Jordan Valley, here often jointly with the similar Prosopis.

When it flowers many insects and also a bird with narrow crooked beak come to harvest nectar. ***Acacia tortilis*** grows in extremely arid conditions up to 20 m in height. The tree carries leaves with 4-10 pairs of pinnae, each with up to 15 pairs of leaflets (Fig. 12.5b). Flowers are small and white, highly aromatic, and occur in tight clusters. Seeds are produced in pods which are flat and coiled into a spring-like structure.

The plant tolerates high alkalinity, drought, high temperatures, sandy and stony soils, and sand blasting. Fruits are often eaten and the seeds within these have a better chance to germinate than such fallen out of the dry fruit. When having passed the digestive system they are within the feaces and thus have a better start for growth than the single seeds, which are often collected by insects for food.

Figure 12.5:a. Cress acretica in Wadi Shita, b. Acacia tortilis flowers along the hills east of the Dead Sea 2013

Next to the flat dry lake, with its mud cracked cover and thin salt crusts a rim of vegetation consisting of palm trees, and Tamarix bushes along with Phragmites reeds form together dense thickets at the margin of the Sabkha. A zone with the loose growths of Juncus arabicus, Tamarix nilotica, Tamarix tretragyna, and quite characteristically of Nitraria retusafollows. Nitraria retusa also forms small thicket islands further towards the mud-cracked flats of the Sabkha with no flora around them and no plants further on the mud flat.

Phoenix dactylifera, date palm, occurs commonly in Jordan, in the wild and as fruit tree (Fig. 12.6a). When fully grown it ranges from 5 to 15 m forming a tree with single woody stem. The leaves are compound, pinnate, spiny and about 3 m long. Their flowers have compound and spiked arrangements and usually appear during spring time.

The date palm grows near all the springs on the slopes to the Dead Sea. The trunk is surrounded from the ground upward in a spiral pattern, by leaf bases and in not attended trees the dry leaves remain attached forming a protective veneer.

The palm is either male or female and pollination is by wind. Fruits of the *Phoenix* palm are the dates with oblong, elongate shape. They are edible with yellow to brown color and contain much sugar.
Phoenix dactylifera is the important culture plant in the Sahara-Arabian region, resembling in its importance the olive in the Mediterranean area. *Phoenix* tolerates alkaline conditions and also grows with moderately salty water, but high salt content has a negative effect and lowers the quality of the fruit. Brackish and fresh water springs along the steep slopes of the Dead Sea are usually quite well recognized by the date palm which is usually accompanied by *Phragmites australis,* as is also the case at Taba.

Nitraria retusa is a salt-tolerant shrub or bush that grows to 2.5 m, although it is usually less than 1m in height. It has tiny, white to green, fragrant flowers, and small edible red fruit. *Nitraria retusa* was recognized by Zohary (1972, pl. 371) as living in saline deserts and recognized by us in Taba salt lake (Fig. 12.6b). It has woody stems with many hanging

branches which carry succulent leaves and sharp brownish horns. The leaves are simple, triangular, and alternate with one leaf at each node.
The small whitish flowers bear five petals and 15 stamens and flower in March and April. *Nitraria retusa* inhabits salty and dry environments and can live in poor soil quality. It also grows on sand and stony soil near to water, which at Wadi Atun, has a salinity of more than 2000 (µS/cm).

Figure 12.6: a. *Phoenix* tree in the Taba salty soil, 2014, b. *Nitraria retusa* from the southern wadi Araba, Taba, March 2014

Juncus maritimus arabicus is the same reedas that growing near the western pool at Azraq with lower salinity of the ground. Its inflorescences are about 60 cm high and leaves have very acute apices. It grows in salt marshes and salt water pools by oases. It is also found near springs in Jordan often together with ***Juncus acutus***. Feinbrun Dothan (1986, pl.186, 187) noticed the mix of both species, especially in saline soils.

12.4 Azraq basin and Sabkhas

Azraq and Al-Jafr Basin represent nodes on a chain of ancient lakes that stretched from northwestern Saudi Arabia to northeastern Syria during the wetter times of Pleistocene. During times at which ice covered much of northern Europe the climate in Jordan was considerably wetter than today and the open plains between shallow lakes were ideal for hunting.

Animals such as elephants, rhinos and horses were hunted by early men when they came for drinking. The lake at Azraq, during the

Pleistocene pluvial period, covered up to 600 square kilometers, with a zone of reeds on its margin and trees near the shore.

The lake was quiet so that organic sediments formed in the central part of it. Only near the mouths of wadis entering the lake in the east, west and south coarser sediment were washed into the lake and formed fans, documenting that its shores were of low relief. Further to the west of Azraq basin a wedge of debris was washed from the large volcanic fields extending to Jebel Druz. Here volcanic activity had resulted in the production of much new rock material, that during rainy periods, reworked volcanic rocks formed large alluvial fans.

It finally separated the Azraq Lake from its former outflow to the west that existed along Wadi Dhuleil to River Zerqa at the time when Lisan Lake filled much of the former Jordan Valley. Also the flow of water from Wadi Sirhan further south and east was hindered by ridges of debris between the individual basins.We noticed in March 2014 that, especially, the area near the western pond and the ancient building structures, were strongly influenced by grazing camels which have trampled the ground.

The reconstructed pond is surrounded with growths of Tamarix, and some Nitraria, and Juncus maritimus next to the Phragmites reeds. The water of the pond is almost fresh and contains Myriophyllum spicatum in dense growths (Fig. 12.7a) and many fish.

Myriophyllum spicatum, milfoil, is a submersed aquatic plant. It has elongate stems that may be several meters long with air canals and whorled leaves that are finely, divided (Fig. 12.7b). The flowers are small and usually borne in leaf axils and grow to bel held above the water surface. The fruit splits into four nutlets at maturity.

The submerged leaves are approximately 2 cm long and arranged in pinnate whorls of four, with numerous thread-like leaflets. The Jordan River, before it became polluted, included a rich diversity of submerged macrophytes which are currently totally absent from the river. The submerged macrophyte community included among others the milfoil (Myriophyllum spicatum) (Zohary 1972, pl. 549) and that plant is now growing in the Azraq pond.

Figure 12.7: a. The pond provides a good growth environment for Myriophyllum. Myriophyllum plant from Azarq pond

Tamarix tetragyna forms a belt of bushes around the ponds at the western margin of Azraq flats (Fig. 12.8a) where ponds have been reconstructed near to ancient walls of Roman and early Islamic times. The ponds are now settled by the water plant Myriophyllum and the reeds Phragmites, also Juncus grows here, since water is almost fresh.
Albert et al. (2004) noticed that Halopeplis amplexicaulis and Cressa cretica grow here each year after the area has fallen dry in summer. Halocnemum strobilaceum was present, and on the open salt-meadows, Aeluropus littoralis grass is growing. They noticed Tamarix passerinoides and Nitraria retusa growths (Fig. 12.8b), Juncus maritimus arabicus and Phragmites australis forming belts of reeds and on drier ground growths of Salsola tetrandra and Suaeda fruticosa.

Figure 12.8: a. *Tamarix tetragyna* in Azarq, b. *Nitraria retusa* near the pond of Azarq natural reserve

Aeluropus littoralis was noticed by Albert et al (2004) to secrete fluids with concentrated sodium salt. This grass grows on moist ground and can tolerate some salt (Albert 1982, Albert et al 2000, Eisawy 1996).Brackish and saline grounds have *Aeluropus,* as well as *Phragmites,* but the latter is not found on the salty flats NE of Azraq plain, but surrounding the ponds on its western edge. The zones with bushes are largely dependent on influences by humans due to wood cutting, driving, and extraction of ground water.

On the north-eastern side of the large mostly barren Azraq sabkha a thin veneer of plants is found next to sparse growths of Tamarix bushes. Here a rim of low plants has grown at the margin of a shallow lake that form after some rains. When we visited the place it had already dried up again leaving a mud cracked plane that only rarely exposed moist surface area. This rim is the place of growth of two small sized species belonging to *Spergularia.* One landward, formed by ***Spergula marina*** which has narrow thick green leaves, and the othercomposed of ***Spergula media*** with oval and grayer leaves.

Spergularia marina has a flower diameter of about 6-8 mm. The leaves are fleshy and of semi-cylindrical shape. The narrow stem is lined with green fleshy linear leaves. The flowers have five pointed short, green sepals and five oval white or pink-tinged petals. The tiny seeds have winged margins. The sprawling annual plant may survive in its roots and is salt loving.

It lives close to ***Spergularia media*** which looks rather similar. Both grow next to juvenile ***Suaeda***. ***Spergularia marina***, with narrow fleshy and green leaves, forms the upper rim that reflects the highest stand of the lake when it was filled and the other just a little below is composed of *Spergularia media* with grey, smaller leaves (Figs. 12.9a&b).

Its growth zone reflects the position of the beach of the lake when it had evaporated that much that the water level was few centimeters lower. *Spergularia* here develops purple globular leaves in which surplus salt is stored (Fig. 12.10a).

Among individuals that grew in former puddles below the beach zone *Spergularia* had more such puplish storage leaves. Growths were commonly accompanied by juvenile *Suaeda*. Within the puddles the salt content of the water had obiouvsly increased even more during evaporation of the water. When the lake level decreased, neither *Suaeda* nor *Spergularia* were able to grow due to the high salinity level.

Tamarix bushes can act as collector of clay dunes on the flats of Azraq. We noticed it to grow near the beach of periodical lakes and next to earth walls that piled up by the construction of salt pans. In case of ***Tamarix passerinoides*** leaves are scale like and of gray-green color while the flowers are relatively large and of pink-rose color (Fig. 12.10b).

Figure 12.9: *a. Spergularia marina* from Azraq 2014, b. *Spergularia* of the lower lake rim with bluish bubble.

Figure 12.10: a. *Spergularia,* Azraq 2014 with the salt storing leaves of Spergularia, b. Azraq salt flat 2014 *Tamarix passerinoides*

Trigonella stellatum was noticed to grow along of the upper former shore among the *Spergularia*, and ***Suaeda vermicularia*** with young plants were found between the plants of the lower zone and within former puddles. *Trigonelle stelletum* also grows on the salty ground at the northern salt flat of Karama reservoir and near Aqaba shore (Fig. 12.11a).

Neotorularia torulosa is a cruciferan with a characteristic growth. The first formed rosette of narrow elongate leaves has a small group of white flowers in the center. In case growth continues, long side shoots develop with numerous centers of flowers. This further growth is dependent on the

availability of water, thus plants in drier surrounding is present, while those growing in more humid surrounding have long flowering side branches. The plant was found growing on the muddy ground of the Azraq dry lake after it was flooded and dried off again (Fig. 12.11b).
It here tolerates salty water and salt covering the mud next to the plants in dried out depression of former relict puddles of the shallow lake after heavy rains. Its locality of growth appears to be in an area less affected by salt as is the case with Spergularia.

Anthemis haussknechtii and another composite with yellow flower, probably ***Crepissancta*** are found in Azraq. In *Anthemis* leaves are lobed and disected into narow elements and the flower has a yellow disc and white leaves surrounding it.

Figure 12.11: a. *Trigonella stellata*, Yutum 2014, b. *Neotorularia torulosa* Cruciferan, Azraq 2014

12.5 Plants on salty grounds in Aqaba region

Plants growing on salty ground display distinct character regarding their systematic composition in the different localities in Jordan. Thus a quite specific flora composes the community that grows next to the Gulf of Aqaba on the uppermost sandy beach that was separated from the lower beach by an earth wall heaped up during construction works.

This wall prevented the water of one of the rare rains in the area, falling during the end of March 2014, to simply flow off into the sea, but rather collected in a shallow pond. Rain had fell only one week before our survey, and since that time weather had been dry and sunny as is usual for the shore region Aqaba in that time of the year. The water diluted the salt crust of the soil which accumulated here during the extended period of no rain had.

A dense plant cover grew only in those parts of the small intermediate pond that held water for some time and thus remained moist for a sufficient time to allow the plants to grow. The last puddles left a crust of salt when their water evaporated.

The plants studied on the 23rd of March 2014 thus reached their size and usually also the flowering and fruiting stage within a time of about 10 days. Here, close to sea water between the hotel complex and the Royal Diving Center, rain water was held back from simply running into the sea on the beach by the earth wall produced artificially in the course of construction works. A shallow large puddle formed and its water subsequently formed some smaller puddles in shallow pits and remained a little longer in the depressions. Here water evaporated and thus salt concentrations rose with salt crystals covering the surface (Fig. 12.12).

Figure 12.12: Growth zone near the Gulf of Aqaba. The depression near the sand-dam held water which became so salty that no plants could grow in it (Salt can be seen).

Albert et al (2004) reviewing also data provided by Zohary (1973) suggested that the shore area may have a flora influenced by salt. Here ***Atriplex halimus, Sueada aegyptiaca, Suaeda monoica, Tamarix negevensis, Tamarix tetragyna,*** and also ***Typha angustata*** were recorded on sandy soils having ***Salsola baryosma, Traganum nudatum, Alhagi maurorum*** and ***Cressa cretica*** growing on them. But the flora encounterd by us growing in the shallow water pond, dammed from the sea shore by the artificial wall of earth, has a quite different composition. *Tamarix* was not noticed at all and probably had no time to grow, and *Traganum* may have been among the young plants encountered by us.
We noticed a community on that southern part that has a quite different composition. The character plant of the community has basal larger leaves with similar color and shape as in ***Atriplex halimus*** and in contrast to it, it is smaller and has globular green leaves in its upper part. Within the Chenopodiaceae a tendency of efficient uptake of ions storing them in distinct parts of the plant has developed.
High salt concentrations in some cells thus decrease the salt present in other cells. Albert et al (2004) described the mode by which *Atriplex halimus* deals with the problem. Here salt is deposited in blister-like hairs which grow on the surface of leaves and subsequently become detached from the plant. But other species of *Atriplex* have developed such separated deposits of salt, concentrated in thick special leaves with large

liquid storing cells. It is suggested that the small *Atriplex* forming the characteristic plant of the community encountered by us had developed such leaves to store salt with the rounded leaves forming the upper part of the plant (Fig. 12.3a).

While most of the plants encountered by us were in full flower, *Suaeda* was present only as juvenile and thus has to continue to grow to flower and form seeds. The others had reached maturity and were in the seed production and ripening stage (Fig. 12.3b).

Figure 12.13: a. Character plant of the population (*Atriplex* sp) from the beach salty soil, b. *Atriplex* sp jointly with *Suaeda* and with salt in a dried out puddle (from Aqaba beach, 2014)

Also the white flowering ***Anthemishausknechtii*** with hairy leaves was commonly encountered, but in less frequency than *Atriplex*. Al- Eisawy (1998, fig. 130) noticed that this plant grows in the desert, and we found it also in the dry bed of Wadi Yutum. According to Feinbrun-Dothan (1978) its growing environment is actually the mountain area above 800 m. But *Anthemishaussknechtii* probably represents the *Anthemis* which we found on salty moist ground in Aqaba (Fig. 12.14a).

The characteristic ***Aaronsohnia factorovskii*** with yellow composite flowers with only the central tubular ones present with no outer flower leaves is relatively common. Both composite flowers also grow in the desert of wadi Yutum, and were observed here as flowers on the same day (Fig. 12.14b).

Figure 12.14: a. *Anthemis* in Aqaba salty ground near the beach, b. *Aaronsohnia* grows on salty soil close to Aqaba beach

The thick green fleshy leaves of *Suaeda* can be found commonly accompanying ***Sclerocephalus arabicus*** (Fig. 12.15a) and ***Aizoon canariensis*** (Fig. 12.15b). Of these *Sclerocephalus* also grows in not salty soil in wadi Yutum. *Aizoon* is especially characteristic to the salty soil of the beach of Aqaba. Similar environments of the salty flats of the brackish Karama Reservoir in the Jordan Valley have similar ***Mesembryanthemum***. ***Aizoon*** prefers to grow in places which contained puddles with water which during evaporation become increasingly saltier.

Figure 12.15: a. *Sclerocephalus arabicus* from Wadi Yutum, March 2014, b. Aizoon from salty soil on Aqaba beach

The thistle ***Picnomon*** can be recognized by its spines, even when still without flowers, occurring rarely when other thistles are missing.***Picnomon acarna*** as noticed by Al-Eisawy (1998 fig.200) has the stem right above the basal rosette branching as is the case in the juvenile

plant that we found growing on salty ground near the beach of Aqaba. Otherwise the plant was described to grow on cultivated land and waste fields in the highlands of Jordan.
Along the ridge of sand separating the salty area that held the shallow pond during the rain flood the small bush ***Halocnemum strobilaceum*** had grown and here also ***Amaranthu salbus*** was found (Fig. 12.16a). ***Anabasissetifera*** or *reticulata* form larger bushes, and ***Chenopodium ambrosioides*** is one of the larger plants here with large stands of flowers of rather indistinct small size. This bush-like growth also follows former water canals.
Among the Brassicaceae four species are present, the most characteristic is the almost naked ***Zilla spinosa*** forming thorny bushes with bluish flowers, *Eruca sativa* with larger veined flowers, its relative ***Sisymbrium septulatum*** with yellow flowers and *Diplotaxishara* of the same character as flowering also in the dry bed of Wadi Yutum. *Erucasativa* can obviously not only tolerate relatively dry ground as on the slopes of the Zor in the Jordan Valley, but can also grow on salty ground, as near the beach at Aqaba.

Diplotaxis harra, and ***Sisymbrium*** grow in similar environments in the Jordan Valley probably sometimes with salinity higher than usual. *Zilla* likes hot moist places, even when they are not salty. But they also grow on the dry ground of Wadi Yutum, following the moisture here after floods (Fig. 12.16b).
The small clover ***Trigonella stellata*** with its small yellow flowers grows flat on the soil, and is found in other salty places in Jordan. The other member of the Leguminosae ***Astragalus*** grows close to the ground but has purple flowers both tolerate salty ground and can be found elsewhere in the country (Fig. 12.17a).
Opophyton foscalii was present with its characteristic thick leaves, without flowers in March. Characteristic also are the yellow ***Arnebia hispidissima***, ***Reseda*** bushes of ***Ochradenus baccatus*** forming plant with woody base and many green branches with small leaves and yellow small flowers.
All these may grow around puddles after stong rains in the Eastern desert of Jordan. ***Anchusa aegyptiaca*** of the Boranginacea and *Sclerocephalus* of the Caryophyllacea grow here as they do on sandy grounds in Wadi Yutum, and here in the Gulf next to flowering *Aizoon* and juvenile *Suaeda*, both are typical salt loving plants (Fig. 12.17b).

Figure 12.16: a. *Halocnemum* near Aqaba beach, b. *Zilla spinosa* from Wadi Yutum, March 4014.

Figure 12.17: a. *Astragalus* grow on salty ground near the beach of Aqaba, b. *Anchusa aegyptiaca* growing on salty mud cracked gound in Wadi Yutum

The yellow composite ***Crepis sancta*** or a related species of it is present here as well as in desert areas near dry puddles. Its fruits are attached to a pappus and fly off with the wind. *Crepis sancta* closelyresembles ***Crepis biennis*** and was described by Feinbrun-Dothan (1978, pl.753). Accordingly, the up to 20 cm high annual herb has a forked stem rising from a rosette of elongate and dentate leaves with hairs. The yellow flowers are found at the end of each branch. The plant grows in the desert and also on salty ground near the beach of Aqaba together with *Aizoon* (Fig. 12.18a). In the literature it was not indicated that *Crepissancta* or any of the other species of the genus can grow successfully on salty grounds.

Among the monocotyles, only the lily ***Asphodelus fistulosus*** occurs here very rarely while it commonly occurs on dry stony ground in the Jordan Valley. It is an annual or short-lived perennial herb growing a hollow stem up to 70 centimeters in height. The root system has a series of tuber-like parts at the base of the stem (Feinbrun-Dothan, 1986 pl.28; Al-Eisawy 1998, fig.368).

The inflorescence consists of widely-spaced flowers. Each flower is 5 to 12 millimeters wide with six tepals which are generally white or very pale pink with a neat central longitudinal stripe of brown to reddish-purple. This is the smaller of the two species of the genus from Jordan and was found in rather dry environments as well as near Zarqa River and near Aqaba (Fig. 12.18b). Thus it tolerates salty ground, and is usually found in quite dry areas.

Figure 12.18: a. Crepis from Aqaba, 2014, b. *Asphodelus* from a salt ground near the beach of Aqaba, spring 2014

Only three grasses were noticed among the small specialized flora. Of these ***Pennisetum divisum*** has a characteristic florescens and ***Hordeum marinum*** which is common (Fig. 12.19a). ***Dichanthium annulatum*** grows in irrigated places and ditches as well as banks of water reservoirs in the Jordan Valley. *Dichanthium* also grows along the Gulf of Aqaba even in salty environment (Fig. 12.19b).

Figure 12.19: a. Grasses of *Hordeum marinum* growing in *Atriplex* settlement on salty ground near the Gulf of Aqaba, b. Grass of Bromuswith *Dichantium* from Aqaba

SUMMARY OF DISCUSSION

In this book we discussed the fauna and flora as indicators for different environmental condition such as, salinity, pollution and special environmental situations like high trace element contents of water.

The creek in Wadi Shueib downstream of Salt can exemplify the pollution history with transition from clean water spring to polluted water and transition from water flowing from the highlands of the country to a reservoir at the margin of the Jordan Valley (Fig. 13.1). Here the changes which occur between slow runoff during the dry months and rapid flood flow in the rainy season is documented. Four sites were chosen along Wadi Shueib; the first at Jadoor spring site, the second is creek a near Al Farkhah and Deak springs, the third site downstream of Salt sewage treatment plant and the final site is a pond near Shueib dam. Jadoor spring at the western margins of Salt, is clean and has clean water signal with the gastropods *Theodoxus*, and *Melanopsis*, the crustaceans *Gammarus* and *Asellus* living in it.

This signal disappears when pollution increases along Wadi Shueib due to the added household sewage. Even further downstream the effluents of the Salt treatment plant are added to it with strong impact on the type of insect larvae in the creek. When Shueib water mixes with the effluents of the sewage treatment plant and flows over stony beds bordered by *Nerium oleander* bushes towards the Jordan Valley the only gastropod remaining is *Physa*.

Elevated phosphorus and nitrate concentrations in this water due to the added treated waste water is reflected in a strong growth of cyanobacteria on surfaces and in the water as phytoplankton, supporting reproduction and growth of the sewage worm *Tubifex* and the similarly red larvae of Chironomidae which settle in the organic sludge.

These two organisms are good indicators for the water quality degraded by sewage. Both organisms can tolerate water with depleted dissolved oxygen. Floods caused by winter rains may flush down all muddy bottom sediments and with it the substrate for *Tubifex*. The return of moderate flow conditions produces the sludge again and red worm and larvae colonies return to it. The amount of winter floods determines the living conditions in Shueib reservoir at the end of the Valley with water polluted to different degrees. In 2012 pollution was strong and dipteran larvae settled near shore puddles and in 2013, pollution was more moderate and a large population of *Daphnia* developed in the shallow parts of the lake.

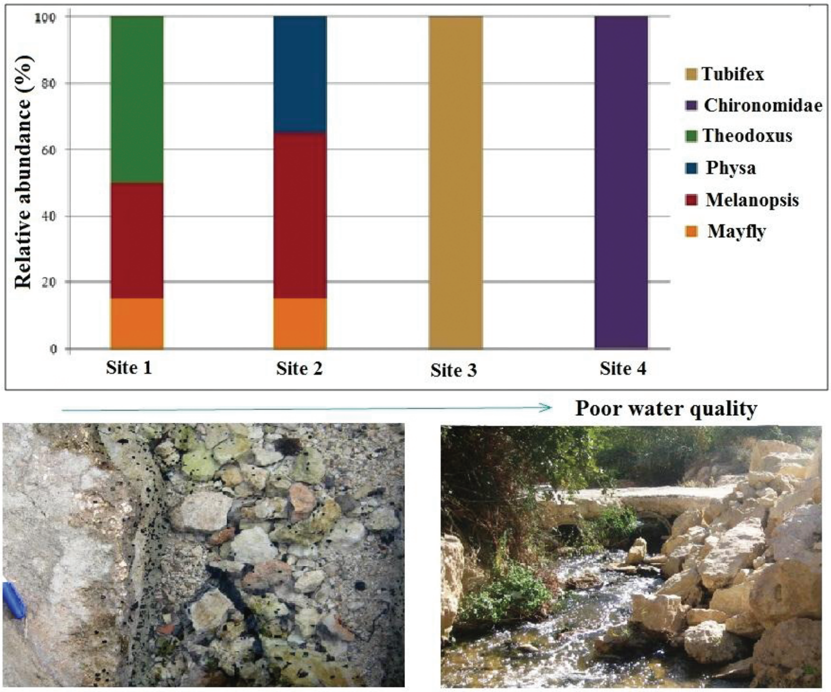


Figure 13.1: In Wadi Shueib, aquatic macrobio-indicators document a shift in community composition related to human activity (Site 1: Jadoor spring; Site 2:Creek near Al Farkhah and Deak spring; Site 3: Creek downstream of the Salt sewage treatment plant; Site 4; A pond located near Shueib dam)

In the case of Wadi Mujib downstream of the dam site, change to much better water quality compared to that of the lake and some of its tributary streams was observed. Here initially nutrient tolerant species (e.g., *chironomids*, *Tubifex* and *Physa*) are associated with the high nutrient production as evidenced by the strong growth of algae and phytoplankton. Here also the content of dissolved oxygen is relatively low. Still close to the dam *Melanopsis* appears, fish and frogs are common and within a short distance of about 2 km downriver the biological communities change completely documenting a rapid improvement of the water quality also as a result of the turbulent flow of the river across many rapids in the stream bed.

The river bed is stony and air mixes with the river water, and pollution-tolerant organisms such as Tubifex and red chironomid larvae are replaced by the pollution-intolerant organisms such as *Theodoxus*, and *Melanopsis* (Fig. 13.2).

In general, the river is cleaned by self-purification processes, but there are still strong nutrient concentrations in the water which support the growth of rich phytoplankton. The mud that settles in quiet puddles on the side turns black just below the surface, and the lower sides of stones become black. The high quality water containing many planktonic organisms here enables the growth of fresh water sponges covering rocks in the river rapids.

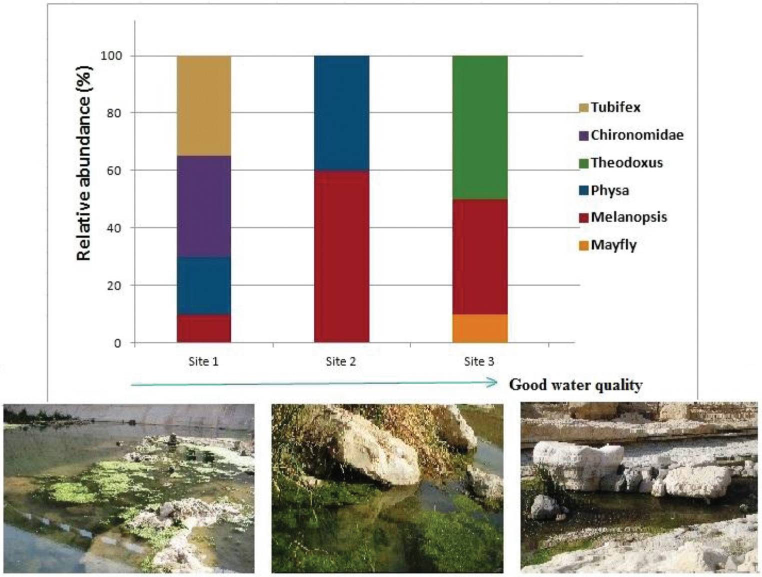


Figure 13.2: The occurrences of bio-indicators along Wadi Mujib (Site 1: Lake below the dam; Site 2: Creek in Wadi Mujib about 1 km from site 1; Site 3: Creek about 2 km downstream of Wadi Mujib).

It was possible to classify the quality of running and standing water in Jordan by using biological indicator species, providing a basic frame by which easily and rapidly the status of water quality and pollution is recognized in the field. It is based strongly on gastropods which can usually be detected on stones and determined in the field and monitoring improves with other invertebrates, especially aquatic worms and insect larvae.

They have been selected according to their common presence and their characters which can usually be rapidly determined in the field and thus serving as bio-indicators. As a result of field and libratory work, aquatic fauna have been found to tolerate *different* levels of *pollution*, generally falling into two categories; Pollution tolerant organisms (including: *tubifex*, *chironomid*s, and *Physa*) (Fig. 13.3) and pollution intolerant organisms: observed in unpolluted water systems in Jordan such as *Turbellarian*, *Theodoxus*, *Melanopsis*, *Galba*, *Amphipoda*, *Isopoda*and *Mayfly* larvae.

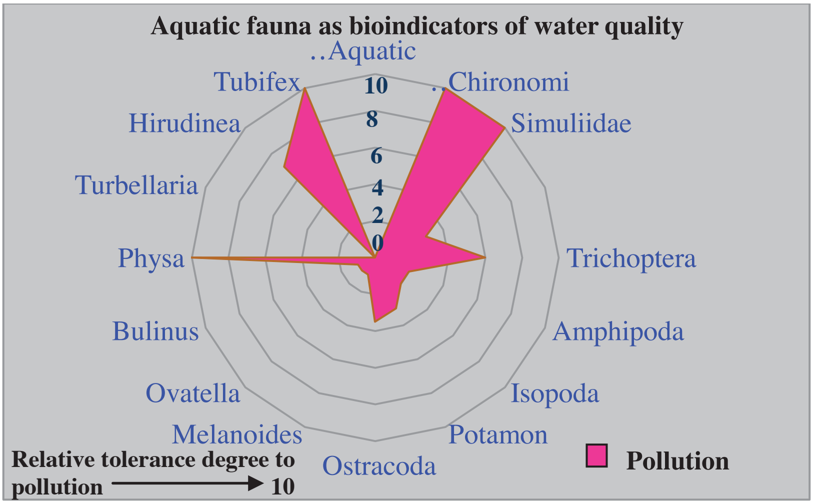


Figure 13.3: Biological indicators of water quality in Jordan

Gastropod (mollusca) group represent a good indicators for environmental status because they respond rapidly to environmental changes from clean to polluted water. Furthermore, the reason for using molluscs as bio-indicator is that they can easily be recognized and collected from the field having a size that makes them visible in water. Also they are well researched and can be determined to species level, even in the field.

Additional to gastropods which represent the frame bio-indicators in the present work, other animals were chosen for the analysis, predominantly flat worms (Turbellaria), annelid worms of *Tubifex* and leeches (Hirudinea), larvae of insects (e.g., mayflies, caddisflies, black flies, shore flies and chironomids) and crustaceans (ostracods, amphipods, isopods and the decapod *Potamon*) (Fig. 13.4).

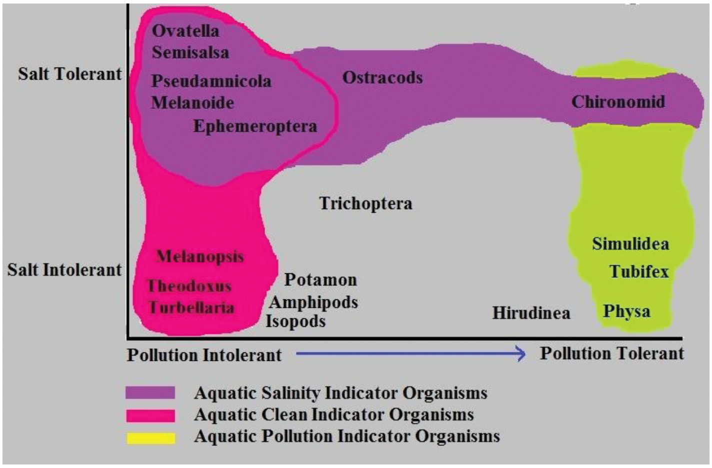


Figure 13.2: Aquatic indicator organisms of salinity and the ecosystem health in Jordan

The results of the present study suggest a "**Jordanian Biomonitor System for Watercourses (JBSW)**" which classifies water qualities in 12 categories as shown in Table 13.1.

Category	Water quality	Aquatic organisms bio-indicators	Tolerance degree	Environment description including; Substrates, water body type, and color.	Chemical indicators	Locations, examples
1	High water quality (very clean/ non-polluted)	Theodoxus, Turbellarian (flat worm), and Mayfly larvae *(Caenis antoninae)*	Organisms highlysensitive to pollution	Rocks and gravels, clear shallow water from still to slow running water	Low COD, BOD values and main ions;Ca^{2+} and Mg^{2+}	Hisban, and Shita Springs.
2	Very good water quality by self-purification	No Turbellarian (flatworm). Theodoxus, Melanopsis, Mayfly larvae, (*Baetis monnerati*), and sponges.	Organisms highly sensitive to pollution and not sensitive to strong growth of phytoplankton (no nitrate)	*Exposed* riverbed *rocks*but with darker mud deposits thannormal due to additional nitrate. Shallow water from moderate to swift current.	COD value is around 15 mg/L and BOD 0 mg/L. High values of SO4 (>7 meq/l), NO3 about 0.2 meq/l, and Na 5 meq/l	Mujib River a few kmbelow dam site and KACduring spring 2013.

3	Good water quality	Gastropods (Melanopsis, Galba and Bulinus). Crustacea (Amphipoda) and mayfly larvae such as *Baetis monnerati*	Organisms sensitive to pollution, clean water to slightly polluted water.	Gravel bottom stream with moderate running water and springs issuing from carbonate rocks.	Normal freshwater chemistry but small increase in NO3 and PO4 values	W. Hisban below spring area, Wadi Sir, small spring creek in upper Wadi Zarqa.
4	Fairly good water quality	Melanopsis coming from continuous sources, Physa, Mayfly larvae (Caenis sp), and leeches.	Semi tolerant organisms that tolerate some degree of house sewage added to streams.	Rock and gravel, less sand occurs in the relatively turbid running water from moderate to swift current with high occurrences of aquatic vegetation.	NO_3 concentration up to 1.0 meq/l and low concentration of Na dissolved ions	W. Shueib and Wadi Sir upstream of the treatment plant.
5	Moderate	Chironomidae (blood worms), Physa, Mayfly larvae, and Caddisflies larvae.	Tolerant organisms which survive with moderately polluted water	Bottom surface between stones with organic mudand sand below surface black.	COD value reach to 50 mg/L and BOD 22mg/L. SO_4^{2-} around 6meq/l, NO_3^- 1.5 meq/l , and PO4 0.3 mg/l.	Periodicallyin lowerZarqa River
6	Slightly bad	Low densities of Physa and leeches or disappearance and well present Simulidae (Black fly larvae) and tube- building animals such as Chironomid	Pollution tolerant organisms but still with well aerated water	Rocks with muddy organic rich deposits in interspaces. Brown, turbid water with moderate to swift	Relatively high values of COD with 60 mg/L and BOD reach 35 mg/L. SO_4^{2-} about 1,5 meq/l, NO_3^- 1.0 meq/l ,	Wadi Shueib downstream of the treatment plant and periodicall-y parts of Zarqa River

		(blood worms), and Tubifex (Sludge worms.)		current.	and PO4 1.0 mg/l	
7	Bad (Eutrophic)	High occurrence of Chironomidae (blood worms), Tubifex and Physa with their eggs.	Tolerant to eutrophicatio-n organisms.	Fine sediment below surface and lower side of rocks black with still greenish turbid water and high growth of algae and Cyanobacteria.	COD is 35.0 mg/L and BOD 5.0 mg/L.SO_4^{2-} (4.5 meq/l) , NO_3^-(0.20 meq/l), and PO4 (0.30 mg/l)	Wadi Mujib Lake directly below dam
8	Very bad water quality	Red Chironomid worms, frogs and fish.	Organisms not sensitive to pollution.	Muddy sediment between rocks,black below surface, rockscovered with bacterial slime.	COD >70 mg/L and BOD >10 mg/L. NO_3^- (1.50meq/l) , PO4 (0.30 mg/l), HCO_3^- (8.0 meq/l), and CL (11.98 meq/l)	Periodically Zarqa River especially upstream of King Talal Reservoir.
9	Poor water quality (Heavily polluted water) (smelly and colored water).	No insect larvae only bacterial slimes. In Kafrain lake fishperiodically killed.	Organisms highly tolerant to pollution.	Muddy with high sludge content. Turbid - gray color in creeks brown in lake.	COD up to 83.0 mg/L and BOD 40.0 mg/L. high concentration of PO4 and NO3	Wadi Sir after and belowtreatmen t plant and Kafrain dam

10	Mineral water		Large numbers of Pseudamicola (snail), Simulidae (Black fly larvae) and Chironomid worms. Larvae of mayflies such as *Nigrobaetis vuatazi*and caddisflies.Springs with mosses and ferns	Organisms tolerant to mineral water and slightly salty water.	Springs with Gravel and siltyground in creeks.	Relatively high concentrations of Sr (reaching 37.0mg/L) Br 10.0mg/L, *and Zn* 0.02 mg/L	Wadi Atun stream
11	Warm water		No macroaquatic animals only dense crust of Cyanobacteria and springs with reeds (Phragmites)	Organisms are able to survivehigh temperatures.	Warm springsissuing from basalt and sandstone aswarm as 60°C.	Relatively highconcentration of trace elements suchas Mn 5.0mg/L, Cu 0.2 mg/L, Ba 700*mg/L*	Zara andZarqa-Ma'in springs
12	Brac kish water	Class 1	Pseudamnicola(snail), Ostracods (e.g., *Heterocypris salina, Cyprideis torosa* , and *Heterocypris reptans*) and Insect larvae such as Ephydridae (shore fly), Chironomidae,mayfly (*Cloeon sp*).	Salt tolerant organisms which survive with salinities of 16000 - 21000 μS/cm	Creek on gravel with algae and aquatic plants. Pools surrounded by salt tolerant plants with ostracodes.	Relatively high concentrations of dissolved salts.Br and Sr.	Karama area

		Class 2	Periodically with ostracods (e.g.,*Heterocypris reptans* and *Cyprideis torosa*) up to 2011 with Melanoides but from 2012 on without Melanoides- surrounded by salt tolerant plants	Up to 2011 with salinity about 23600 μS/cm. In 2012 and 2013 the salinity level reached 26100 μS/cm	Standing water with muddy ground	Higher salt concentrationsand Br 16mg/L and Sr 50mg/L.	Karama Reservoir lake.

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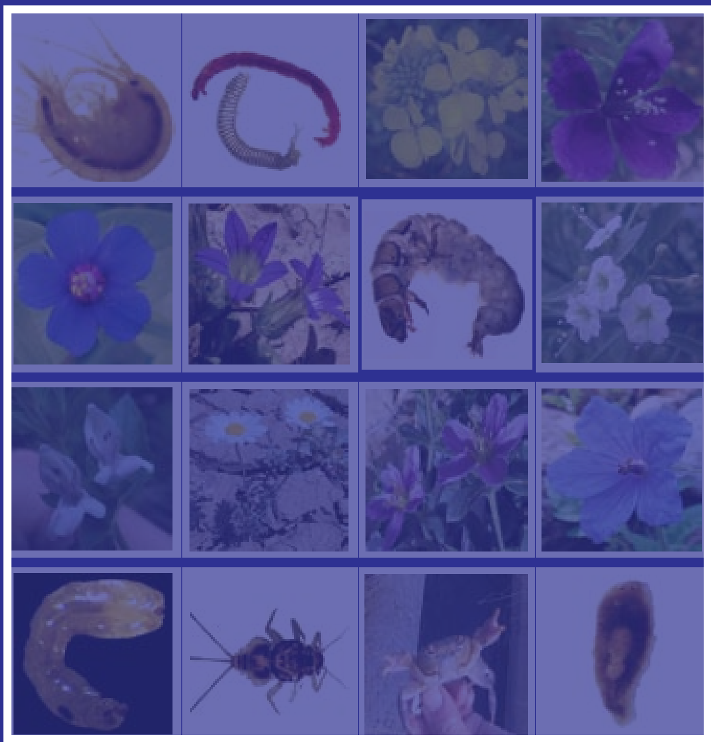

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