Tracking and evaluating changes in vegetation and habitat structure in the En-Afeq Nature Reserve, Israel

A comparative study

Tracking and evaluating changes in vegetation and habitat structure in the En-Afeq Nature Reserve, Israel

MSc-thesis - an EBONE project

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Preface

During summer 2010 a repeated mapping of the vegetation was carried out in the En Afeq Nature Reserve near Haifa, Israel. This project is part of the MSc ´Nature and Forest Conservation´ at the Wageningen University in the Netherlands (WUR).

This project was funded by the European Biodiversity Observation Network (EBONE) and has been supported by the Department of Environmental Sciences – Nature Conservation and Plant Ecology Group and the Israeli Nature and Parks Authority (NPA).

This project has been supervised by Linda Olsvig-Whittaker. I would like to thank her for all the help during my stay in Israel and especially with the data analysis. From the Wageningen University I was supervised by Karlé Sykora who was of great help with the data classification.

I would like to thank Giselle Hazzan, Iftah Sinai, Didi Kaplan, Hillel Glazman, Margareta Walchzak and all the other people of the En Afeq Nature Reserve, who made my stay at En Afeq a nice experience. Last, thanks to Nico Burgerhart for the comments and support he provided when intrepetating his dataset.

I hope this project will contribute to the quality of the management in the En Afeq Nature Reserve and that it provides valuable *knowledge* for EBONE in the context of monitoring biodiversity.

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Summary

Wetlands are important for life on earth. They deliver a wide range of ecosystem services and support a high concentration of species. Worldwide wetlands are lost and degraded due to human intervention, which is especially true for the Middle East. In Israel only a few remnants remain and suffer from declining water tables and invasive species. From the perspective of conservation it is important to manage those wetlands as well as possible. An essential tool for evaluating management is monitoring the flora and fauna.

This research is focused on mapping the En Afeq Nature Reserve, a small wetland area on a coastal plain in western Galilee. The purpose of this study is (apart from monitoring changes and evaluation management) to test the efficiency and usefulness of EBONE structural mapping methods versus traditional phytosociological mapping. En Afeq was previously mapped by Nico Burgerhart in 1998; a twelve year period of management is evaluated by comparison of both 1998 and 2010 maps.

Fieldwork was conducted in the spring of 2010. For phytosociological mapping 54 relevés were resampled, clustered and ordered. In addition, the relation between vegetation composition was studied by means of a gradient analysis (DCA). After classification with all relevés (both from 1998 and 2010) nine vegetation clusters were distinguished. Over time, sixty percent of the relevés from 1998 changed in species composition and shifted to another cluster. The vast majority of changed relevés showed a trend towards a dryer vegetation type. Linear regression on the delta DCA values of both axis revealed that indeed moisture is likely to be the major driving factor. Spatial analysis showed that drying out is most evident in areas where no water management has been applied. Changes had no effect on species richness, which remained constant in the area.

Structural mapping was done by direction of EBONE by using the BioHAB tool, a habitat classification system based on the Raunkiær plant growth forms. It was found that Tamarisk coverage was reduced in many areas, but constant in others, despite the fact that in was cleared between the studies. Furthermore new wetland habitat types

emerged and typical dry communities dominated by shrubby chamaephytes, grasses and thistles increased.

This study showed that drought is a persistent and increasing problem in the En Afeq Reserve. Evidently this is mainly caused by an increasing demand of water in the neighbourhood.

BioHAB was assigned to be more appropriate for monitoring changes at En Afeq, at least for this study as classical phytosociology could not be performed properly. Which monitoring tools to choose for future management evaluations is dependent on the weight that is given to certain management goals, the needed frequency of monitoring and the time/money that is available.

1. Introduction

1.1 Wetlands

1.1.1 Ecosystem services

Wetlands cover a significant portion on the planet, estimated at 1280 million ha (circa 9 % of land surface). *(RAMSAR, 2007)* The importance of wetlands for life on earth is reflected in the wide range of ecosystem services they deliver. Among these are provisioning services (such as food and water); regulating services (such as regulation of floods, drought, land degradation, and disease); supporting services (such as soil formation and nutrient cycling); and cultural services (such as recreational opportunities, and increasingly, tourism). These services together have been valued at US$14 trillion annually, indicating the great economic importance. *(MA, 2005)* Besides the benefits that people obtain, wetlands support a high concentration of mammals, birds, amphibians, reptiles, fish and invertebrate species. Especially freshwater wetlands are relatively species rich, with circa 100,000 described freshwater animals worldwide. *(RAMSAR, 2007, RAMSAR, 2010)*

1.1.2 Threats

The ecosystem services and species richness of wetlands described above are in danger as a result of human developments. Worldwide wetlands are lost and degraded due to land conversion, eutrophication and water abstraction. *(MA, 2005)* Already half of the world's wetlands have been lost the last century. *(CBD, 2010)* Furthermore the loss and degradation of wetlands is more rapid in comparison with other ecosystems. The same holds for the deterioration of species. Future climate change might even further exacerbate the decline in biodiversity of wetlands. *(RAMSAR, 2007)*

1.1.3 Wetlands in the Middle-East

Wetlands in the Middle-East are particularly under serious stress, as most of them lie within one of the most arid zones in the world. This put an additional climatological constrain on the already existing problems caused by human activities. *(Scott, 1995)*

The region of Israel, Jordan, Syria, Lebanon and Turkey has already lost most of its wetlands. One of them was the Amiq Gölü wetlands, which covered 600 square kilometres of swamps and 90 square kilometre lake area and was totally drained. *(Burgerhart, 1999)* With this disappearance, a number of endemic fish and bird species went extinct. Together with the drainage of Lake Hula, in Northern Israel, the region's biodiversity was seriously harmed; a true ecological disaster. *(Hambright and Zohary, 1998*) The remaining wetlands in the Middle East are under serious pressure and are, besides loss of water availability, eutrophication and disturbance, affected by invasive species and wildfires. (*Olsvig-Whittaker et al, 2009*)

1.1.4 Israeli Coastal Wetlands

The loss and deterioration of wetlands is certainly the case in Israel, where only 2000 ha of wetlands are left. In the past the whole west of Israel was covered with swamps. (*Mollema and Pronk, 1999*) This region was covered with valuable coastal freshwater swamps, covering over 10,000 ha. These swamps were the host of numereous species which are now extinct or drastically reduced in the region. Examples are typical wetland plant species like *Nymphea alba, Nuphar lutea* and *Cyperus papyrus*, animals such as the Nile crocodile and endemic fish species. (*Levine et al., 2009; Kaplan, 1993)* Another important ecological function of these wetlands was that they nurtured and supplied millions of migratory birds flying from Africa to Eurasia and vice versa during spring and fall. Together with the previously described ecosystem services they have to offer it is clear that it is essential to protect these remaining wetlands.

1.1.5. Na´aman stream area

One of the largest remaining coastal wetland areas is the Na´aman stream area, located in the Acre plain between Haifa and Acre (figure 1.1A). The Na´aman Stream is fed by the Na´aman aquifer, which includes areas in the western Lower Galilee and the eastern Acre Valley and extends over 300 square km.

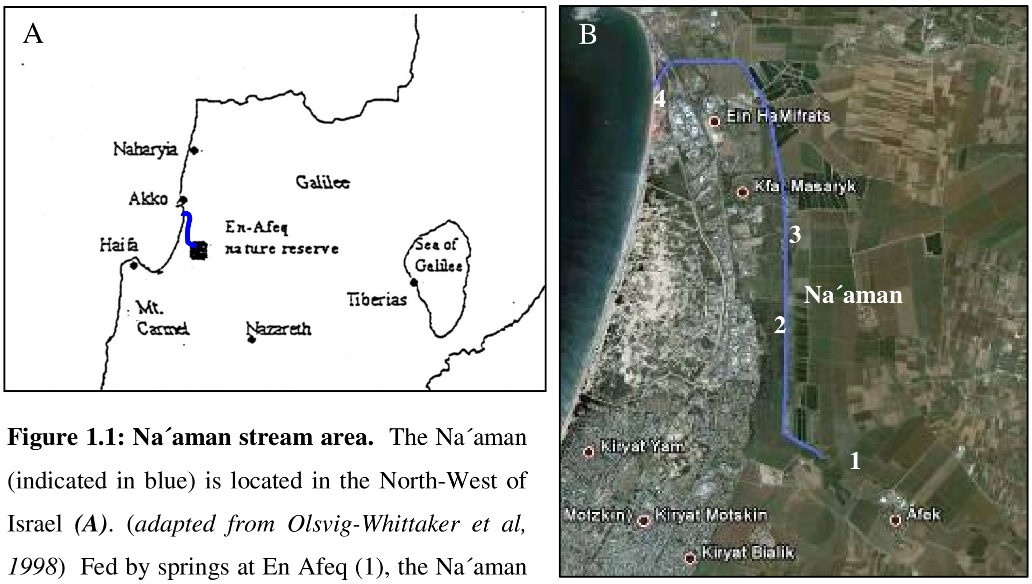


Figure 1.1: Na´aman stream area. The Na´aman (indicated in blue) is located in the North-West of Israel ***(A)***. (*adapted from Olsvig-Whittaker et al, 1998*) Fed by springs at En Afeq (1), the Na´aman runs nine km NW via the Kareem (2), Nimphyt (3) and Sefech (4) nature reserves into the Mediterranean Sea ***(B)***. (*adapted from Google Earth, 2002*)

The Na´aman stream originates from the springs in the En Afeq Nature Reserve and flows nine kilometres through highly urbanized land; including pastures, fish ponds and neighbourhoods to its estuary at the Mediterranean Sea south of Acre. (*En Afeq pamphlet, 1999*) The present course of the Na´aman stream follows a man-made channel and its associated wetland habitat is mainly converted into arable land (*pers. comm. Yihtach Sinai, 2010*). A few pocket reserves remain and include; The En Afeq Nature Reserve, Nimphyt, Kareem Na´aman Reserve and Sefech (figure 1.1B). These nature reserves are protected and managed by the Israel Nature Reserve Authority (INPA) for several reasons. An important one is that they harbour a lot of endangered and rare species. This is especially known for plant species, mainly because there have been numerous vegetation surveys in the area. At least nineteen Israeli IUCN Redlist plant species are found in the area with IUCN status ´vulnerable´ or ´endangered´, making them a good indication for making conservation priorities. All these plants are in the ´Threatened plants of Israel´ and are listed in table 1.1. (*Burgerhart, 1999; Iftah, 2005; Iftah, 2007; Shmida, 2010; Walczak, 2006*) Besides those endangered and vulnerable species, some 26 rare to very rare species are found in the area (see appendix 2.2).

Species	**Red Index**	**IUCN cat.**	**Na´aman**	**En Afeq**	**Kareem**	**Nimphyt**	**Sefec**
Allium schubertii	6	VU					x
Aster tripolium	9	EN					x
Bupleurum orientale	8	EN	x				
Elytrigia elongatus	7	VU					x
Euphorbia peplis	6	VU		(x)[2]			
Euphorbia microspaera	8	EN	x		x	x	x
Ipomoea sagittata	9	EN	x	(x)[2]	x	x	
Juncus articulatus	8	EN		(x)[2]	x		
Orchis laxiflora	9	EN			x		
Parapholis filiformis	8	EN			x		x
Persicaria lanigera	8	EN	x	x	x		
Plantago arenaria	7	VU			x		
Polygonum maritimum	7	VU					
Rosa phoenicia	8	EN		x			
Salsola soda	7	VU	x	x			x
Suaeda splendens	7	VU					x
Sarcocornia perennis	8	EN					x
Trachomitum venetum	7	VU			x	x	

Table 1.1: Occurrence of Israeli Redlist plant species in nature reserves of the Na´aman stream area. The Red Index together with the IUCN category indicates respectively the national and global status of that species (*Sapir, 2004; IUCN, 2010*)[1]. The species observed along the Na´aman stream, excluding the reserves, are based on a vegetation survey of Walczak in 2006. Species found at En Afeq are based on fieldwork data in 1998 of Burgerhart. Species between brackets were not found in 2010**2**. Species found at Kareem Na´aman, Nimphyt and Sefech were the result of different surveys carried out by Sinai in 2005 and 2007. This table was completed by observations made by de Gelder in 2010.

[1] The Red Number is an additive index used in Israel, whereby it summarizes the values of four parameters: Rarity, Declining rate and habitat vulnerability, Attractivity and Distribution type. This index contains fifteen categories; the higher the number the higher the priority for conservation.

[2] These plant species are not found during fieldwork of this thesis. These species could either be lost from the reserve or have been overlooked. A complete plant species list of En Afeq can be found at appendix 2.1

1.2 En Afeq

1.2.1 Status and Importance

The En Afeq Nature Reserve is of particularly importance from different perspectives, which is mainly reflected in the status of this wetland. Since 1996, En Afeq has the status of Ramsar Site on basis of criterion 1: `*it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region´* and criterion 2: *´it supports vulnerable, endangered, or critically endangered species or threatened ecological communities´*. (*RAMSAR*[a], 2007). Two other important functions of the reserve are education and tourism. Education is visible in the GREEN and BIOTOP programs, respectively focused on the environmental interaction between rivers and communities and biological phenomena of wetlands. Each year around 60,000 people visit the reserve, which is a large number comparing to its size. (*Burgerhart,* 1999 *and pers. comm. Hazzan*, 2010)

1.2.2 Characteristics

The reserve is 66 ha in size and centred at 32°51'45"N, 035°05'41"E. (*RAMSAR*[b], 2007) En Afeq is surrounded by governmental land, which is rented by the Kibbutzim Afeq and En HaMifraz, Arab villages (Iblin and Tamra) and the northernmost suburbs of Kiryat Bialik. Figure 1.2A shows En Afeq and surroundings. Clearly visible from the reserve are the arable land, the fish ponds in the north and the cemetery in the west.

Two-third of the area is wetland habitat, while the other one-third is dry habitat including the Bronze Age Tel Afeq archaeological site. (*Burgerhart, 1999*) Despite its small size a lot of different habitat types are found, either semi-natural created or man-made. Figure 1.2B gives an overview of the different habitats found at 1998. Ranging from wetland habitats such as the eastern swamp and the river terrace area till dry habitats such as the Pine plantation and the tell Afeq dry grassland. (*Whittaker-Olsvig et al., 1999*)

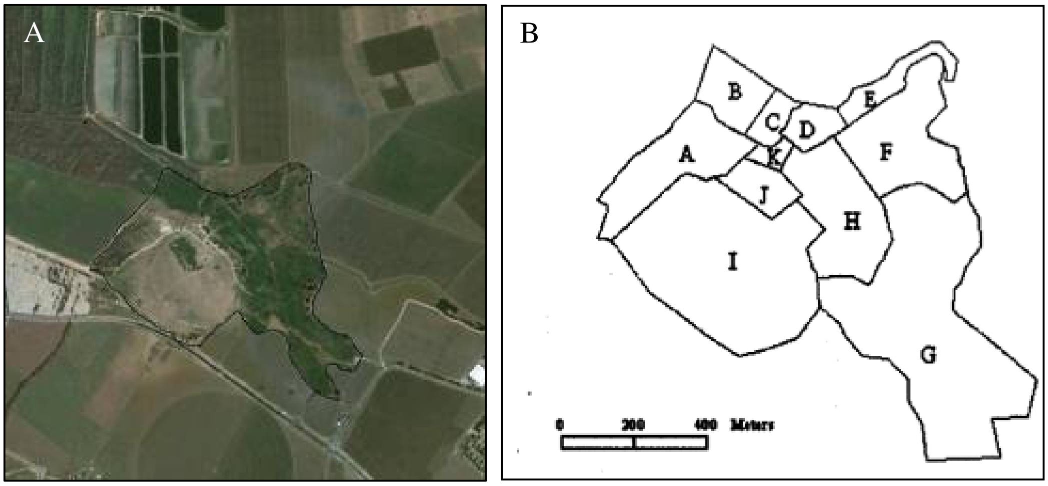


Figure 1.2: Satellite image from The En Afeq Nature Reserve. *Figure A:* The reserve (indicated with black boundary) seen in the centre, surrounded by fishponds, pastures and settlements further away. Just south of the reserve is a intensive used road and a cemetery. (*Adapted from Google Earth, 2002*) *Figure B* The reserve itself is composed of different habitat types: A. Open woodland of pine and cypress; B. Western swamp with tamarisk; C. Two mill-pond pools; D. River terrace area; E. *Eucalyptus* woodland; F. Water meadow with buffalo grazing; G. Eastern swamp with freshwater springs; H. Lake; I. Tel Afeq dry grassland; J. Pine plantation; K. Office and other buildings). (*From Olsvig-Whittaker et al., 1998*) [3]

1.2.3 Climate, Hydrology and Soil

The climate type at En Afeq is Eastern Mediterranean and falls in the sub-humid zone of Israel. Winters are mild and rainy and summers are prolonged, hot and dry together with high air humidity. Average rainfall is 550 per annum, where the majority falls between December and January. (*Zohary, 1962; Ortal, 1996*)

The Reserve is indirectly depended of the rainfall in the river's catchment area and directly on the En Afeq springs, which are the natural outlet for ground water of the Na´aman aquifer. Through an extensive drilling network in the upper basin area the ground water level has seriously been dropped over the past decades, causing a number of springs to become inactive and others drying out during the hot and dry summers. Together with this the water quality dropped as well as the average discharge rate of the springs, from 50 mcm[4]/year to only 2 mcm/year in a drought

[3] Some areas depicted in Figure 1.2B changed seriously, either through drought or management, and transformed into another habitat. This has been visualized in the result section of chapter 3.2 and 4.2; and discussed in chapters 3.3 and 4.3.

[4] Million cubic meters.

year. (*En Afeq pamphlet, 1999; pers. comm. Hazzan, 2010*) Management measures to counteract the effects of drought are being discussed in chapter 1.3.1.

The major soil type at En Afeq is of hydromorphic character. This is an alluvial soil usually with a high groundwater table and is found in swamps, river banks and drained ephemeral water courses. This soil type is usually deep, fine-textured and waterlogged, is salting up under arid conditions and causing air deficiency for e.g. plant life. Air deficiency varies in degree and duration according to the arrangement of zonation around swamps and along river banks. (*Zohary, 1973*) The hydromophic soil type in the swamps of the nature reserve is a silty-swampy type with a lot of mollusc remains. (*Ortal, 1996*) Other soils present in the neighbourhood of En Afeq are Terra Rossa and Alluvial Soils. (*Ortal, 1998*)

1.2.4. Fauna

The reserve harbours a great diversity of species, most of them related to wetland habitat. The Absolute eye catcher is the water buffalo (*Bubalus bubalis*), present as a herd of ten individuals. See chapter 1.3.2 for more information. Other mammals include the Egyptian mongoose (*Herpestes ichneumon*), the invasive species coypu (*Myocastor coypus*) and nocturnal species like the Indian crested porcupines (*Hystrix indica*), jungle cats (*Felis chaus*), wild boars (*Sus scrofa*) and northern jackals (*Canis aureus*). (*En Afeq pamphlet, 1999*)

The reserve is important for birdlife and hosts permanent and migratory birds. In the western part of the reserve Herons, Egrets and the Glossy Ibis roost and nest mainly in Tamarisk trees. The eastern part, which is covered with a dense thicket of e.g. *Phragmites australis*, attracts a large number of Warblers during migration and breeding season (*Burgerhart, 1999*). Among the other typical wetland birds present are: White-throated Kingfisher (*Halcyon smyrnensis)*, Pied Kingfisher (*Ceryle rudis*), spur-winged lapwings (*Recurvirostra avosetta*), mallards (*Anas platyrhynchos*) and teals (*Anas crecca*). (*En Afeq pamphlet, 1999*)

Besides those conspicuous species, numerous species live under the water table. Fish species like common tilapia (*Tilapia zillii*), carp (*Cyprinus carpio*), mosquito fish (*Gambusia affinis*) and clarids (*Clarias gariepinus*) are found. Some of these fishes are invasive and not endemic; these are mentioned in chapter 1.3.4. Soft-shell turtles (*Trionyx triunguis*), terrapins (*Mauremys caspica rivulata*), various kinds of mollusk and crustaceans as freshwater shrimp (*Decapoda*) and river crab (*Potamon*) complete the swamp life.

1.2.5. Flora

As already mentioned in chapter 1.1.5 the Na´aman stream area is rich in plant species. At En Afeq over 250 plant species have been found, including a number of rare and threatened species (see tables 1.1 and Appendix 2.1-2.3)[5].

As plants are directly dependent on soil hydro-morphology and indirectly on the water table in the area, they are among the first that react to drought or wetness. This leads to changes in vegetation types, either to more wet or dry species communities. For that reason, plants are often used as indicators to detect spatial changes in nature. In such a way management could be evaluated and questions like: ´did the measures result in a more heterogeneous landscape´ or ´was the clearing of Tamarisk sufficient enough to counteract further desiccation´, could be answered. Most of the work, research and management at En Afeq is focused on vegetation (in combination with water management). For the same reason this thesis will almost exclusively deal with vegetation; what the current status is and how it changed through time. To completely understand the importance of this research a glimpse of history, current management and problems will be discussed in the next chapters.

1.2.6. History

The En Afeq reserve and surroundings has a rich and long history and has been linked to agricultural activities for centuries. The presence of water and valuable land created the opportunities for the area to become an important farming area during the crusader period (1100-1300 CE). In the En Afeq area mills were built to process products such as barley and sugar cane. For the operation of these mills several ponds and a network of channels was created. This artificially created water system still regulates the flow of water through the nature reserve. It must be stressed that the reserve would not

[5] For a full list of plant species being found see table 2.1 in the appendixes.

exist without the mill pond system created by the crusaders. The history of events of the En Afeq reserve in its present appearance has been summarized in table 1.2.

Year	Event
1930	Eucalyptus trees are planted under British mandate for drainage purposes.
1935	The area in front of the head office was full of water and most of the area was covered with Phragmites, almost no Tamarisk was present.
1963	The west side of the area was almost free of Tamarisk and Nymphea
1970	The '*Water buffalo area'* is bare and dusty due to overgrazing.
1978	Pools north of the Mill are being dug, become covered with Tamarisk later on.
1979	Buffalo area was established, sheep and goats were introduced in the area.
1982	Crusader mill ponds were renovated by digging out sediment
1983	Reserve opens for public.
1984	Pools full with *Nymphea spec.*[6]
1986	Eastern side of large pond was dug.
1989	Reintroduction of grazing with sheep and goats in the *Water buffalo area*.
1991-92	Sheep and goats removed; introduction of buffalo's (7 females, 2 males).
1992	Eastern part of the reserve is flooded, followed by emergence of numereuous *Rubus Sanguineus.*
1993	Start removal of Tamarisk, crusader ponds, "Seitzer"7 mill ponds and water tunnel.
1996	Reserve declared as a RAMSAR Site. Removal of Tamarisk around offices. Introduction of *Salix acmophylla*.
1998/99	Deepening of almost all ponds. Removal of Tamarisk in central area.
2000	"Mamduch"[8] pond was dug
2001	Removal of 8 dunam of Tamarisk[9]
2003	"Seitzer" ponds in front of the offices were opened
2004	Pond in front of crusader building was dug. "Sophia" pool was cleared of Tamarisk and tunnel was cleaned up
2005	A lot of water due to excessive rainfall
2006-10	Not much rainfall, drought.
2010	Reservoir in the central part of the reserve will be dug[10]

Table 1.2: Major events in the history of En Afeq.

This table was partly obtained from the thesis of Burgerhart (1999) and supplement with personal comments from Hazzan (2010). The locations at En Afeq where table 1.2 refers to, are find and depicted in Appendix 1.4

[6] Re-introduced in the period 1950-1960
[7] Remnants of fish ponds dug by Seitzer; a pioneer in commercial fish-breeding.
[8] Named after a warden working in the reserve
[9] A standard Turkish land unit.1 dunam corresponds with 0.1 ha.
[10] This pool will be very deep en substantial large. The purpose is mainly for back-up and safety reason, to keep open water windows available in dry to very dry years. This pool is still under construction.

1.3. Management and problems

1.3.1. Water

The viability of the En Afeq wetland stands or falls with the presence of substantial water during the whole year. If no measures would have been taken most of the reserve would already be a dry and dusty area. Hence the reserve is to a large extent artificial. Several measures have been taken to counteract this: (1) extra pools were dug and existing ones were deepened. This created also more water windows and opportunities for water life. (2) The available water in the large pools is retained by means of dams. (3) When springs dry up during late spring and summer, water supply from a nearby drilling site is assured. (*pers. comm. Giselle Hazzan, 2010*)

1.3.2. Grazing

This management practice is introduced for several reasons. A herd of 50 cows graze in the eastern swamp area and on the Tel[11] during the summer mainly to avoid wildfires. Water buffalo's have been introduced in 1991-1992 into the *Water buffalo area* as these species are considered to be native to similar habitat types elsewhere in the Middle East. Moreover as grazing is supposed to halt succession, opportunities for rare plant communities are created and species richness could increase. This herd consists of 10 individuals, which graze year-long with a grazing intensity of 1/ha. There is also one, non-introduced, natural grazer species present in the area; the wild boar. They graze mainly in the western Tamarisk forest and are considered to be of minor importance since there is little herbaceous or geophyte cover in that area. (*pers. comm. Hazzan, 2010*)

1.3.3. Tamarisk clearing

Another persistent problem is the presence and spread of Tamarisk species. This opportunistic species benefits from the drought and accompanying salinization of the soil. Tamarisk forms dense thickets in the reserve, excluding other species, and

[11] A mount of accumulated debris containing ancient settlement remains. In this case of Bronze and Iron age biblical Aphek.

therefore need to be reduced. In previous studies it was found that *Tamarisk spp.*[12] changed plant species composition and caused a declining species diversity (Olsvig-Whittaker, 2009). This problem is also encountered with clonal species such as Rubus and Phragmites. Table 1.2 shows the various moments in time and the location where Tamarisk was cleared. After clearing, the trees were left in the field or burned in some cases. From 2004 no Tamarisk trees were removed anymore, mainly due to substantial disturbance that comes along with clearings. Appendix 4.2 shows an areal photograph of 2000 (1:5000) where areas with Tamarisk clearance are shown.

1.3.4. Invasive and rare species

Like any other nature reserve, En Afeq also suffers from invasive species that compete with native species (and often rare species) for space. Appendix 2.3 gives an overview of invasive plant species present at En Afeq (and the other Na´aman stream area reserves). One conspicuous plant species at En Afeq is the *Eucalyptus camaldulensis* tree, planted under British mandate. Others invasive plants present at fairly high densities are *Aster subulatus* and *Conyza Canadensis*. Exotic fish species like carp and mosquito fish, originating from the fish ponds nearby, are also to be invasive (*Goren and Ortal, 1999; Segev et al., 2009*).
As already mentioned in chapter 1.1.5, En Afeq and the other Na´aman reserves are host to a large number of rare and very rare plant species. In previous times even more plant species did occur in the reserve and surroundings. Once wetland plant species like *Nymphea nouchali, Persicaria lanigera* and *Ipomoea sagittata* were very common at En Afeq, but have disappeared now through desiccation and eutrofication. Several treatments, such as restoring suitable habitat and introduction of plants, have not resulted in the settlement of these rare species. Since a few years a botanical garden has been set up at En Afeq to ensure the continuation of endangered and rare species in the reserves of the Na´aman stream area (see Appendix 2.4 for an overview).

[12] *Tamarix* is very difficult taxonomically; therefore the taxon is kept at the genus level in most studies, including this present study. See also chapter 2.2.1.

1.4. Previous research at En Afeq

1.4.1. The "*Scenario* Project"

In 1998, the need for clear management plans for the future resulted in the "Scenario Project", a conservation management modelling study. The major aim of this study was to create a practical management tool able to: *´predict whether a desired landscape condition can be reached, to search for an optimal management protocol or to anticipate changes´*. En Afeq was chosen to serve as a pilot study. Firstly this resulted in revised management goals and tools for En Afeq, based on expert opinion. A relevant subsection on management goals, from an ecological point of view, is summarized in table 1.4. (*for full data see Olsvig-Whittaker, 2000*)

1	To represent the former extensive swamp landscape, species and dynamics as much as possible
2	To maximize biodiversity
3	To protect rare and valued species
4	To maintain low habitat fragmentation
5	To maintain ecosystem structure and function integrity
6	To restore and maintain naturalness of the landscape

Table 1.4: Management goals of En Afeq Nature Reserve. All goals were based on expert opinion in the context of the problems that were visible in 1998.

The first step in analysing the management regime that most closely reaches the desired management goals involve input of data. *´Nearly all the goals involve manipulations of vegetation, which in turn drive the dynamics of animal populations and communities. Therefore, data collection for this study was oriented towards vegetation and factors affecting vegetation´.*

The project could not be successfully continued because the modelling part did not work as the result of an emergency water level loss in 2010. Drastic steps had to be taken which were outside the frame of the model. Nevertheless, the scenario project studies did provide valuable knowledge and raised several important questions for further research. (*pers. comm. Olsvig-Whittaker et al., 1999*)

1.4.2. Vegetation survey

One of the components of the scenario project was to describe the different vegetation types at En Afeq and to analyse the main driving factors for the differentiation in floristic composition. This was carried out by Burgerhart in 1998 and resulted in a total of 23 vegetation clusters, where 17 did originate from the wetland part of the reserve. The main driving factor for differences in plant communities appeared to be moisture of the soil. Also a formation map, showing the most dominant species for the wetland area, was created. Other important findings of this study include the need for complete Israeli syntaxonomy and the following citation: *´The vegetation at En Afeq is not in an equilibrium state at this moment. Due to a lack of grazing pressure, there is a severe thistle encroachment in the Water buffalo area compared with some years ago. A decrease of the amount of thistles and shrubs is expected in the next years due to the growth of the water buffalo herd, and related with this, the grazing pressure´.* The author also suggests some recommendations for further research, including: the use of a Global Positioning System (GPS) to improve the accuracy of measurements and to include soil and water measurements to understand e.g. the distribution of opportunistic species like *Tamarisk spec*. and *Rubus sanquineus*. (*Burgerhart, 1999*)

1.4.3. Grazing

To obtain parameters for a grazing model, as part of the scenario project, Mollema and Pronk (1998) measured the cover of dominant plant species. Also the average altitude for different areas within the reserve was calculated. With this information the influence of grazing and invasion of plant species and plant groups on the species composition was simulated. Important findings were: *´Wet areas had an increase of Tamarisk and Rubus when grazed, where dry areas showed an increase of Perennials under grazing. Biomass of Annuals and Phragmites was kept very low by grazing, due to their relatively high edibility´.*

1.4.4. Tamarisk

As the cause of the rapid Tamarisk spread in the En Afeq Nature reserve was and is unknown, Wubbels (1999) modelled the Tamarisk growth. Models describing the increase in Tamarisk spread were constructed to get a better understanding of the structure of the system and to reveal weaknesses in our knowledge of this system. The models could not be used to investigate possible management solutions to the Tamarisk problem in the reserve. Dynamic environmental conditions should have been included in the model as well as Tamarisk growth processes such as competition. An important recommendation was made: *'stressing the importance of incorporating salt and water dynamics in the models'*.

1.5. Research Questions

From all mentioned above it is obvious that further research and monitoring at En Afeq is very important. Questions from two concerned parties are being dealt with during this thesis and include: (1) the management of En Afeq being part of the Israeli nature and parks authority (NPA) and (2) the European Biodiversity Observation Network (EBONE).

1.5.1. INPA

Since the last vegetation survey in 1998 by Burgerhart various measures have been taken, mainly to create more wetland habitat and counter damaging effects (see table 1.2 and chapter 1.3). The management of En Afeq and the ecologists in the Galilee area are interested in vegetation changes by which the management could be evaluated. There was special interest for the effectiveness of Tamarisk clearings; in particularly if species diversity increased at those locations (see chapter 1.3.3.). Some additional (sub) questions arise from previous research: ´what causes the distribution of the opportunistic species Rubus and Tamarisk´ (see chapter 1.4.2.) and ´was thistle and shrub encroachment at the Water buffalo area reduced´? According to this requested information the following research questions were formulated:

1) **How did the vegetation change in terms of species composition, distribution and habitat structure?**
    a. **What is the spatial pattern in vegetation change observed in the area?**
    b. **Did biodiversity increased in the area?**
    c. **Did an increase of the water buffalo herd cause a decline in thistle and shrubs?**
2) **How is this succession related to management and abiotic conditions?**
3) **Was the management applied successful for the repulsion Tamarisk encroachment?**
    a. **Was species richness affected by the measurements?**
    b. **Did the total Tamarisk coverage area decreased?**

4) What are the environmental drivers for distribution of Tamarisk, Rubus and Phragmites?

Vegetation change will be evaluated by using two monitoring tools, traditional phytosociological mapping and BioHAB, providing information on species composition and distribution and habitat structure. Since the core of this study is to repeat a mapping done in 1998 (see chapter 1.4.2.), a period of 12 years will be evaluated on management and influence of abiotic factors.

Chapter 2 gives an overview of the methods used, where chapter 3 will present and discuss the results of the phytosociological research and chapter 4 will deal with the BioHAB survey. Chapter 5.1 will summarize the findings and answer the research question.

1.5.2. EBONE

This study originates from the EBONE request to asses the usefulness and efficiency of EBONE structural mapping methods in comparison with traditional phytosociological mapping in monitoring vegetation change. The followed procedure to asses this is described in chapter 2.4 and results will be presented and discussed in chapter 5.2.

2. Materials and Methods

Fieldwork was conducted from 10 May till 16 July at the En Afeq Nature Reserve followed by data analysis at the Rashud Teva headquarters in Jerusalem till the 3rd of September.

2.1. Site conditions

As the fieldwork was conducted in the summer temperatures averaged around 30 degrees with no rainfall being observed during the whole period (see also chapter 1.2.3.). Since 2005 the Nature Reserve is in severe drought due to limited amounts of rainfall in the fall and winter. This was observed by the moisture status of several temporal pools in the Reserve, which did run dry during the fieldwork. The vegetation flourished during the fieldwork; the summer is the blooming period for wetland vegetation. At the end of June some land near the *Water buffalo area* was completely cleared, followed by archaeological investigation to establish a large pond in the of the summer. A good preview of the reserve appearance and surroundings during my stay are the photographs in appendix 6.

2.2. Phytosociology

2.2.1. Fieldwork

To re-map the area and compare species composition between 1998 and 2010, relevés were relocated using the sample map of Burgerhart and the accompanying description (see Appendix 5 for sampling maps). The location of the relevé was then set with a waterproof GPS device (Magellan, meridian platinum) with an accuracy of 2 meters.
The average relevé size is 25 m^2 and square shaped. A number of relevés have an aberrant size, e.g. 6*3 meter, which was usually caused by impenetrable vegetation or, the appearance of pools on the original relevés and the shape of the vegetation zone.

For each plant species in the relevés the coverage was estimated using the Braun-Blanquet scale. This dataset was transformed into an ordinal scale. (*Barkman et* *al., 1964; Maarel, 1979*) Cover estimations at a class limit were classified in a higher class. See table 2.1 for the used percentages and ordinal scale.

Scale	No. Indiv.	Cover in %	Ordinale scale
r	1	<5	1
+	2-5	<5	2
1	6-50	<5	3
2m	>50	<5	4
2a	n.a.	5-12.5	5
2b	n.a.	12.5-25	6
3	n.a.	25-50	7
4	n.a.	50-75	8
5	n.a.	75-100	9

Table 2.1: *The Braun--Blanqet scale and the ordinal scale as modified by Barkman, Doing & Segal (n.a. = not applicable)13*

Plant species were determined using Zohary (1976) and Israeli flora sites (*HUJI, 2010 and WILDFLOWERS, 2010*). Questionable plant species were identified using expert knowledge. (*Walczak, 2010; x, 2010*) Tamarisk species were only indentified at genus level, because extensive expert knowledge is needed to distinguish the several Tamarisk species present at En Afeq. (*Wubbels, 1999*)

To analyse the relevés on environmental drivers, the same parameters Burgerhart used for his study were recorded for each relevé; (1) moisture condition of the soil, (2) presence of grazing and (3) topographic height. The moisture condition was qualitatively recorded using three classes: dry14, intermediate and wet respectively 1, 2 and 3. The presence of grazing was recorded with a binominal variable: no grazing pressure was given value 0, whereas a value of 1 was acquainted to a relevé with grazing pressure. Topographic height of the relevés location was not changed since 1998; therefore values in mean sea level (MSL) from Burgerhart were copied. (*Burgerhart, 1999*) Besides these parameters, for each relevé the following information was described: (1) the dominant vegetation type or plant species in the surrounding habitat and typical landmarks, (2) extra comments on the site, (3) intensity of grazing being defined as low, medium and high (respectively 1, 2 and

[13] Adapted from Syllabus PVSE 2009; Field Course Vegetation Science and System Ecology.
[14] Dry must be interpretated as mesic.

3)15, (4) the percentage of coverage per relevé and (5) the structure of the relevé consisting of a description of the dominant species or life form. This information is available on request by the author.

2.2.2. Data analysis

To analyse changes in floristic composition trough time the relevés made in 2010 and in 1998 were treated as one database. This was accomplished by selecting the 54 identical relevés of 1998 out of the original CND file of Burgerhart's study and subsequently adding it to the relevé data of 2010, resulting in 108 samples. All following steps in data analysis make use of this merged dataset in CND format. To each species a six letter name was assigned manually, consisting of the first three letters of the genus name and the first three letters of the species name.

Database adjustments

Before analysis, the database was checked on differences in identification and naming between 1998 and 2010 and between relevés of the same year. Some plants changed from Latin name: so did *Atriplex hastata* and *Paspalum paspalodus* changed in respectively *Atriplex prostrate* and *Paspalum distichum*. *Polygonum equisitiforme* was not recognized by Burgerhart, but was found extensively in this present study. The polygonum species *Polygonum equisitiforme* and *Polygonum arenastrum* are very alike which make determination errors in Burgerhart's and this study likely. For this reason the two species were combined at genus level; *Polygonum spec*.

Malva nicaeensis and *Lavatera cretica* were put together as Malva+Lavatera (MALLAV), because of identification problems in 2010. This is justified by the fact that they occupy the same habitat. In the combined 1998 and 2010 dataset *Malva nicaeensis* is however in 90% of MALLAV identification identified positively.

Rumex pulcher, *Rumex conglomeratus* and *Rumex dentatus* were all put together in *Rumex spec*. This was done because of uncertainty in identification, the possibility of hybridization between *Rumex conglomeratus* and *Rumex pulcher*. (*Stace et al., 2011*) and the fact that they all appear in more or less humid environments.

[15] Grazing classes (1) Low: only wild tracks present. (2) Medium: wild tracks and dung present. (3) High: Wild tracks, dung and clear sings of herbivory present.

Classification

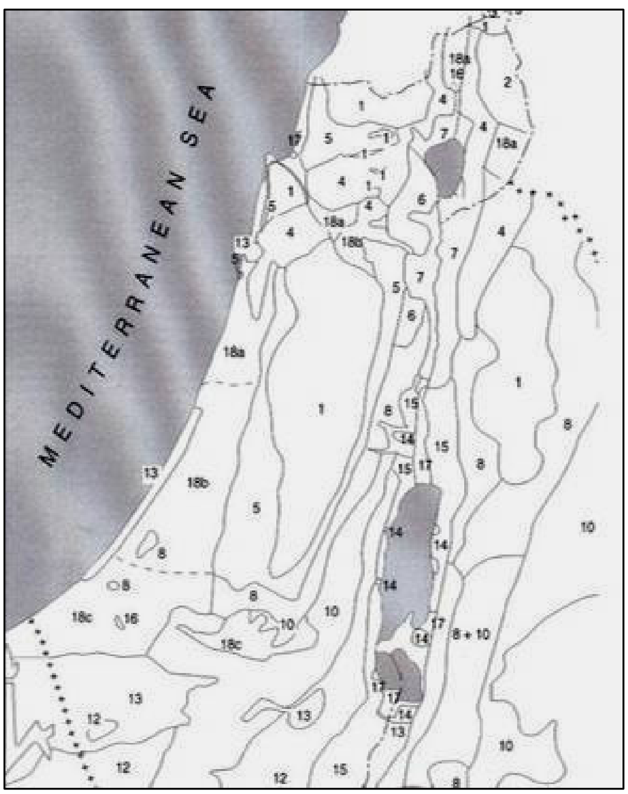
The upgraded database, consisting of 108 relevés and 138 species, was clustered using TWINSPAN (*Hill, 1979*), a FORTRAN for Two-Way Indicator SPecies Analysis. The program makes a classification of both samples and species. The program WinTWINS 3.2 was used to execute the TWINSPAN algorithm. The analysis was performed with 9 cut levels and *Tamarisk spec*., *Poa inferma* and *Polygonum spec.* were identified as non indicator species. In this study Tamarisk species is mainly considered as an invasive species, persisting once they invade an area, relatively independent of changes in abiotic conditions. As this research is focussed on changes in plant communities, instead of looking at the present vegetation communities, Tamarisk was considered to be a driver for changes instead of being a diagnostic species for classification. This will be discussed in more detail in chapter 3.2.1. As determination of *Poa inferma* and *Polygonum spec.* was uncertain they were considered to be of non-diagnostic value for classification.

The output of TWINSPAN-analyses has manually been translated into a combined synoptic and differential species table. Presence value, defined as the presence of a species in a given cluster, was calculated by dividing the sum of species prevalence's in the cluster by the number of records in the cluster multiplied by 100. The characteristic cover of each species was calculated by dividing the sum of species coverage's by the number of relevés where the species is really present.

Clusters of species were identified first by applying four levels of division to limit the number of clusters. On bases of the differential species in the synoptic table some clusters at the third division level were manually combined to obtain a limited number of really distinctive clusters of species. The synoptic table with differential species, together with the in formation obtained from fieldwork as described in chapter 2.2.1, was used to describe the different clusters.

Syntaxonomic classification

Today 19 different principal plant communities are distinguished for Israel and are listed in figure 2.1. The vegetation at the En Afeq reserve is almost completely hydrophytic and reflected in plant communities 16 and 17, respectively “Swamps and reed thickets” and “Wet Salins”. As the environment of En Afeq is being artificial and dependent of human intervention, “Synantropic” vegetation types are also found. (*Danin, 2010*) The hydrophytic plant communities are further classified by work of Zohary (1973) following the descriptive technique of the Zurich-Montpellier school. (*Shimwell, 1971*) Clusters of species are classified according to both the syntaxonomical describtion of Danin (2010) and Zohary (1973). Since a complete and detailed overview of Israeli plant communities is missing, is was not possible to link all the clusters to known syntaxonomical elements. See chapter 3.2.1 for a more elaborate discussion of this problem.



1. Maquis and forests
2. Quercus calliprinos woodlands on basalt
3. Montane forest of Mt. Hermon
4. Open forest of Quercus ithaburensis
5. Open forests of Ceratonia siliqua and Pistacia lentiscus
6. Ziziphus lotus with herbaceous vegetation
7. Mediterranean savannoid vegetation
8. Semi-steppe batha
9. Tragacanth vegetation of Mt. Hermon
10. Shrub steppes
11. Shrub-steppes with trees
12. Desert vegetation
13. Sand vegetation
14. Oases with Sudanian trees
15. Desert savannoid vegetation
16. Swamps and reed thickets
17. Wet salinas
18. Synanthropic vegetation
19. Mangroves

Figure 2.1 Spatial distribution of principal vegetation unities present of Israel. Numbers 1-19 on the map correspond with the numbers mentioned in the text on the right site.

Twelve groups, on the class level, are distinguished for the Middle East. What is known from historical and present floristic data of the En Afeq reserve it could be concluded that only four classes are or have been present at the En Afeq Reserve. A complete overview of all the hydrophytic communities present at the Middle East as described by Zohary is being found Burgerhart's thesis, 1999.

I. POTAMETEA Klika in Klika et Novák 1941

Communities of fresh-water radicant submerged and floating macrophytes. Characteristic species in this class are *Potamogeton spp*., *Ranunculus spp*., *Nuphar luteum*, *Nymphea alba*, *N. lotus*, *N. caerulea*, *Nelumbo speciosum*, *Myriophyllum spicatum*, *Limnanthemum indicum*, *Trapa natans*, *Callitriche spp*. and others. Zohary proposed the following subdivision for Israel and Jordan. (*Zohary, 1962*):

1) *Nuphar luteum–Ceratophyllum demersum* ASSOCIATION
2) *Potamogeton lucens–Myriophyllum spicatum* ASSOCIATION
3) POTAMOGETONETUM PECTINATI
4) POTAMOGETONETUM FLUITANTIS
5) LEMNETUM MINORIS

Each association is represented by just one or two species.

II. PHRAGMITO-MAGNOCARICETEA Klika in Klika et Novák 1941. 16

[**PHRAGMITETEA** R. Tüxen et Preising 1942]

Swamp and fen vegetation dominated by graminoids, sedges and dicotyledonous herbs, often species poor with patchy mosaic, on mineral or peaty substrates in open water transitions and along river and stream sides.

The following subdivision, of four alliances, for Israel and Jordan has been proposed by Zohary (1962).

A. PHRAGMITON MEDITERRANEUM ORIENTALE

1) *Cyperus papyrus-Polygonum acuminatum* ASSOCATION

[16] Mucina (1997) has classified the "**NASTURTIETEA OFFICINALIS** Zohary 1973" within this class

2) SCIRPETO-PHRAGMITETUM
3) POLYGONETUM-SPARGANIETUM NEGLECTI
4) PANICETUM REPENTIS
5) CYPERETUM ALOPECUROIDIS

B. RUBION SANCTI

1) *Rubus sanctus-Lythrum salicaria* ASSOCATION
2) DORYCNIETUM RECTI

C. INULION VISCOSAE

1) INULETUM VISCOSAE
2) JUNCETUM ACUTI
3) CYPERETUM PYGMAEI
4) LIPPSETO-TRIFOLIETUM FRAGIFERI

D. VERONICION ANAGALLIDIS

1) HYDROCOTYLETUM RANUNCULOIDIS
2) *Veronica anagallis-Nasturtium officinale* ASSOCATION

III. CRYPSIDETEA MINUARTIOIDIS Zohary 1982

This class compromises plant communities from winter inundates sites drying up in the summer. Characteristics plants are *Crypsis minuartoides*, *C. faktorovskyi*, *C. aculeate*, *Heliotropium supinum*, *Glinus lotoides*, *Corrigiola littoralis*, *Scirpus cernuus*, *Cyperus pygmaeus, Chrozophora plicata* and many others,

IV. NERIO-TAMARICETEA Braun Blanquet et O. de Bolòs 1958

[**POPULETEA** sensus Zohary 1962]

Mediterranean riparian gallery woods and related shrub compromising the following characteristic species *Salix spp*., *Tamarisk spp*., *Nerium oleander*, *Populus pubescens*, *P. euphratica*, *Platanus orientalis*, *Elaeagnus hortensis*, *E. angustifolius* and others,

Ordination

To get a general idea about the species composition a Detrended Correspondence Analysis (DCA), an indirect ordination technique, was applied on all samples. (*Ter Braak and Šmilauer, 2002*) As this analysis was to explore the data no environmental variables were used. So the variation in the diagram is described only by the species composition. According to the results of classification envelopes were drawn around each cluster. To explore which environmental factors drive the changes in clusters, a DCA was performed using the cluster centroids, an average sample of each cluster. Both axis of the DCA were afterwards tested, with linear regression, against the following environmental drivers: *Moisture*, *Grazing* and *Tamarisk*. The variable that explains most of the variation was used to order the clusters in a gradient

Vegetation composition changes

A number of techniques and methods were used to analyse the data on changes in vegetation composition. First, on basis of the TWINSPAN produced and manually described clusters, a cross table was constructed showing the change for each relevé between 1998 and 2010. The magnitude of change per relevé was recorded using the following rules.

When of a certain relevé both 1998 and 2010 sample was present in the same cluster, the relevé was considered to have not changed. When a relevé changed 1 cluster position from 1998 to 2010, a slight change was indicated. A relevé was assigned a moderate change when a difference of two clusters was observed. When three or more cluster steps were present, the relevé was considered to show a strong change. The nature of change was related to the main gradient that appeared from the DCA with cluster centroids and environmental factors. This means that a change could have two directions, e.g. 'dryer' or 'wetter'.

To analyse differences in a more objective way, the DCA output with all the samples and without variables was used. To start with a paired t-test was carried out to determine if the 1998 dataset significantly differed from the 2010 dataset. From the values of the 1st and 2nd DCA-axis a total DCA-value for each sample was calculated using Pythagoras[17]. The 54 samples of 1998 were subsequently compared to the 54 samples of 2010.

[17] The first two axis are considered to explain most of the variation within a dataset.

The total difference in DCA-value between 1998 and 2010 for each relevé was calculated subtracting the total DCA-values from each other, resulting in a value that gives the relative amount of change for each relevé. This relative value was linked to the coordinates of each relevé and inserted into GIS, resulting in a map with the magnitude of change per relevé in spatial format.

The influence of environmental factors on changes in species composition was analyzed afterwards by means of a regression on the differences in: (1) the combined first and second axis, (2) the first axis and (3) the second axis. Only *Moisture* and *Tamarisk* were used as variables in the regression, there Grazing presence appeared to remain constant between 1998 and 2010 (this will be discussed in chapter 3.2.2). The delta Moisture and Tamarisk values were obtained by subtracting the nominal value of 1998 from the nominal value of 2010 for each relevé. The values of the axis, together with the environmental factor, which explains most of the changes (e.g. variation) will be presented in GIS in the same way as described in the last paragraph.

General spatial patterns of changes in vegetation composition have been studied by separating the Reserve into four more or less different areas. Figure 2.2 show these different areas.

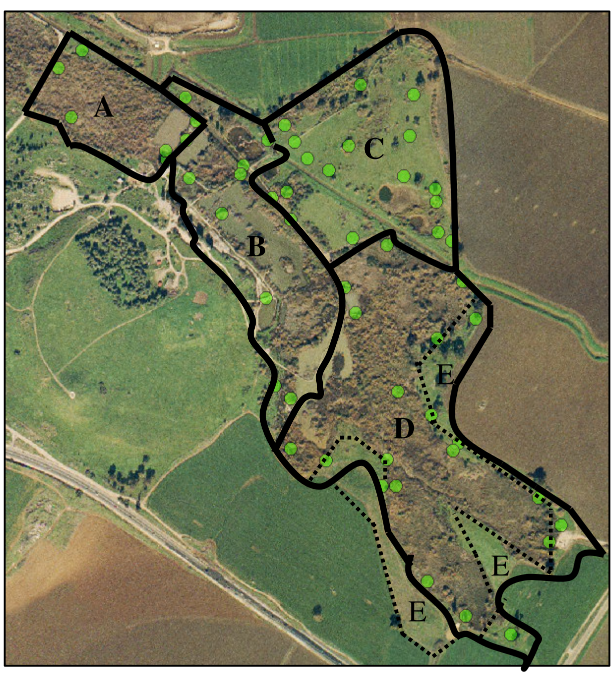


Figure 2.2: Spatial distribution of the relevés visited in 1998 and 2010 and the different areas that were used for analysis. (A) Western Swamp Forest, (B) Central area, (C) Water Buffalo area and (D) Eastern Swamp. The Area indicated with E shows the boundaries that were used by BioHAB analysis.

The following reasoning for separation of the different areas was used: (1) Western Forest Swamp; almost completely covered by a Tamarisk thicket. (2) Central area; active water management, intensive Tamarisk clearance in the past and visitors present. (3) *Water buffalo area*; isolated from the other areas by fences, no visitors in the areas, presence of a water buffalo herd and no active water management. (4) Eastern Swamp; Grazed by cows during spring and summer, except from the western part no active water management and a distinctive thicket of *Rubus sanguineus*, *Phragmites australis* and *Tamarisk spec* in the central part of this area For each area the direction of change per relevé is plotted by separate DCA's. This is presented into biplots.

To see if changes in vegetation composition and the influence of environmental factors had any effect on the species richness between 1998 and 2010, several analyses were performed. Because there is a great amount of fluctuations throughout the years, due to differences in rainfall and temperature, and just two points in time are available, only perennials were taken into account for species richness analysis.[18] This is tested using paired t-tests, using the nominal values of species richness in 1998 and 2010 for the following data: (1) all relevés, (2) and relevés per area, as described in the last paragraph. To determine if possible changes between species richness are driven by changes in environmental factors a one-way ANOVA is performed with the nominal delta Moisture and Tamarisk values against the nominal delta species richness values.

All statistical analysis described above were performed with SPSS 17.0.

Vegetation Mapping

In Burgerhart's study, mapping the vegetation according to the TWINSPAN classification was not possible for a number of reasons mentioned in the thesis of Burgerhart, 1999. This means that a vegetation map of 1998 is missing and no comparison could be made with a possible vegetation map of 2010. For this study it was also not possible to map the area according to the TWINSPAN classification. See the discussion section for an elaborate discussion.

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[18] Perennials are not depended of short term fluctuations and reflect the more long term changes in species richness.

2.3. BioHAB

As mentioned in literature, the BioHAB project major achievement is the "*development of a standardized field recording system for Europe that transcends the need for specialist knowledge. It will be able to provide valid, statistical estimates of habitats and link these with other habitat classifications and biodiversity.*" (*BioHAB, 2005*)

Habitats in BioHAB are defined by structure, in contrast to more conventional methods which rely on floristic information. The General Habitat Categories (GHC's) are the primary structure for recording habitats and are based mainly on plant Life Forms, as described by Raunkiaer, with added detailed information on environment, site, management and species composition. Habitat is in this context defined as:"*An element of land that can be consistently defined spatially in the field in order to define the principal environments in which organism live.*" (*Bunce et al, 2010*)

The elegance and simplicity of this method lays in the fact that only about 15 groups need to be learned, e.g. trees, shrubs and grasses and is applicable on a European scale. Like any other method some disadvantages are included; this will be described and discussed in chapter 5.2.

2.3.1. Fieldwork

"Field procedures have been developed involving a set of rules that enable consistent recording on a single visit and these have been validated in the field. A monitoring handbook has been produced describing the rules and procedures." (*Bunce et al, 2010*)

The rules described in this handbook have been used to divide the Reserve into individual polygons. The actual rules used and deviations made are summarized in the steps shown below[19].

(1) Scanning of the area was performed by use of the most recent ortho-photo (2008) with scale 1:5000.
(2) Mapping of elements in the field, areal, line or point features, were made with a pencil, on transparent overlay sheets placed on the ortho-photo.

[19] For all the rules used see the Handbook for Surveillance and Monitoring Habitats, Vegetation and Selected species.

(3) The data for mapped elements is recorded on standard forms (see appendix 7.)

(4) The Minimum Mappable Element (MME) for an areal element is 100 m2 with minimum dimension of 5 x 20 meter

(5) If the element is smaller than 5 meter it is recorded as a Linear Element with a Minimum Mappable Length (MML of 30 meter.

(6) Elements that do not pass both criteria will be mapped and recorded as Point Elements.

(7) Elements are separated from each other when they fulfill one of the following criteria:

   a. A change in GHC
   b. A change of more than 30% coverage of a GHC
   c. A change in management qualifier e.g. fence line
   d. A change of at least 30% in the cover of an individual species over the whole element

(8) Each element is assigned a three-digit GHC code accompanied with the dominant species within the GHC.

(9) For each element all present Life Forms are recorded, if it has over 10% cover, to further refine the GHC's. Also the dominant species per Life Form is recorded., with a maximum of two per Life Form.

(10) For each element different qualifiers are recorded, the ones used in this study are:

   a. *Environmental qualifiers:* Moisture (Aquatic, Waterlogged, Seasonally, Wet and Mesic) in combination with *Saline medium* is used (codes 1.6 – 4.6)
   b. *Site qualifiers:* Inland water (4.1) Evidence of previous water cover, (4.2) Temporary running water, (4.4) Spring, (4.16) Lake artificial and (4.18) Pond artificial; Elements with woodland or sparse trees (9.4) Swamp woodland
   c. Management qualifiers: level 1 (A) Active management, (B) Recent management, (C) Neglected management and (D) Abandoned management; level 2 (2.7) Regular grazing by (1) water buffalo's and (5) Cows and (3.8) Animal grazing by (40) Wild boars.

2.3.2. Data analysis

The spatial data belonging to the 2010 dataset, obtained by the above described procedure, was inserted into ArcMap Arcview Version 3.2. The different overlays with areal, line and point elements was scanned and georeferenced to the aerial photograph of 2008 on basis of landmarks and cross-roads. Then, the elements were digitized in the form of polygons, lines and points. Polygons and lines were created by tracing the elements in the georeferenced files. This created two separate shapefiles, one with polygons and one with lines. The point elements, which were recorded with GPS in the field, have been inserted using the XY-coordinates.

The dataset of Burgerhart, containing 115 relevés with phytosociological data did not match very well with polygons in the 1998 vegetation map (see discussion Burgerhart) and reclassification of this dataset would not be reliable. Instead, the 1998 formation map, based on dominant species, was transformed in a BioHAB habitat map with Life Form dominance. The 1998 vegetation map was scanned and georeferenced. Subsequently the polygons elements were traced resulting in a polygon shapefile.

The descriptive information of each dataset was loaded into Excel and subsequently linked to the spatial data by linking the Excel table to the attribute table in GIS. With this information a habitat map showing the different GHC's per polygon could be created for 1998 and 2010 as well as coverage map of Tamarisk for both years. Changes were quantified by calculating the total area's of each GHC in 1998 and 2010 for the whole reserve and the five subareas as shown in figure 2.1. This spatial data was exported to excel where further analysis was done.

For management purposes a map showing the dominant species per polygon in 2010 was also created.

2.4. Spatial distribution of (opportunistic) species

To answer the fourth research question: 'What are the environmental drivers for distribution of Tamarisk, Rubus and Phragmites'; a subset of the re-sampled relevés is analysed on soil chemistry. As recommended in previous research, soil analysis could elucidate factors that might drive the presence and abundance of species (see chapter 1.4.2.)

2.4.1 Fieldwork

Soil samples were collected in the field by taking a mixture of the first 10 cm from the soil in the centre of a relevé. Soil material was put into sealed jars and placed directly into a refrigerator (4°C), followed by analysis in the lab within 48 hours. Lab analysis included (1) percentage of dry matter (% of total weight), Chlorine in mg/kg and (2) Nitrate (NO_3) in mg/kg. Analysis was done by Bactochem, Hacharach, Israel. For further information please contact H'lil Glazman.[20]

2.4.2. Analysis

To get a general idea about the total species distribution in relation with environmental drivers a DCA with 31 samples, 137 species (without *Tamarisk spec*) and five environmental variables was carried out. The following environmental variables were used: *Tamarisk* (TAM), *Grazing* (GR), *Moisture* (MO), *Nitrate* (NO^3) and *Salinity* (CH)

To investigate the competitive character between *Tamarisk spec, Rubus sanguineus* and *Phragmites australis* the species dataset with *Tamarisk spec* was used. After a DCA was run a generalized additive model (GAM) created multiple response curves for *Tamarisk spec, Rubus sanguineus and Phragmites australis* with the following settings: predictor 1 = 3, predictor 2 = 2, Poisson distribution, maximum value and stepwise selection use AIC.

To quantify the percentage of species distribution being explanation several regressions were used. This was performed for *Tamarisk spec, Rubus sanguineus* and

[20] H'lil Glazman is available by mail: hillel@npa.org.il

Phragmites australis against the following environmental variables: *Moisture* (MO), *Water Buffalo Grazing* (BGR), *Cow Grazing* (CGR), *Nitrate* (NO^3) and S*alinity* (CH). The option 'Curve Estimation' in SPSS was chosen to apply a series of regression models. The model that most significant fitted the data was chosen.

2.5. Assessment of BioHAB

2.5.1. Qualitative assessment

BioHAB was qualitatively compared with Classic Phytosociology (PS) on basis of field experience resulted from the surveys as described in this thesis. The following aspect will be discussed as they are considered to be valuable for management questions or evaluations linked to monitoring: (1) Time, (2) Knowledge, (3) Coverage, (4) Rules, (5) Biodiversity and (6) Classification.[21]

(1)Time: The time it takes to carry out fieldwork, process and interpretate the data.
(2)Knowledge: The (state-of-art) knowledge that is needed to carry out fieldwork and perform data analysis
(3)Coverage: The area surface that is described and covered by the methodology; is each habitat represented in the data by sufficient samples?
(4)Rules: The objectiveness of the rules used during the fieldwork and in the analysis.
(5)Biodiversity: The amount of the biodiversity present that is described (α, β or both)
(6)Classification: The applicability of the classification system used.

2.5.2. Quantitative assessment

BioHAB was quantitatively compared with PS by means of a test of independence in the form of an extended chi-square using Excel. Comparison was possible by linking a GHC to each relevé. This was done in ArcView by superpositioning the relevés on the BioHAB habitat map. To match the number of GHC categories, the third division level of the TWINSPAN classification table was chosen.

[21] As considered by the author of this thesis.

3. Phytosociology

3.1. Results

3.1.1. Fieldwork

From the 115 relevés described by Burgerhart only 54 relevés were relocated, assessable or still covered with vegetation. This was caused by an inaccurate description of relevés, removal of landmarks, clearance of former sites and the transformation of terrestrial habitat into pools and ponds. This was particularly true for the *Eastern swamp area* and the *Western swamp forest* (see figure 2.1). The relocated relevés are indicated with green dots in figure 3.1 (and appendix 5.1).

Figure 3.1: Relocated relevés in the Reserve. Green dots indicate the location of the relevés.

3.1.2. Floristic notes

In total 152 plant species were identified during the phytosociological survey, BioHAB analysis and additional field trips (see appendix 2.1). Three Redlist species were found; a few specimens of *Persicaria lanigera* around the Sophia Pool, a lot of *Salsola soda* at the periphery of the reserve and some *Rosa phoenicea* in the *Central ar*ea and *Eastern periphery*. The following rare plants were found at the reserve: *Asparagus palaestinus*, *Bromus brachystachys, Festuca arundinacea,* Kickxia spuria, *Limonium narbonense, Lotus tenuis, Paspalum paspalodus, Rumex conglomeratus, Samolus valerandi and* Scirpus litoralis. Appendix 1.4 shows the spatial distribution of Redlist and rare species at the En Afeq reserve.

3.1.3. Vegetation types

Classification

After classification, the complete dataset of 108 relevés resulted in the cluster division shown in table 3.1. The synoptic table including all species is visualized in Appendix 3. The cluster division follows the arrangement of the relevés in the original output, with the exception of clusters 4, 5 and 6. Instead of being separate clusters they have been merged to one cluster (4) and subsequently designated as sub-communities within the new merged cluster.

Cluster	1	2	3	4a	4b	4c	5	6	7	8	9
# Relevés	1	8	16	18	18	11	12	4	6	8	6
Euphorbia valerianifolia	-	3^{2}	-	-	-	-	-	-	-	-	1^{1}
Polypogon monspeliensis	-	4^{4}	3^{3}	-	-	-	-	-	-	-	1^{2}
Pulicaria dysenterica	-	1^{1}	5^{4}	2^{2}	-	-	-	-	-	-	-
Samolus valerandi	-	-	4^{5}	-	-	-	-	-	-	-	-
Aster subulatus	-	2^{2}	4^{3}	2^{3}	1^{2}	1^{1}	-	2^{2}	-	1^{1}	-
Lythrum salicaria	-	2^{1}	4^{4}	4^{4}	2^{2}	1^{5}	-	-	-	-	-
Cynanchum acutum	-	1^{1}	3^{3}	4^{2}	5^{5}	4^{4}	3^{3}	4^{4}	-	1^{1}	1^{2}
Rubus sanguineus	-	-	3^{5}	5^{7}	5^{8}	5^{7}	5^{4}	4^{2}	-	-	1^{2}
Galium aparine	-	1^{1}	-	2^{3}	2^{4}	1^{2}	4^{4}	-	-	-	1^{2}
Cephelaria joppensis	-	-	-	1^{4}	2^{3}	2^{2}	4^{4}	2^{2}	1^{1}	-	1^{2}
Solanum villosum	-	-	1^{2}	-	-	1^{2}	-	3^{2}	-	-	-
Torilis arvensis	$+^{1}$	-	1^{3}	2^{4}	2^{3}	1^{4}	1^{2}	5^{6}	1^{2}	-	2^{2}
MALLAV*	-	-	-	1^{1}	-	-	2^{2}	4^{2}	4^{2}	4^{1}	-
Silybum marianum	-	-	-	-	1^{2}	-	3^{2}	5^{4}	5^{4}	5^{3}	3^{1}
Avena sterilis	$+^{1}$	1^{2}	-	-	-	1^{2}	3^{5}	4^{4}	5^{6}	4^{4}	5^{4}
Scolymus maculatus	-	-	1^{1}	1^{1}	-	1^{2}	3^{1}	3^{2}	5^{3}	4^{2}	5^{2}
Hordeum bulbosum	-	1^{2}	-	1^{2}	-	1^{2}	2^{3}	-	4^{5}	4^{4}	3^{3}
Brassica nigra	-	-	-	1^{2}	-	1^{5}	1^{4}	-	4^{5}	2^{4}	-
Carthamus argentatus	-	-	-	1^{2}	-	-	1^{2}	-	3^{1}	1^{5}	1^{2}
Cichorium pumilum	-	-	-	-	-	1^{1}	1^{1}	-	5^{2}	3^{2}	3^{2}
Rapistrum rugosum	-	-	1^{1}	-	-	-	-	2^{3}	1^{2}	5^{4}	2^{1}
Centaurea Ibericum	-	1^{1}	-	-	-	-	1^{1}	-	-	5^{5}	5^{1}
Daucus carota	-	-	-	-	-	-	1^{1}	2^{2}	2^{5}	4^{4}	4^{2}
Lolium rigidum	-	-	-	1^{2}	-	-	-	-	-	5^{3}	5^{2}
Phalaris paretaria	-	1^{2}	-	-	-	-	1^{1}	-	-	-	4^{6}

Table 3.1: Differential species of the eleven cluster from the classified En Afeq dataset

The major, and first, division is seen between clusters 1-4c (72 relevés) and 5-9 (36 relevés) and is mainly differentiated by on the one side *Lythrum salicaria* and *Aster subulatus* and on the other side by *Sylibum marianum*, *Avena sterilis*, Scolymus *maculatus*, *Malva/Lavatera* and *Hordeum bulbosum*.[22] The first group of clusters harbours relative wet relevés and the second group of clusters are relative dry relevés.

Communities 5 and 6 are transitional between both main groups sharing their differential species. Communities 1-3 are related to relative high moisture contents. On the wet side community 1 is negatively differentiated by the absence of differential species. Community 2 is differentiated by *Euphorbia valerianifolia*. Community 3, characterised by *Samolus valerandi*, *Pulicaria dysenterica* and *Aster subulatus,* is transitional between communities 2 and 4, sharing respectively *Polypogon monspeliensis* and *Lythrum salicaria*, *Cynanchum acutum* and *Rubus sanguineus*. Community 4, from intermediate moisture conditions, is mainly characterised by the last two species and misses further differential species. Communities 7-9 are characterised by the high presence of *Cichorium pumilum* and *Hordeum Bulbosum*. Community 7 is differentiated by *Brassica nigra* and *Carthamus argentatus*, Community 8 by *Rapistrum rugosum* and community 9 by *Phalaris paretaria*. *Centaurium ibericum*, *Daucus carota* and *Lolium rigidum* are common differentials for communities 8 and 9, whereas Malva/Lavatera is shared by 7 and 8. The following plant communities were distinguished:

<u>Cluster 1: Relevé with *Nasturtium officinalis* and *Chenopodium murales*</u>

No. Relevés: 1

Moisture indication: 3

Grazing presence: No

Species present: *Chenopodium murales, Nasturtium officinalis, Lotus palustris, Polypogon virales, Paspalodus, distichum, Amaranthus cruentis, Ammi visnaga, Phragmites australis, Mercurialis annua, Sinapis alba, Torilis arvensis, Avena sterilis*

Differential species: Only one relevé is present in this cluster, so no differential species have been selected. This relevé is characterised by the dominance of

[22] According to the separate different divisions as shown by 000000111111 in the Twinspan table (see appendix 3.1)

Nasturtium officinalis. No unique species have been found compared to the other relevés.

Cluster 2: Community of *Scirpus maritimus* with *Tamarisk spec*., *Polypogon monspeliensis* and *Euphorbia valerianifolia*

No. Relevés: 8

Moisture indication: 2.38

Grazing presence: 0.75

Tamarisk abundance: 4.25

Constant Species: *Tamarisk spec., Polypogon monspeliensis, Scirpus maritimus, Inula viscosa*

Differential species: *Euphorbia valerianifolia, Polypogon monspeliensis (together with cluster 3).*

Cluster 3: Community of *Pulicaria dysenterica* and *Inula viscosa*

No. Relevés: 16

Moisture indication: 2.50

Grazing presence: 0.19

Tamarisk abundance: 4.50

Constant Species: *Tamarisk spec., Pulicaria dysenterica, Samolus valerandi, Aster Subulatus, Lythrum salicaria, Inula viscosa, Phragmites australis*

Differential species: *Pulicaria dysenterica, Samolus valerandi, Aster subulatus Polypogon monspeliensis* (together with cluster 2), *Lythrum salicaria* (together with cluster 4) and *Cynanchum acutum* (together with clusters 4a-6)

Cluster 4: Community of *Rubus sanguineus* with *Phragmites australis* and *Cynanchum acutum*

This cluster is characterized by a high presence value and characteristic cover of *Rubus sanguineus*, between 25-50% coverage. Furthermore this cluster is differentiated from all other cluster by *Rubus sanguineus* and *Cynanchum acutum* (together with clusters 3 and 5-6). This cluster is divided into the following sub-communities.

Cluster 4a: Sub-community with *Inula viscosa* and *Lythrum salicaria*

No. Relevés: 18

Moisture indication: 2.00

Grazing presence: 0.50

Tamarisk abundance: 2.28

Constant Species: *Lythrum salicaria, Inula viscose, Cynanchum acutum, Phragmites australis, Rubus sanguineus*

Differential species: Within community 4, this sub-community is differentiated by *Inula viscosa* and *Lythrum salicaria*. The latter (together with cluster 3) differentiate this cluster also from all other clusters.

Cluster 4b: Sub-community of *Rubus sanguineus* and *Phragmites australis*

No. Relevés: 18

Moisture indication: 2.00

Grazing presence: 0.67

Tamarisk abundance: 2.22

Constant Species: *Cynanchum acutum, Phragmites australis, Rubus sanguineus*

Differential species: No differential species against between the other sub-communities in cluster 4 has been found. However the co-dominance of *Rubus sanguineus* and *Phragmites australis* with *Cynanchum acutum* and the absence of any other dominant species is striking for this community.

Cluster 4c: Sub-community with Scirpus maritimus

No. Relevés: 11

Moisture indication: 1.91

Grazing presence: 0.64

Tamarisk abundance: 0.27

Constant Species: *Scirpus maritimus, Cynanchum acutum, Phragmites australis, Rubus sanguineus*

Differential species: No differential species between the other sub-communities in cluster 4 has been found. The combination of a relative high presence value and characteristic cover of *Scirpus maritimus* and low presence value and characteristic cover of *Inula viscosa* separate this cluster from the other sub-clusters.

Cluster 5: Community of *Prosopis farcta* and *Rubus sanguineus*

No. Relevés: 12

Moisture indication: 1.45

Grazing presence: 0.67

Tamarisk abundance: 0.00

Constant Species: *Rubus sanguineus, Galium aparine, Cephelaria joppensis, Prosopis farcta, Sinapis alba*

Differential species: *Galium aparine* and *Cephelaria* joppensis, *Rubus sanguineus* (together with clusters 3-4c and 6) *Sylibum marianum* and *Avena sterilis* (both together with clusters 6-9) differentiate this cluster from all other clusters.

Cluster 6: Community of *Sinapis alba* and *Torilis arvensis*

No. Relevés: 4

Moisture indication: 1.25

Grazing presence: 0.50

Tamarisk abundance: 1.50

Constant Species: *Cynanchum acutum, Rubus sanguineus, Sinapis alba, Torilis arvensis, MALLAV*, Sylibum marianum, Avena sterilis*

Differential species: *Torilis arvensis, Rubus sanguineus* (together with clusters 3-5) MALLAV (together with cluster 7-8), *Sylibum marianum* and *Avena sterilis* (both together with clusters 5 and 7-9) differentiate this cluster from all other clusters.

Cluster 7: Community of *Avena sterilis* and *Prosopis farcta*

No. Relevés: 6

Moisture indication: 1.17

Grazing presence: 1.00

Tamarisk abundance: 0.00

Constant Species: *Prosopis farcta, MALLAV*, Sylibum marianum, Avena sterilis, Hordeum bulbosum, Brassica nigra, Cichorium pumilum, Scolymus maculatus*

Differential species: Brassica nigra, Carduus argentatus, MALLAV (together with clusters 6 and 8), *Sylibum marianum*, *Avena sterilis* (both together with clusters 5-6 and 8-9), *Hordeum bulbosum* and *Cichorium pumilum* (both together with cluster 8-9)

Cluster 8: Community of *Centaurea iberica*, *Prosopis farcta* and *Rapistrum rugosum*

No. Relevés: 8

Moisture indication: 1.00

Grazing presence: 1.00

Tamarisk abundance: 0.13

Constant Species: *Prosopis farcta, MALLAV*, Sinapis alba, Sylibum marianum, Avena sterilis, Hordeum bulbosum, Scolymus maculates, Rapistrum rugosum, Centaurea iberica, Daucus carota, Lolium rigidum, Rumex spec.*

Differential species: *Rapistrum rugosum*, MALLAV (together with clusters 6 and 7), *Sylibum marianum*, *Avena sterilis* (both together with clusters 5-7 and 9), Hordeum bulbosum, *Cichorium pumilum* (both together with cluster 7 and 9), Scolymus *maculatus*, *Centaurea iberica, Daucus carote* and *Lolium rigidum* (all together with cluster 9) differentiate this cluster from all others.

Cluster 9: Community of *Rumex spec* and *Scirpus maritimus*

No. Relevés: 6

Moisture indication: 1.20

Grazing presence: 1.00

Tamarisk abundance: 3.00

Constant Species: *Avena sterilis, Hordeum bulbosum, Scolymus maculates, Bromus brachystachys, Centaurea iberica, Daucus carota, Lolium rigidum, Rumex spec., Phalaris paradoxa*

Differential species: *Phalaris paradoxa*, *Sylibum marianum*, *Avena sterilis* (latter two together with clusters 5-8), Hordeum bulbosum, *Cichorium pumilum* (both together with cluster 7 and 8), Scolymus *maculatus*, *Centaurea iberica, Daucus carote* and *Lolium rigidum* (all together with cluster 8) differentiate this cluster from all others.

Ordination

Figure 3.2 shows the DCA output of all the 108 samples from both 1998 and 2010. Plant communities distinguished in the TWINSPAN table are enveloped. The ordination diagram indicates that the subcommunities (clusters 4A-4C) of cluster 4, the community of Rubus sanguineus with Phragmites australis and Cynanchum acutum are very similar in species composition. The relevé with *Nasturtium officinalis* and *Chenopodium murales*, the community of *Scirpus maritimus* with *Tamarisk spec*. and the community of *Pulicaria dysenterica* and *Inula viscosa* are clearly separated.

The clusters are clearly arranged along a hydrological gradient, indicated by the envelope colours and the corresponding moisture indication number[23]. The wet clusters; 1, 2 and 3, respectively (1) the relevé with *Nasturtium officinalis* and *Chenopodium murales,* (2) Community of *Scirpus maritimus* with *Tamarisk spec*., *Polypogon monspeliensis* and *Euphorbia valerianifolia* and (3) Cluster 3: Community of *Pulicaria dysenterica* and *Inula viscosa*, are positioned on the right hand side of the diagram. Typical dry cluster like 7 and 8, respectively the community of *Avena sterilis* and *Prosopis farcta* and the community of *Centaurea iberica*, *Prosopis farcta* and *Rapistrum rugosum*, are located on the far left hand side of the diagram.

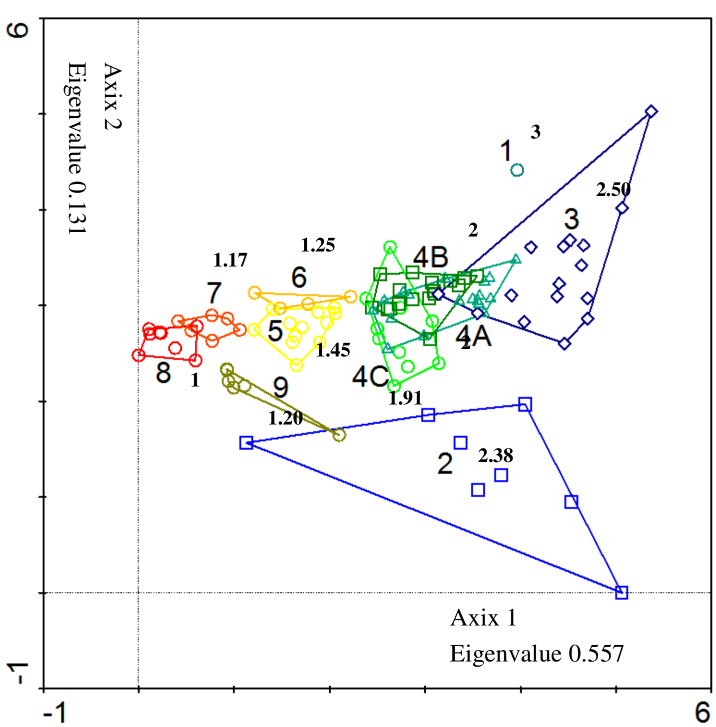

Figure 3.2: DCA ordination diagram (first two axes) of all relevés 1998-2010. Plant communities distinguished are outlined and correspond with the TWINSPAN clusters described in chapter 3.1.1. The clusters are assigned a colour according to their moisture indication: from a high to a low value respectively from blue to red. The average moisture condition of each community is depicted in sub- and superscript.

[23] The average moisture condition of a community, as defined in chapter 2.2.1

Cluster centroids

Figure 3.3 shows the DCA ordination of the 10 cluster centroids. Cluster 1 is not included as it only contains one relevé. A number of clusters are clearly separated from each other (e.g. cluster 5, 6 and 3), while others tend to aggregate (e.g. 2, 4a, 4b and 4c).

The first two axes explain 33% of the total species variability. Most of the variation being observed in figure 3.3 is linked to first axis (27%) which is strongly correlated to environmental data (r=0.989). This axis showed a negative correlating with *Moisture* (r=-0.97) and *Tamarisk* (r=-0.71) and a positive correlation with *Grazing* (r=0.83). Tamarisk is strongly positively related to Moisture (r-value of 0.70) and consequently both arrows point in the same direction. *Grazing* is negatively correlated with *Moisture* and *Tamarisk* (r-values of respectively -0.73 and -0.50). The second axis has no important relation with the any of the environmental variables.

	Axis 1	**Axis 2**
Moisture	0.92	0.03
Grazing	0.69	0.02
Tamarisk	0.50	0.01

Table 3.2: Coefficients of determination from DCA axis and environmental variables

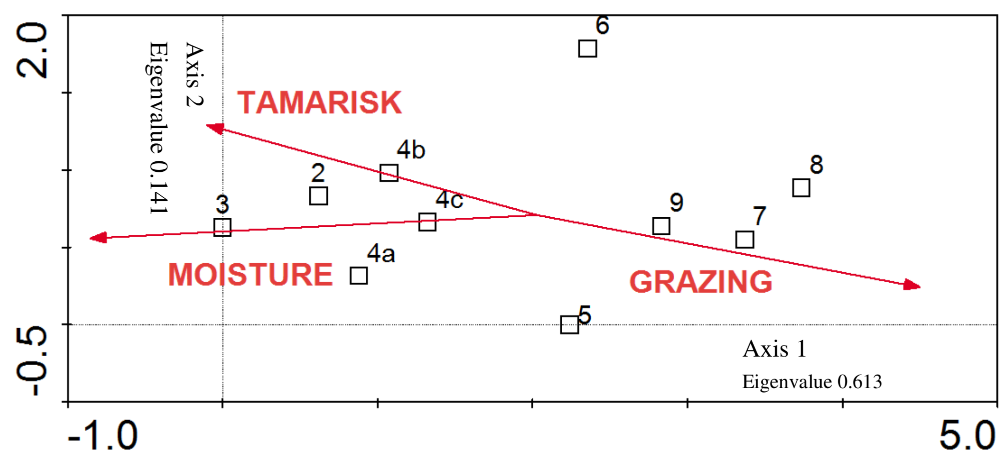

Figure 3.3: DCA ordination diagram (first two axes) of the cluster centroids. The relation between syntaxonomical clusters, moisture, Tamarisk, grazing and the first two axes is indicated by red arrows. Plant communities are described in section 3.1.2.

The communities are ordered along a hydrological gradient as follows:

(1) Relevé with *Nasturtium officinalis* and *Chenopodium murales* [1]

(2) Community of *Pulicaria dysenterica* and *Inula viscosa* [3]

(3) Community of *Scirpus maritimus* with *Tamarisk spec*., *Polypogon monspeliensis* and *Euphorbia valerianifolia* [2]

(4) Community of *Rubus sanguineus* with *Phragmites australis* and *Cynanchum acutum*

- (4a) Sub-community with *Inula viscosa* and *Lythrum salicaria* [4a]
- (4b) Sub-community with co-dominance of *Rubus sanguineus* and *Phragmites australis* [4b]
- (4c) *Sub-community with Scirpus maritimus* [4c]

(5) Community of *Prosopis farcta* and *Rubus sanguineus* [5]

(6) Community of *Sinapis alba* and *Torilis arvensis* [6]

(7) Community of *Rumex spec* and *Scirpus maritimus* [9]

(8) Community of *Avena sterilis* and *Prosopis farcta* [7]

(9) Community of *Centaurea iberica*, *Prosopis farcta* and *Rapistrum rugosum* [8]

3.1.4. Vegetation change

	%	No. relevés		%	No. relevés
No change	**33,3**	18			
Slight increase	29,6	17	*Slight decrease*	5,6	3
Moderate increase	16,7	9	*Moderate decrease*	1,9	1
Strong increase	11,1	6			
Total increase	**59,3**	32	**Total decrease**	**7,4**	4

Table 3.3 Changes in vegetation composition between 1998 and 2010 on basis of the TWINSPAN clusters. As the clusters described in 3.1.1 follow a hydrological gradient from wet to dry, changes in this case are designated to changes in aridity.

The information obtained from chapters 3.1.2 and 3.1.3 is used to describe changes in vegetation. As the clusters described in 3.1.1 follow a hydrological gradient from wet to dry, changes in this case are mainly designated to changes in moisture regime. So changes in clusters are directly related to an increase or decrease in aridity, which is shown by table 3.3. One third of the relevés have not changed, whereas, almost sixty percent of the relevés increased in aridity and hardly ten per cent decreased in aridity. From those relevés that suffered from aridity fifty per cent showed a moderate to strong increase. Only one fifth of the relevés that became wetter showed a moderate decrease.

2010 \ 1998	1	2	3	4a	4b	4c	5	6	7	8	9
1	-	-	-	-	-	-	-	-	-	-	-
2	-	1	1*	-	-	-	-	-	-	-	-
3	-	1	3	$2^{3,4}$	-	-	-	-	-	-	-
4a	-	-	**4**	3^{5}	-	1^{2}	-	-	-	-	-
4b	-	-	**3**	**2**	4	1	-	-	-	-	-
4c	1	-	-	**3**	-	2^{6}	-	-	-	-	-
5	-	-	-	1	1	1	3^{1}	-	-	-	-
6	-	-	-	-	2	-	**2**	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	-	**1**	-	-	-	-	-	-	**5**	1	-
9	-	**3**	-	**1**	-	-	-	-	-	-	1

Table 3.4: Cross table of relevé changes in clusters between 1998 and 2010. Relevés that did not change are depicted in the grey boxes. In superscript the relevés depicted in figure 3.5 are shown.

Table 3.4 shows where major shifts between 1998 and 2010 did occur. Community one (relevé with *Nasturtium officinalis* and *Chenopodium murales*) and seven (community of *Rumex spec* and *Scirpus maritimus)* disappeared, were cluster six (community of *Sinapis alba* and *Torilis arvensis*) was new in 2010. Many relevés in community 2, 3, 4a, 4b and 7 transferred to dryer communities. Striking is that all relevés that did show a decrease in aridity are directly linked to active water management. Figure 3.5 shows the spatial location of relevés that did become wetter.

The results described so far only showed cluster shifts from relevés linked to a hydrological gradient, but the exact magnitude and nature of change and spatial context is not elucidated. Therefore the DCA output as shown in figure 3.2 was used. The delta DCA values for each relevé were loaded into GIS and super positioned above an aerial photograph, as shown in figure 3.4.

Figure 3.4: Magnitude of change in vegetation composition in relevés between 1998 and 2010. Representation of figure 3.1 where differences are calculated using Pythagoras with DCA values of the 1st and 2nd axis and visualized in ArcView.

Magnitude of change in vegetation composition is visualized by the size of bullets, the larger bullet size the higher magnitude of change. Clearly shown is that changes in relevés are various around the reserve, where the magnitude of change is highest in the northern part of the reserve, where the majority of relevés shows a relative large change in vegetation composition. The nature of change when analysing all relevés together was explained by both *Moisture* and *Tamarisk*[24]. *Moisture* did significantly explain 27 % of all the variation present when analysing the axes together, where 35% of the first axis was explained and 10% of the second axis. *Tamarisk* significantly explained 13% of variation in the second axis. There *Moisture* explains a significant proportion of variant in the first axis and the first axis explains by far most of the variation in the dataset (see eigenvalues in figure 3.2), the delta DCA values for the first axis was chosen to represent the magnitude of change in Moisture regime and is visualized in figure 3.5. As this matches with the described changes in clusters previously, which followed a hydrological gradient, it seems appropriate to link the delta DCA values of the first axis to changes in aridity. This will be discussed in chapter 3.2.

Figure 3.5: Magnitude of change in vegetation composition in relevés between 1998 and 2010, correlated to aridity. Red colored bullets indicate an increase in aridity were blue circles indicate a decrease in aridity. Representation of figure 3.1 where differences are calculated using the DCA values of the 1st axis. Delta DCA values are linked to spatial coordinates and is visualized in ArcView. The number that corresponds with the 'blue relevés' is highlighted as superscript in table 3.4.

Obvious from this figure is that the majority of relevés show an increase in aridity; just six relevés tend to become wetter.

Further analyses of spatial patterns revealed that change in vegetation composition was different for the four geographic separated areas (see figure 2.1). Clearly visible in figure 3.6 is the average direction of change per area; no specific direction in the *Central area* and *Western swamp forest*, a clear horizontal direction

[24] Grazing was not included as environmental variable. When recording grazing only as 'present' or 'absent', there is hardly any difference in grazing regime between 1998 and 2010.

for the *Water buffalo area* and a more vertical direction of the *Eastern area*. The nature of this direction of change is very well explained for the *Water buffalo area* where *Moisture* significantly explains 70 per cent of all the variant present at the first two axes. Changes along the first axis in the *Eastern area* are significantly explained very well by both *Moisture* (29 per cent) and *Tamarisk* (53 per cent). For the other areas no significant explanatory factors were found. Table 3.5 summarizes the variance explained for the above described results.

	Moisture			**Tamarisk**		
	1+2 axis	*1 axis*	*2 axis*	*1+2 axis*	*1 axis*	*2 axis*
Total area	0.27[1]	0.35[1]	0.10[3]	-	-	0.13[2]
Water buffalo area	0.70[1]	0.64[2]	0.67[1]	-	-	-
Eastern area	-	0.29[3]	-	-	0.53[2]	-
Central area	-	-	-	-	-	-
Western swamp forest	-	-	-	-	-	-

Table 3.5: Proportion of variation in species composition change of both axis together, and separately by the first and second axis, explained by *Moisture* and *Tamarisk*. Results are obtained by linear regression on the delta *Moisture* or *Tamarisk* value and delta of the DCA axis values of 1998 and 2010. The DCA value of both axes combined was calculated using Pythagoras. Only significant results are shown, with the following p-values: (1) P>0.001, (2) P>0.01, (3) P>0.05

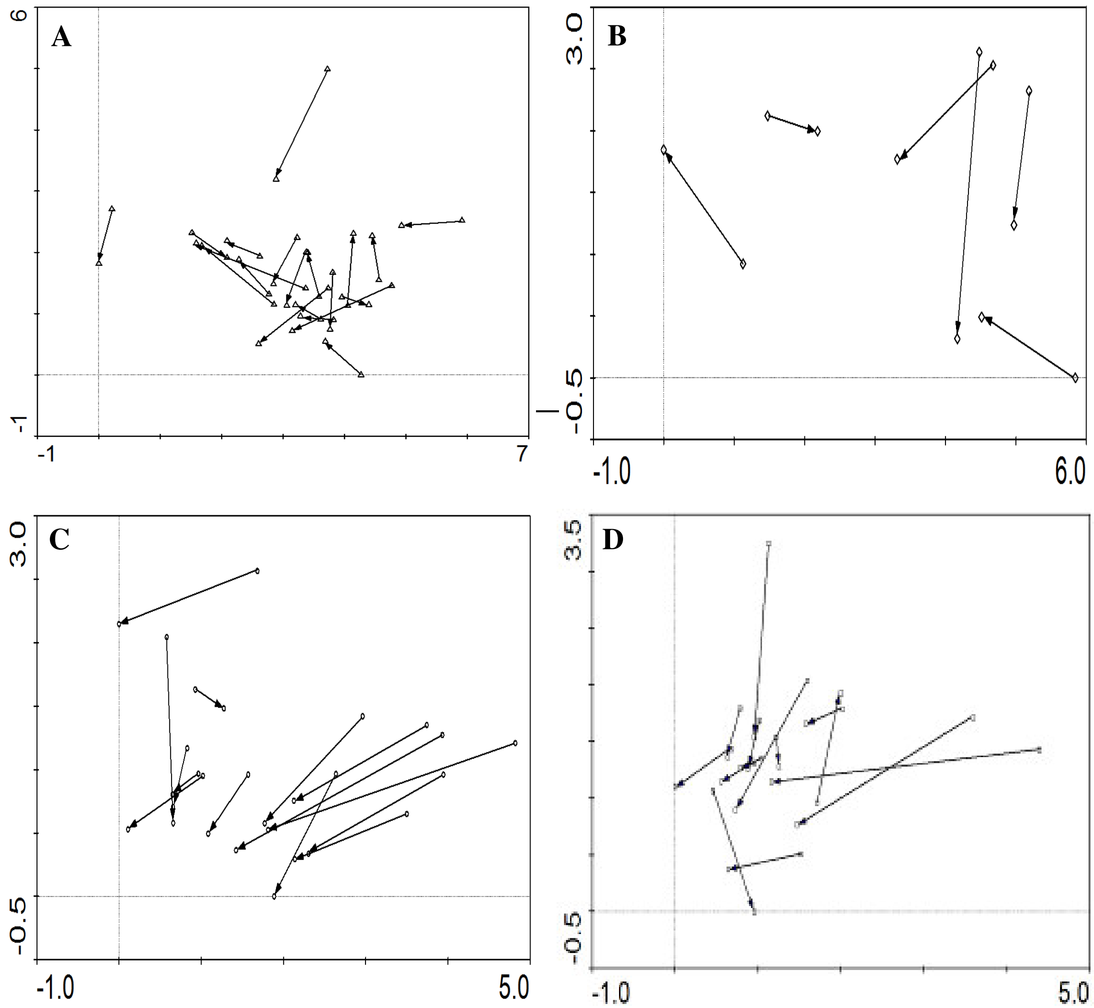

Figure 3.6: Ordination diagrams of the relevés. The direction of change in species composition between 1998 and 2010 is indicated by arrows. All four biplots are representations of figure 3.2, showing the relevés of the following zones: (A) Central area, (B) Western swamp forest, (C) Water buffalo area and (D) Eastern area[25] (see figure 2.1).

No significant differences between species richness of 1998 and 2010 were found when analysing all relevés together and separately per area. Therefore environmental drivers for change could also not be identified. Also species richness did not significantly change in relevés where Tamarisk was cut, for all species and perennials alone.

[25] For BioHAB analyses in chapter 4.2 the *Eastern area* has been divided into the *Eastern swamp* and *Eastern periphery*.

3.1.5. Distribution of (opportunistic) species

Figure 3.7 shows the distribution of the relevés with soil samples along two DCA axes. The first axis explains about 12% of the total species variability, whereas the second axis explains 6%. The first and second axis are respectively strong and moderately correlated with the environmental data (r= 0.891 and 0.680). *Moisture* (r= -0.78), *Grazing* (r= 0.72) *Nitrate* (r= 0.70) are strongly correlated with the first axis. Moisture and Grazing are negatively correlated (r= -0.68), as explained in section 3.1.3; cluster centroids. *Moisture* and *Nitrate* are positively correlated (r= 0.67), i.e. relevés which a relatively dry have a lower nitrate content in the soil than wetter sites. The second axis is correlated with Tamarisk presence (r= 0.13) and Salinity (r= 0.04). Tamarisk and salinity are correlated and mainly independent of grazing, moisture and NO3.

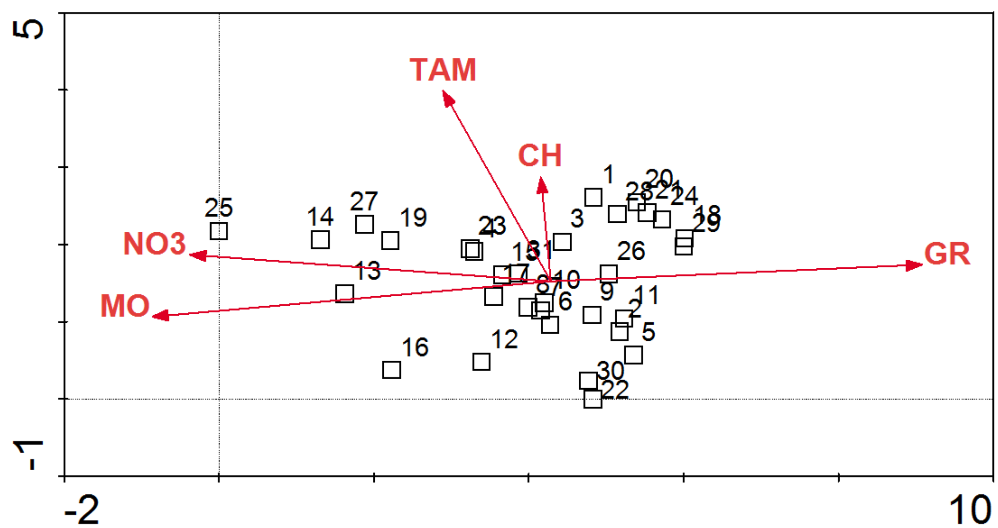

Figure 3.7: DCA ordination diagram (first two axes) of the subset relevés. The relation between relevés, *Moisture* (MO), *Grazing* (GR), *Tamarisk* (TAM), *Nitrate* (NO^3) and *Salinity* (CH) and the first two axes is indicated by red arrows.

Table 3.6 shows the coefficients of determination for the variance in of species composition. *Salinity* (CH) and *Tamarisk* has almost no explanatory value. When separating *Grazing* (GR*)* into *Water Buffalo grazing* (BGR) and *Cow grazing* (CGR) the explanatory value of grazing is seriously reduced for the first axis (r-values:

BGR= 0.34 and CGR= 0.38) and increased for the second axis (r-values: BGR= 0.43 and CGR= -0.36).

	Axis 1	Axis 2
Moisture (MO)	0.61	0.00
Grazing (GR)	0.52	0.02
Salinity (CH)	0.00	0.04
Nitrate (NO^3)	0.49	0.00
Tamarisk (TAM)	0.04	0.13

Table 3.6: Coefficients of determination from DCA axis and environmental variables

As the main variation in species composition (axis 1) is explained by *Moisture*, *Grazing* and *Nitrate* and as the second axis had only very low coefficients of determination, a response curve for *Tamarisk spec.*, *Rubus sanguineus* and *Phragmites australis* was created only for this axis. Figure 3.8A clearly shows that *Rubus sanguineus* and *Phragmites australis* have almost the same response for the first axis, whereas *Tamarisk spec.* could not be included in the model; *"No candidate additive model had AIC value lower than the null model"*. Surprisingly it appeared that the first axis for these two species was mainly correlated to *Salinity*, see figure 3.8B. Both species peak in abundance between 20-60 mg/kg of chloride.

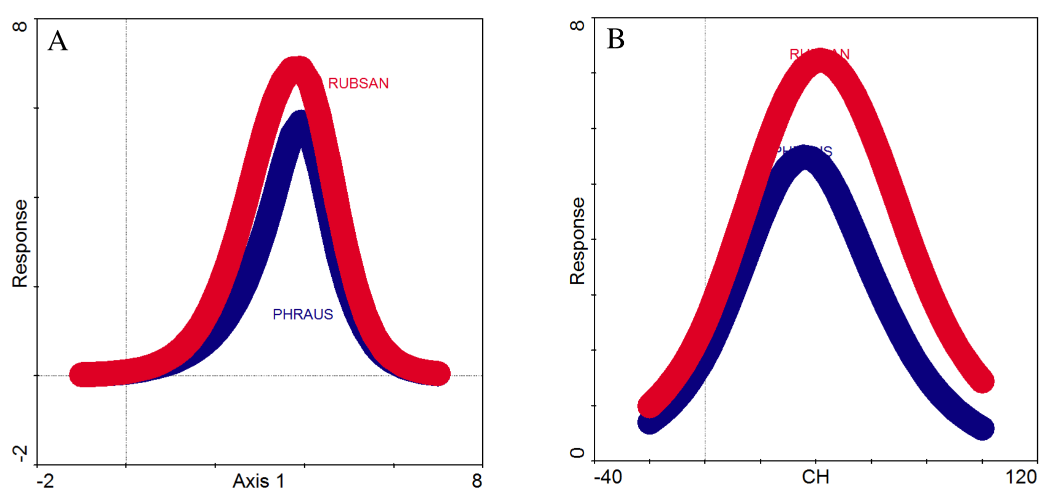

Figure 3.8: Response curves for *Rubus sanguineus* and *Phragmites australis* as created in CanoDraw. Response curves showing on the x-axis: (A) values of the 1st axis and (B) salinity in mg/kg.

This response is validated when observing the regression of *Tamarisk spec.*, *Rubus sanguineus* and *Phragmites australis* against environmental variables, summarized in table 3.7. Distribution of *Phragmites australis* and *Rubus sanguineus* is significantly correlated to soil salinity. The distribution of *Tamarisk spec.* and *Phragmites australis* is poorly explained and only by one factor. More variation is explained for the distribution of *Rubus sanguineus*. Three different factors are found, where *Salinity* appeared to be almost independent of *Moisture* and *Water Buffalo Grazing*; very low correlation values were found in the DCA analysis(r= respectively -0.05 and -0.18). *Moisture* and *Buffalo Grazing* are considered to be moderately correlated (r = -0.42).

	Moisture	**Salinity**	**Water Buffalo Grazing***	**Cow grazing***	**Nitrate**
Tamarisk spec	-	-	-	0.15[1]	-
Rubus sanguineus	0.26[1]	0.33[2]	0.18[1]	-	-
Phragmites australis	-	0.21[1]	-	-	-

Table 3.7: explained variance of species distribution. Values are obtained by regression; the model being most significant to explain variant was chosen. Models used: (1) quadratic regression (2) and inverse regression. * *Grazing* showed no correlation with any of the species and was separated into *Water Buffalo Grazing* and *Cow Grazing*.

3.2 Discussion and conclusion

3.2.1 Methodology

During fieldwork and data analysis several factors have possibly caused errors in the final output and uncertainties in the interpretation of it and will be discussed first.

Fieldwork

First, the accuracy of the relocation of relevés is biased by uncertainty in description and location of the Burgerhart relevés. Unless a detailed description of the relevés, a deviation of 1 or 2 meters from the original location is quite likely. In a gradient rich and patchy area like En Afeq this difference could bias the results. This also means that the coordinates which are assigned to each relevé harbour some uncertainty. This is amplified by the accuracy of the GPS device, which is 2-3 meters in open field and around 10 meters under a closed canopy. Therefore coordinates are rather indicative than precise.

The second point of uncertainty did arise when dealing with plant determination. In this survey there were some serious problems with recognizing plants which were already dead, especially grasses. Also it was hard to distinguish plant species of the same genus, like *Polygonum arenastrum* and *Polygonum equisitiforme* and *Rumex conglomerates* and *Rumex pulcher.* The latter caused by possible hybridizing between the two species. Plant determination done by Burgerhart also harbours possible errors as described in the discussion of his thesis: *'Species identification was sometimes difficult, especially in known 'difficult' genera like Euphorbia, Trifolium or Tamarix. A number of species, mainly annuals, was already dry and brown at the beginning of the fieldwork and difficult to identify'*

The recording of environmental variables is another issue of discussion. *Moisture* was recorded in both studies using only three classes. This was also noticed by Burgerhart, quoting his thesis: *'The subdivision into three groups is rather coarse'*. This is particularly true for relevés which were classified as intermediate and the wet. Differences in the exact soil moisture condition between relevés within one of these two groups were large. As En Afeq is rich in gradients a finer scale should be used. Grazing was recorded on a presence/absence scale. There Burgerhart survey defined this as the potential of a relevé to be grazed by cows or water buffalo's a number of relevés were recorded as 'grazing present', however signs of grazing were absent. Measuring grazing pressure on an ordinal scale instead of a binominal absent/present scale would better reflect the actual situation. This was also noticed by Burgerhart: *'Measuring grazing pressure would have improved the grazing – species composition relationship calculations.'* For example the following ordinal scale for grazing pressure could be used: (1) low; no clear visible signs of herbivory, dung and wild tracks, (2) intermediate; dung or wild tracks present but no signs of herbivory and (3) high; dung, wild track and signs of herbivory present.

Data analysis

As mentioned in chapter 2.2.2 clusters of species were identified mainly on bases of the fourth level of division. The number of clusters was reduced by manually combining some clusters at the third division level. This was based on the visual similarity between clusters as expressed by characteristic cover value and presence value of the differential species (see table 3.1) and knowledge from different habitats that were apparent in the field.[26] Especially the latter is information that is prone to subjectivity.

As mentioned in section 2.2.2 is was not possible to name all the plant communities according to official syntaxonomy as no complete syntaxonomic overviews of Israeli plant communities are available. When management evaluation is based on changes in vegetation composition a syntaxonomical overview is indispensable. Therefore the available syntaxonomic literature in Hebrew should be translated to English and replenished with specific information about Israeli fresh water wetlands. However the question arises if management evaluation should in all cases carried out on basis of changes in vegetation composition. This will be discussed in chapter 5.

Tamarisk was considered to be a driver for change in vegetation composition instead of being a diagnostic species for classification and ordination. This choice was made on basis of the known invasive character of Tamarisk. Tamarisk trees are able to alter their environment and belonging plant species composition by the following

[26] No relevés or clusters of relevés were reshuffled

mechanisms: (1) creating a closed canopy, whereby the transmittance of light to the soil surface is significantly reduced, (2) litterfall in combination with salt excretion from the leaves cause an increase in salinity of the topsoil layer and (3) deep taproots and extended subsuperficial roots are formed to extract water from the soil. (Wubbels, 2000) This justifies the choice of Tamarisk as driver factor, as the main focus of this study was to analyse changes in vegetation composition. On the other hand Tamarisk trees in the form of thickets are an essential part of a plant community, ignoring this in classification and ordination analysis surely has biased the results.

In the DCA output *Tamarisk* showed a strong positive relation with *Moistur*e. As Tamarisk species are dependent of sufficient moisture in the soil it is reasonable to suggest that both share a strong relationship. It was also found that *Grazing* is negatively correlated with *Moisture* and *Tamarisk.* This is reasonable for two reasons: (1) grazing is mainly present at dry places, which are relative easy to asses and have low moisture values. (2) Tamarisk patches are poor accessible.

When analysing changes in vegetation composition based on DCA values it appeared that only a small percentage of the variation present was explained by environmental variables. This is probably caused by two categories of errors: (1) incomplete driving factors (2) and missing drivers. The first category includes the used environmental factors *Moisture* and *Grazing,* which as discussed above have a rather coarse scale. A broader *Moisture* scale and an ordinal *Grazing pressure* scale would reflect the influence of soil moisture and grazing on changes in vegetation composition better. This would increase the species variation being explained by environmental factors. The second category includes factors that were not included in the analysis, but having a great explanatory potential concerning the distribution of plants. Among these are environmental factors like the average water table, soil temperature, soil nutrient content, soil chemicals (e.g. Chloride and Nitrate) and water chemicals (e.g. Sulphite). Other driving factors include management activities like mowing and (unintended) burning of vegetation. A management activity with special attention is the clearance of Tamarisk, which could not be included as a factor because there the exact location of clearings was not known. Furthermore, the number of relevés with suspected Tamarisk clearing measures was too small to perform a meaningful analysis.

One possible major problem when analysing the different areas is the small sample size, especially the *Western swamp forest* (with 6 samples). When having such a small sample size the change of missing valuable information about species distribution in the area is quit high. This error could be amplified when the area is highly heterogeneous and relatively large (like the *Central area*). When dealing with areas like this, the relevés should be well distributed in order to cover all the different habitats. Due to the problems described in chapter 3.1.1 this was not achieved.

3.2.2 Vegetation changes

Despite the above described uncertainties and the low percentage of species variance explained in the DCA, the major general trend is clearly identified as an increase in aridity. This is evident when combining the results of classification and ordination; both show a hydrological gradient that is the major explanatory factor for respectively the distribution of communities and relevés. Around sixty percent of all sites have changed to a more arid state, where only seven percent (six relevés) became less arid. Interview based information revealed that four of these six relevés were directly linked to (water) management after 1998. Relevé 2 that switched from community 4c to 4a is located besides a pond that has been deepened in 1999. Relevé 3 is situated on the shore of a pond created in 2004 and showed a corresponding community switch from 4a to 3. Relevé 6 is located next to the pumping station, where flowing water was observed, probably caused by some leak or agricultural water spill in the neighbourhood, but no switch in community is observed. Relevé 4 switches from community (4a to 3) and is located near the central pond, which was deepened in 1999. Also Tamarisk was cleared in this particular area and this relevé is under regular management by mowing. Relevés 1 and 5 did not move to another community and were not associated with any water management measure or activity.

Also clear spatial trends were observed. Changes in the *Water buffalo area* were strongly correlated with changes in the moisture content of the soil. Grazing at the *Water buffalo area* is an ongoing management activity for a long time. When recording grazing only as ‘present’ or ‘absent’, there is hardly any difference in grazing regime between 1998 and 2010. Most relevés that were grazed in 1998 are still being grazed and vice versa. What has changed the past 12 years is the grazing intensity due to an increase in herd-size from 3 individual in 1998 to 9 adult individuals in 2010. An increase like this could be an important driving factor for vegetation change in the *Water buffalo area*. This was also hypothesized by

Burgerhart (1999), quoting: *´A decrease of the amount of thistles and shrubs is expected in the next years due to the growth of the buffalo herd and, related to this, the grazing pressure´*. Chapter 5 will deal with this hypothesis.

In The *Eastern area* changes were most correlated with *Tamarisk* and to a lesser extend *Moisture*. No correlation with changes and environmental factors were found for the *Central area* and the *Western swamp forest*. Changes in the *Central area* seem extremely undirected due to the various management measures in this area the last decade that changed the habitat and species composition. Tamarisk clearing, mowing, grazing, creation of new ponds, deepening existing ponds and introduction of plants like *Salix acmophylla* combined with environmental drivers have contributed to this scattered direction of change in the area.

Species richness was not affected by the increased aridity, no difference between 1998 and 2010 were observed for both the entire reserve as the separate areas. As the trend of increasing aridity has already started centuries ago, it also possible that losses in plant α-biodiversity have appeared before the first plant species survey, in 1998. Another explanation is that increased aridity has transformed relevés in habitats with similar species richness. Species richness in Tamarisk cleared relevés seems not to increase, which is in contrast by one if the hypotheses by Burgerhart: *'Removing the Tamarisk trees from certain locations in the Central area, the Western Tamarisk area and the Eastern Swamps can increase the plant species diversity in these areas.'* But as only three relevés could be evaluated on this matter, no clear and valid answer is at hand.

3.2.3 Vegetation mapping

In this study it was not able to map the area according to the TWINSPAN classification, as not all relevés could be relocated. If not than insufficient relevés have been made to cover the heterogeneity. If sufficient relevés are made PS is most likely very clearly covering the variation in the area and in detail taking into account the species composition.

3.2.4 Distribution of (opportunistic) species

A very low amount of variation in species distribution is explained. Most of this variation is linked to the moisture content of the soil. *Grazing* and *Nitrate*, both correlated with *Moisture*, also explain some of the variation. The study of Burgerhart did point out that species distribution was mainly driven by *Moisture*. Unfortunately no significant additional environmental factors, explaining variation in species distribution, were found in this study. Apparently soil salinity (as measured in this study) is not an environmental driver at En Afeq; there it showed no correlation with species distribution at all. From literature it is known that salinity is an important environmental factor that drives species distribution. (*Crain et al, 2004 & Engels and Jensen, 2010*) One possibility for this discrepancy is that differences in salinity between samples were not large enough (range: 0 - 89 mg/kg) to see any effect. Another possibility is that soil salinity is not the best factor to elucidate the driving role of salinity. Measuring water salinity might explain this; there the average concentration of chloride in water is relative high (950 mg/l) in the reserve. (*Wubbels, 1999*)

When investigating factors driving competition between *Tamarisk spec*, *Rubus sanguineus* and *Phragmites australis* it was found that none of these species responded to nitrate. The distribution of *Phragmites australis* and *Rubus sanguineus* showed a clear and similar Gaussian response to salinity. Unfortunately *Tamarisk spec.* could not be incorporated in this analysis. Whether salinity is one of the competitive factors between *Rubus sanguineus*, *Phragmites australis* and *Tamarisk spec.* could therefore not be investigated. The number of samples was far too small to conclude anything of out the analysis. This is especially true for samples with Tamarisk coverage (only seven). It would be valuable to increase the sample size and see of salinity, soil and water analysis, is indeed a factor that drives competition between *Tamarisk spec.* and *Rubus sanguineus* and *Phragmites australis*.

4. EBONE

4.1. Results

4.1.1. Total area

In total 210 polygons were identified in the field divided over eleven natural GHC's and 27 different species were identified as dominant species characterizing the GHC's. A total of 44 different species were identified in all life forms of the polygons. The reconstruction of the 1998 vegetation map from Burgerhart resulted in 200 polygons divided in eight natural GHC's. Eleven different species were marked as dominators for the GHC's and all found polygon life forms harbours 24 species. Table 4.1 shows the species per GHC that were found being most frequent dominant and so representative for that particular GHC at the En Afeq Nature Reserve. A number of GHC's have an unique dominant specie as representative, but others such as Therophytes have multiple species that are alternating dominant in different polygons.

GHC	Representative species	No. species
HEL	*Scirpus maritimus*	1
SHY	*Potamogeton nodosus*	1
EHY	*Typha domingensis*	1
LHE	*Lythrum salicaria*	6
CHE	*Phragmites australis*	5
MPH/EVR	*Rubus sanguineus*	2
MPH/DEC	*Prosopis farcta*	1
TPH/EVR	*Tamarisk spec.*	3
SCH/DEC	*Prosopis farcta*	1
THE	*Sinapis alba**	15

Table 4.1 Representative species per GHC. This is as following defined: the species that was found most frequently being dominant per GHC in the dataset of both 1998 and 2010. The third column gives the number of different species that were found being denominators of the GHC. The full names of GHC's abbreviations are found at Appendix 7.2. Only natural GHC's with a vegetation coverage over 30 percent are shown here.

The total area of the wetland reserve consisted in 1998 of 39.4 ha and in 2010 of 42.4 ha. This difference in surface is explained by the purchase of land in the *Eastern periphery*. (*pers. comm..Hazzan, 2010*) See also figure 2.1. The surfaces of the different GHC's found in 1998 and 2010 are shown in table 4.2. Striking is the introduction of two new identified GHC in 2010, submerged and emerged hydrophytes (respectively SHY and EHY). Also apparent is the clear increase in area of leafy and caespitose hemicryptophytes (respectively LHE and CHE), deciduous mid phanerophytes (MPH/DEC), deciduous shrubby chamaephytes (SCH/DEC) and therophytes (THE). Evergreen mid phanerophytes (MPH/EVR) and evergreen tall phanerophytes (TPH/EVR) have clearly been decreased in area, while Helophytes (HEL) and aquatic water bodies (AQU) have remain nearly constant in area.

	Area (ha)		Proportion of total area (%)	
	1998	**2010**	**1998**	**2010**
AQU	2,78	2,92	7,1	6,9
HEL	0,42	0,11	1,1	0,3
SHY*	-	0,08	-	0,2
EHY*	-	0,49	-	1,2
LHE	0,04	0,43	0,1	1,0
CHE	0,35	2,63	0,9	6,2
MPH/EVR	13,54	6,57	34,4	15,5
MPH/DEC	0,00	1,56	0,0	3,7
TPH/EVR	14,78	12,64	37,6	29,8
SCH/DEC	6,46	8,28	16,4	19,5
THE	0,88	5,27	2,2	12,4
ART	0,09	0,10	0,2	0,2
SAN/EAR/URB*	-	1,34	-	3,1

Table 4.2: Changes in surfaces between 1998 and 2010 of the different GHC's. First two columns show the surface in ha. Last two columns give the percentage proportion per GHC of the total area

The Habitat maps of 1998 and 2010 that were obtained after data input and processing in GIS are shown in respectively Appendix 1.1 and 1.2. On request of the Rashud Teva some additional maps in GIS were made for management purposes. These are shown in Appendix 1.3 and 1.4 and indicate respectively the dominant species per polygon and rare plant species found in the reserve. In chapter 4: Monitoring and management, this topic will be dealt with.

An elaborate description of changes in GHC's is given per separate zone in the next chapter. This will be linked directly to management measures that have been taken in the past as derived from information out of interviews.

4.1.2. Spatial description

As described in material and methods 2.3.2 the area is divided into five separate zones.

Western swamp forest

Twelve different polygons and six natural GHC's were found in 2010 against ten polygons and four natural GHC's in 1998. This area, around 4 ha in size, is nearly complete covered by tall Phanerophytes in the form of Tamarisk trees (TPH/EVR). Figure 4.1 shows that the coverage of Tamarisk trees decreased a little as well as the surface of the water bodies. This is accompanied by an increase in evergreen and deciduous mid Phanerophytes (MPH/EVR and MPH/DEC), respectively *Rubus sanguineus* and *Inula viscosa*. The size of other GHC's is too small for meaningful analysis. The reduction of tall phanerophytes coverage is the result of Tamarisk clearance in the eastern part of the western swamp forest around the western crusader pond in 1999. On the sites of clearance mid phanerophytes have emerged and dominate these areas. The reduction in area of water bodies is probably the result of a lower water table, due to drought.

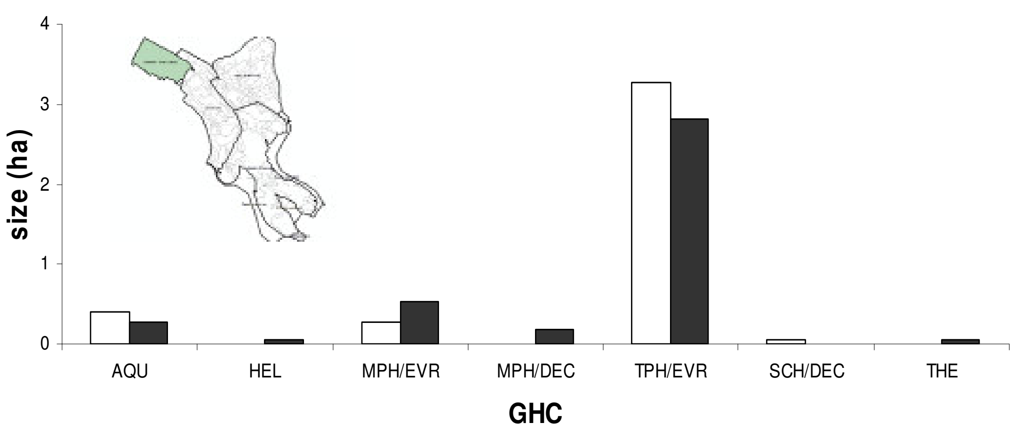

Figure 4.1: Total area size of the different natural GHC's in 1998 and 2010 shown in ha. White columns represent 1998 and black columns 2010.

Central area

The area in 2010 compromised of 55 polygons divided over ten natural GHC's compared to 68 polygons over six natural GHC's in 1998. In general this area is characterized by a mixture of water bodies, Tamarisk patches and in between mainly mid phanerophytes. This area is where most management has been applied over the past years and where visitors walk.

The dominance of evergreen mid phanerophytes in 1998 has been broken by the rise and appearance of several other GHC's. Submerged Hydrophytes, Helophytes and deciduous mid Phanerophytes are new for this area, but surfaces are very small. The area of water bodies, inclusive the area with submerged Hydrophytes have increased by active management in the area; digging new ponds and deepening existing ponds. This explains also the appearance of Helophytes and the increase in leafy and caespitose Hemicryptophytes, respectively represented by *Scirpus maritimus*, *Lythrum salicaria* and *Phragmites australis*. So in areas where water management was applied an appearance and increase of 'wet' GHC's is observed. In area where no water management was applied, an increase of 'dry' GHC's was observed; deciduous shrubby Chamaephytes and Therophytes.

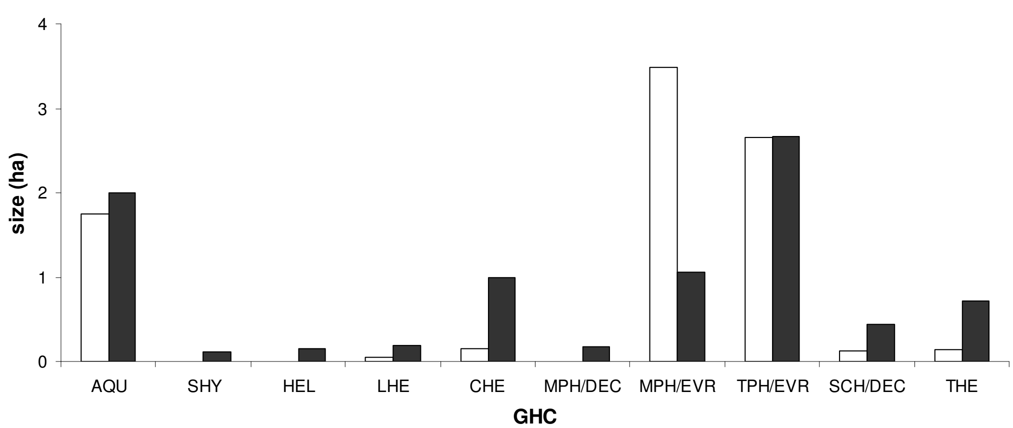

Figure 4.2: Total area size of the different natural GHC's in 1998 and 2010 shown in ha. White columns represent 1998 and black columns 2010.

Water buffalo area

The area in 2010 compromised of 70 polygons divided over eight natural GHC's compared to 58 polygons over six natural GHC's in 1998. This area, around 10 ha in size and grazed by water buffalo's shows a distinct tendency of changes in GHC's (see figure 4.3). A sharp reduction of moistures GHC's like aquatic water bodies (AQU), Helophytes (HEL) and evergreen mid Phanerophytes (MPH/EVR), represented by *Inula viscosa* is shown. This is balanced by an increase in the typical dryer GHC's: deciduous shrubby Chamaephytes (SCH/DEC) and Therophytes (THE) represented by respectively *Prosopis farcta* and grasses and thistles. Evergreen tall Phanerophytes have increased in area unless clearance of Tamarisk (see chapter 1.2.6. and table 2.1).

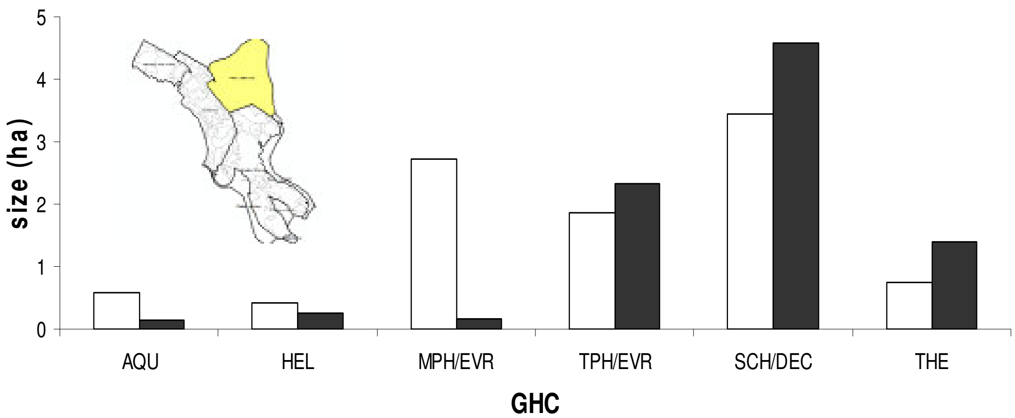

Figure 4.3: Total area size of the different natural GHC's in 1998 and 2010 shown in ha. White columns represent 1998 and black columns 2010.

Eastern swamp

In 2010, 55 polygons were distinguished in nine natural GHC's compared to 42 polygons in four natural GHC's in 1998. The *Eastern swamp,* circa 14 ha in size, is characterized by the presence of mid and tall Phanerophytes (MPH and TPH), represented by respectively *Rubus sanguineus* and *Tamarisk spec.* As shown in figure 4.4 both mid and tall phanerophytes have decreased in area size. The latter being the result of Tamarisk clearings after 1998, which will be more elaborately discussed in chapter 4.1.3. The increased surface of water bodies (AQU) is the result of digging ponds and deepening of existing ponds in the western part of the area after 1998. This is accompanied by an increase in caespitose hemicryptophytes represented by *Phragmites australis*, located near water bodies. The appearance of deciduous mid Phanerophytes (MPH/DEC) at cost of evergreen mid Phanerophytes (MPH/EVR) indicates that these areas have become dryer. Therophytes (THE) have mainly appeared on sites with a relative high altitude and where Tamarisk was cleared.

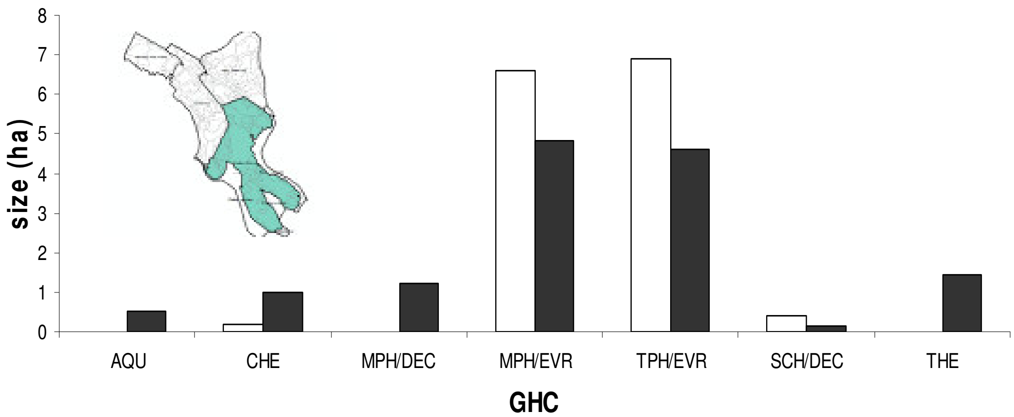

Figure 4.4: Total area size of the different natural GHC's in 1998 and 2010 shown in ha. White columns represent 1998 and black columns 2010.

Eastern periphery

It was found that in 2010 the area consisted of eighteen polygons divided over five natural GHC's compared to 24 polygons over three natural GHC's in 1998. Figure 4.5 shows relative large changes in the GHC's surfaces, which is linked to the fact that land has been purchased after 1998. This increased the area size from 3.2 to 5.5 ha, a 57 percent increase. This additional land, visible in figure 2.1, includes areas with an average altitude of 7.0 m above MSL, which explains the large appearance of Therophytes (THE) and to lesser extent caespitose hemicryptophytes (CHE). The increase of deciduous shrubby Chamaephytes (SCH/DEC) and decrease of evergreen mid Phanerophytes (MPH/EVR) is probably linked to a drop in the average water table from 1998.

4.1.3. Tamarisk distribution

As described in chapter 1.3.3. Tamarisk has been cleared after 1998 to open the area and to stop further invasion of this species. Interviews with the En Afeq staff revealed the areas where a significant proportion of Tamarisk was cleared, which are visualized with blue circles in figure 4.5. An example of such a clearing is shown in figure 4.6, matching with area ‘1’ in figure 4.5. When comparing these cleared areas between 1998 and 2010 it is clearly visible that these areas are now Tamarisk free. On the other hand Tamarisk has appeared on areas where it was not present in 1998, visualized by the red circles.

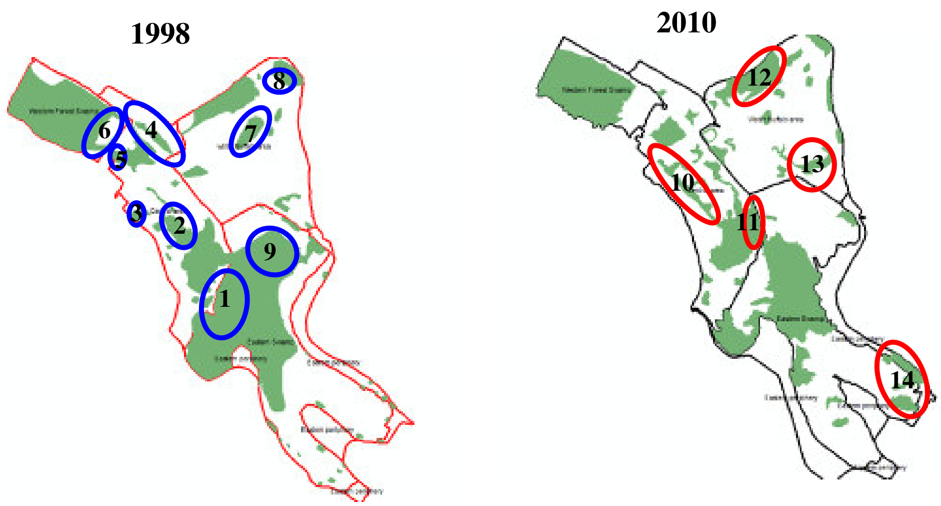

Figure 4.5: Spatial distribution of *Tamarisk spec*. in 1998 and 2010. Encircled with blue are areas where Tamarisk was cleared in the period 1999-2001. Encircled in red are areas where Tamarisk expand significantly

Figure 4.6: Tamarisk clearings and deepening of pond in 1999. The photograph is taken in the central area and pointed out with ‘1’ in figure 4.5. The wooden bridge, visible from left to right, is a clear landmark that separates the central area from the eastern swamp

The total area covered by Tamarisk in 1998 was 14.7 ha, compared to 12.3 ha in 2010, a reduction of 16.8 percent. The coverage of Tamarisk per separate area gives a better view of changes in Tamarisk distribution, as visualized in figure 4.5 and 4.7. Despite the fact that a lot of Tamarisk was cleared in the *Central area* at points 1-5, (figure 4.5) a decrease in coverage is neglectable, caused by an expansion of Tamarisk at point 10 and 11. The clearance of Tamarisk in the *Eastern swamp* at point 1 and 9 had led to a significant reduction of coverage in the western part of this area. However, in the far eastern part Tamarisk is rapidly expanding, indicated by point 14. Overall the decrease in Tamarisk coverage is 33.8 percent. The surface of Tamarisk coverage in the *Eastern periphery* is in both years neglectable, but shows an explosive increase of 73.0 percent due to expansion at point 14. Due to clearance of Tamarisk at point 6 the coverage has decreased with 14.0 percent in the *Western swamp forest*. Overall, Tamarisk coverage has increased the *Water buffalo area*, despite the clearance of 8 dunam[27] at point 7 and 8. This increase is caused by significant expansion of Tamarisk at point 12 and 13.

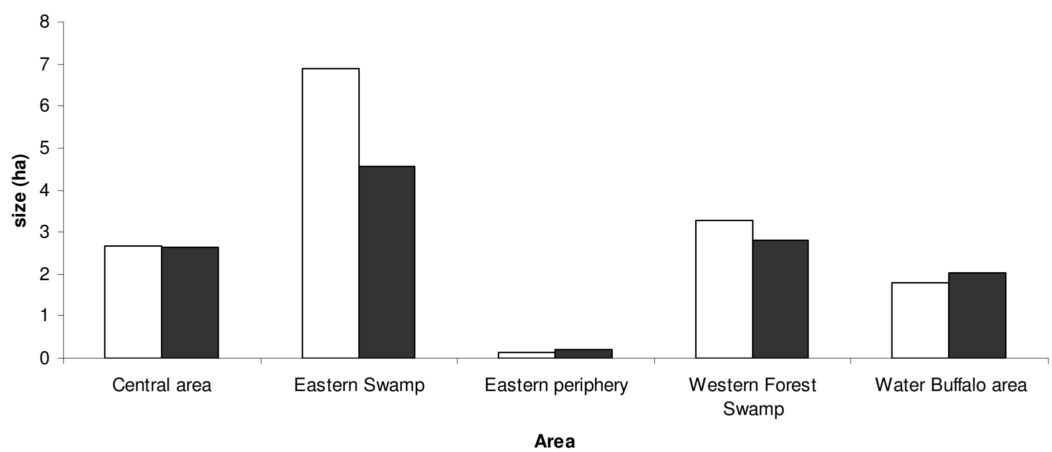

Figure 4.7: Tamarisk coverage in 1998 and 2010 shown in ha per area. White columns represent year 1998 and black columns year 2010.

[27] 1 dunam corresponds with 0.1 ha.

4.2 Discussion and conclusions

4.2.1 Methodology

Fieldwork

A number of uncertainties and errors could have caused deviations in the final output, which will be discussed first. The boundaries of polygons that had to be determined manually by means of a GPS device (see material and methods section, chapter 2.2.1) have a deviation of 2 meters in areas without Tamarisk coverage and 5-10 meters in areas with Tamarisk coverage. To overcome this problem in the future a GPS device with a higher accuracy has to be used, like a DGPS. But this is quite expensive and global positioning will remain inaccurate in forested areas; therefore it is better to avoid the use of such a device. One option to obtain this is to have a more recent and fully updated ortho-photo available. The one used in this study was two years old and did not completely match the present situation in the field.

Another recommendation to avoid using a GPS device is to have an ortho-photo with a higher resolution to distinguish areas with different GHC's or different dominant species better. Especially for areas like En Afeq where gradients are all over the area and patches of different GHC's are small and scattered, a higher resolution would increase the power of visualization and analysis. But such high resolution ortho-photos would be expensive and the question arises if it is necessary to map the area in such a detail. For management purposes an inaccuracy of a few meters might be accepted, as long as major changes are significantly visible and pop out the subsequent analysis.

On basis of above findings in the field I suggest the expand chapter 3.2 and 3.3 of the 'Handbook for Surveillance and Monitoring of European habitats': respectively *'Preparation'* and *'Habitat mapping: general rules'* with the following guidelines. [28] Original guidelines are shown in Italic.

3.2.3b '*Aerial photographs should preferably be ortho-photos*', which are up to date and taken by preference in early spring.[29]

[28] With the notice that this is true for areas which are small and rich in gradients like En Afeq.
[29] When dealing with habitats situated in the Middle-East.

3.2.3c '*Elements can be determined by photo-interpretation and used directly in the field as a basic for mapping GHC's*.' Elements not present or visible at the ortho-photo could be determined in the field by tracking the element boundaries with a GPS device.

3.3.1 *'The minimum Mappable Element (MME)'*, for a gradient rich and patchy area with a total surface lower than 50 ha, for an areal element is 100 m^2, with minimum dimension of 5 x 20 m.

Data analysis

As already explained in material and methods chapter 2.3.2, the 1998 vegetation map is constructed by transforming the map with dominant species of Burgerhart into polygons with GHC's. This procedure includes a number of steps that possibly caused a various amount of inaccuracy in the final vegetation map and subsequent comparison with the vegetation map of 2010.

First, Burgerhart made his map on basis of dominant and co-dominant species for a certain polygon, instead of the dominant life-form. So it is for example possible that a polygon with 30% coverage of tall Phanerophytes (like *Tamarisk spec.)* and 70% coverage of mid Phanerophytes (like *Rubus sanguineus*) is determined by Burgerhart as a patch where *Rubus sanguineus* is dominant and so translated to the GHC 'mid Phanerophytes' in the present study. The same polygon would be determined as a patch with the GHC 'tall Phanerophytes' in the present study on basis of field survey.

Second, it is not clear how dominant is defined in Burgerhart's study, in contrast with the guidelines that comes along with BioHAB monitoring.

Third, the polygons drawn by Burgerhart are based on the areal photograph of 1995 (see Appendix 4.1), which got the following comments in Burgerhart's thesis: *(1) 'this photograph is several years* and *(2) 'it was made in the winter when the Tamarix and Phragmites are brown and the borders between vegetation types cannot be distinguished'*. This means that the actual borders in 1998 from polygons could deviate significantly from the borders derived from the ortho-photo, especially between patches with Tamarisk and Phragmites.

Knowing all these uncertainties that arise from fieldwork and data analysis, one must be careful by analysing the data and comparing the different GHC surfaces between 1998 and 2010. This is especially true if changes are small, for example Tamarisk coverage in the Central area, where only a decrease of 1 percent is observed. Hereby the following questions arise: (1) how much variance should be included per dataset and (2) which threshold value in percentage should be used to make a valid comparison between both datasets. Error propagation that comes with spatial data is a complex story, especially with all the data transformations and procedures carried out in this study, and falls outside the scope of this study. However it would be instructive to carry out an error propagation analysis for studies like this in order to quantify changes more accurate when spatially detailed questions are asked. In this study we are only interested in the major trends and transitions and therefore error propagation is not essential.

The use of BioHAB for monitoring and answering management questions will be discussed in chapter 5: Management and Monitoring.

4.2.2 Vegetation changes

Clearly appearing from the results is the increase in habitat diversity between 1998 and 2010. When looking to the area as a whole, three new GHC's have appeared; SHY, EHY and MPH/DEC and the dominance of MPH/EVR and TPH/EVR in parts of the area is reduced as a result of Tamarisk clearance and digging ponds. On the other hand SCH/DEC and THE have increased in area due to increased aridity.

The spatial variance in influence of aridity and active management is clearly visible when observing the different areas. In areas without active water management, the *Water buffalo area* and *Eastern periphery*, the increase of more moisture independent GHC's is striking. This is contrasted by the *Central area* and western part of the *Eastern swamp* where water management was and is still being applied. Here wetter GHC's have appeared; SHY and EHY, or have significantly increased in area; AQU, LHE, CHE and HEL. These conclusion matches with the expectations of the En Afeq staff. It is known that the water table is still going down due to increased demands for water in the area. Furthermore, the active water management in the

Central area extracts water from neighbouring areas, causing an even further drop in the water table in these areas. This is most evident from the *Water buffalo area.*

The hypothesis that besides increasing aridity increased grazing pressure of the water buffalo's herd caused the striking transformation of this area is not completely valid[30]. One of the major emerging transformations in this area is the shift from *Inula viscosa* (MPH/EVR) dominating patches to patches where *Prosopis farcta* (SCH/DEC) is dominant. Both considered having a low edible factor, because *Inula viscosa* have a strong smell and sticky leaves and *Prosopis farcta* being spiny and having hardly any green biomass. (*Mollema and Pronk, 1999*) On the other hand trampling of the herd could possibly explain some of the changes. But to answer this question one should have determined something like a trampling factor for each polygon showing the intensity of trampling or presence for both years. (*Cole, 1995a; Cole, 1995b & Abdel-Magid et al, 1987*) This topic will be elaborately discussed in chapter 5.1.

How the presence of cow grazing in the *Eastern swamp*, *Eastern Periphery* and partly in the *Central area* have contributed to changes in vegetation structure between 1998 and 2010 could not be evaluated as no obvious changes in grazing pressure did arise31. Furthermore it was not determined what the grazing pressure per polygon was in both years. This could have been measured by looking at the presence and amount of dung, presence of wild tracks and the magnitude of herbivory at edible plants.

The presence and abundance of Tamarisk, after a decade of clearances, also shows a distinctive spatial pattern. In the *Eastern swamp* management significantly reduced the surface of Tamarisk coverage. In other areas the total surface of coverage hardly changed. Relative large surfaces of Tamarisk were effectively cleared in the *Central area* and *Water buffalo area*, but at other places in the areas Tamarisk did expand significantly. This shows moreover the invasive character of Tamarisk. This topic will be elaborately discussed in chapter 5.1.

[30] The water buffalo herd increased from three individuals in 1998 to ten in 2010.
[31] The herd size was kept constant in the period 1998-2010.

5. Management and Monitoring

5.1 Research and management questions

How did the vegetation change in terms of species composition, distribution and habitat structure?

In general: Tamarisk coverage was reduced, new wetland habitat types emerged, typical dry communities dominated by shrubby Chamaephytes, grasses and thistles increased and species richness in the area remained constant.

1a. What is the spatial pattern in vegetation and habitat change observed in the area?

Most striking is the transformation of habitat and vegetation in the *Central area* where habitat heterogeneity increased. More wetland habitat types were observed and existing wetland communities expanded, mainly dominated by *Phragmites australis*. On the other hand, *Rubus sanguineus* dominated communities significantly decreased where dryer communities, dominated by Therophytes increased. Changes in the *Water buffalo area* are less complex. Here *Inula viscosa* dominating mid Phanerophytes habitats were replaced by a *Prosopis farcta* dominating shrubby Chamaephytes habitat. Along with this change is the decrease in Helophytes and increase in Therophytes (e.g. grasses). The *Eastern swamp* became wetter and Tamarisk coverage was significantly reduced, where the *Western swamp forest* did not show an obvious change in vegetation composition and habitat structure.

1b. Did an increase of the water buffalo herd cause a decline in thistle and shrubs

A decline in shrubs was observed in the *Water buffalo area*. Mid Phanerophytes, represented by *Inula viscosa,* were replaced by short shrubby Chamaephytes, represented by *Prosopis farcta*. As discussed in chapter 4.2.2 it is not likely that increased grazing pressure has caused this transformation as aridity is probably the main driving factor. Thistle encroachment on the other hand has further increased.

One possible explanation is that water buffalo's tend to graze on the same spots during the year; as was observed in the field.

1c. Did biodiversity increased in the area?

No, species richness did not significantly changed over the 12 year period for both the area as a whole and the separated zones.

2. How is this succession related to management and abiotic conditions?

The observed succession has two major explanations: on the one hand aridity causing a transition to dryer habitat types and communities in the area. On the other hand active water management resulting in more open water and more wetland related habitats. A minor trend is the reduction in the coverage by invasive Tamarisk (TPH/EVR) by clearings.

3a. Was the management applied successful for the repulsion of Tamarisk encroachment?

Where Tamarisk was cleared it hardly did not invade in return, but it was observed that at some places new sprouts did emerge from the biomass that was left in the field. Tamarisk is known to be able to reproduce vegetatively. When cuttings of Tamarisk are put in wet soil, they are sure to sprout (*Howard and Horton, 1965*). After human intervention, clonal reproduction might become an important factor of Tamarisk expansion. (*Wubbels, 1999*) Knowing this it would be better to completely burn the cleared biomass or transport it to dryer places. Despite massive Tamarisk clearings the coverage was only decreased by hardly twenty percent. This is caused by the fact that Tamarisk invaded in areas where it was not present before. Therefore it is essential to keep tabs on with Tamarisk distribution and management.

3b. Was species richness affected by the measurements?

No, plots that were cleared of Tamarisk did not show a significant increase or decrease of species richness.

4. What are the environmental drivers for distribution of Tamarisk, Rubus and Phragmites?

This question remains largely unanswered as sample size was inadequate. From literature it is known that all three species are dependent of a high water table. *Rubus sanguineus* is particularly fond of nutrient rich soils and *Tamarisk spec*. is believed to be relative salt tolerant. This study showed some indication that salinity is indeed an important environmental driver, however what exactly drives the distribution of the different species remains unclear.

5.2 Comparing methods

5.2.1 Qualitative comparison

The aspects as depicted in table 5.1 and described in chapter 2.5.1 will be discussed in the light of management and monitoring.

Aspect	PS	BioHAB
Time		X
Knowledge		X
Coverage		X
Rules	X	
Biodiversity	X	
Classification		X
Research questions		X
Overall		**X**

Table 5.1: Comparison of the PS and BioHAB methodology. Aspects in methodology being considered important are chosen. For each aspect a cross indicates the methodology with the 'highest score'.

Time

Phytosociological monitoring as done in this study is quit time consuming; this is especially true for fieldwork where only 5-8 samples (relevés) per day could be achieved. With BioHAB it is possible to visit around 25 samples (polygon's) a day.

Data input, processing and analysis takes more or less the same time for both methods. Based on the time in the field to gather the information, BioHAB is significantly less time consuming then PS.

Knowledge

To perform a solid analysis on phytosociological data one must have extensive knowledge on the plant species appearing in the reserve. In this case 152 plants were identified. This problem is magnified when dealing with difficulties in identification due to herbivory and already dead vegetation (e.g. grasses). These problems were not encountered with BioHAB, there only dominant species needed to be identified. Assigning a GHC to each polygon only required knowledge about several life forms and 27 different and common plants and. The knowledge and skills needed to process the data and perform analysis is for both methods quit specialistic. For PS one must able to handle software like TWINSPAN and CANOCO and process and analyse the data properly. For BioHAB one must have the skills to work with GIS and analyse data in Excel. Interpretation of the BioHAB data, especially by managers, requires not a lot of knowledge. One only has to know about life forms and GHC's. To interpretate one must be familiar with classification and multivariate techniques and how to read the output. The knowledge, and skills, needed to perform all steps from fieldwork to interpretation for BioHAB is significantly lower than for PS.

Coverage

The way to map an area like En Afeq with PS is by sampling each habitat sufficiently, classify the data, describe communities and extrapolate this information to similar areas in the field. The latter step has to be checked in the field. BioHAB works the other way around. First the area is divided in polygons (habitat's) on basis of an areal photograph, polygons are described in the field and a map is produced by processing the data. There mapping with BioHAB is performed directly in the field makes processing faster[32]. In this study it was not able with PS to map the area, as not all relevés could be relocated (see chapter 2.2.2:"vegetation mapping" and 3.2.3.) These shortcomings also indicate that PS does not cover the variation present in the area. For

[32] With PS the different vegetation clusters have to be checked in the field before a vegetation map can be drawn

these reasons BioHAB is for certain more suitable for this study and probably in general for all sorts of mapping studies.

Rules

For a methodology to be sufficiently applicable in all sorts of research it is essential that rules and guidelines are clear and as objective as possible. Their PS research has already quit a history and is often used in monitoring; rules in the field and for data analysis are clear and almost objective. The BioHAB methodology has just been developed and not testes on Reserves like En Afeq. Therefore a number of rules had to be manually adapted. The method also contains a quit amount of subjectivity; when interpreting ortho-photos, by assigning a GHC to polygons and describing the coverage of life forms per polygon. On basis of maturity and objectivity of the methodology PS is significant better at this point in time. It is expected that BioHAB methodology will further improve in the future as expert knowledge and field experience will accumulate.

Biodiversity

The biodiversity in an area like En Afeq could be described by both α- and B-diversity, Alpha diversity is simply defined as the species richness of any community or area where beta diversity is defined as; '*the extend of differentiation of communities along habitat gradients*' (*Whittaker, 1972*) There with PS all habitats have been sampled on species diversity both alpha and beta biodiversity could be measured. BioHAB only recorded the structural differences within the reserve, where all habitats were described on structure and the dominant species present. The habitat gradient is described very well with BioHAB, but species diversity for each habitat is missing; only habitat diversity could be measured in this sense. This diversity could be a predictor for beta diversity be assuming that the more habitats are present the higher the extend of differentiation of communities. It must also be mentioned that there could be more habitats than given by BioHaB as it is only based on structure and dominance (e.g. it could be that more habitats could be defined if all species are taken into account). It is clear that PS has a great advantage over BioHAB for measuring biodiversity[33].

Classification

Both methodologies make use of a unique classification system. To classify a dataset with PS would preferably require syntaxonomical data to make sense in a nation wide framework. There sufficient syntaxonomical data is missing for Israel the classified data could not be named completely according to a syntaxonomic overview that is at least nationwide. BioHAB make use of a universal classification system based on all the life forms present on earth. Therefore this method is applicable everywhere in Europe or even on a global scale. To classify data in studies like this BioHAB would be most applicable. However because it is only based on main life forms it is unsuitable to describe changes in vegetation composition in terms of species and biodiversity. For nature conservation purposes it is highly advisable to work on an overview of plant communities of Israel as it will give far more ecological and biodiversity information than systems only based on dominance and structure.

Results

When answering the research and management questions, results of both methods were used. Each question will be evaluated on the magnitude of explanation for each method. Questions 1A-1C was mainly answered by means of the BioHAB results. For the concerned En Afeq management staff the major trends was important, instead of exact changes in species composition resulting from PS analysis. Question two was answered with the results of both methods, where PS proved the staff's expectation that moisture was indeed the driving factor behind vegetation change. BioHAB mapping clearly showed the effect of active management in the area. From the change in GHC's through time one could also have derived that aridity was the problem. On the other hand PS research, when could performed properly, when all the shortcomings as described earlier were not present, should have concluded the same as BioHAB. This is also true by answering question 3: now just the BioHAB results

[33] BioHAB has a module in the methodology to measure species richness.

could be used. Question 4 could be answered with the results of PS analysis, which is quit logic as the nature of this problem is quit complex and needs specialistic analysis.

Summarizing: PS has a greater potential for answering the specialistic questions, like distribution of Red List and opportunistic species. With the BioHAB results, management could be properly evaluated in this case. Therefore BioHAB was assigned to be more appropriate for monitoring changes at En Afeq, at least for this study with the belonging information request.

Overall

To start with, research or management questions must be the driving factor for a choice in methodology. This question is almost directly linked to the amount of biodiversity that has to be revealed. There the concerning management was just interested in trends of change in dominant species and structure only, rather than to know the exact impact on species composition and botanical value of the area, BioHAB monitoring is considered to be sufficient enough. Another important aspect in monitoring is time. Time is money, and money is not abundantly at hand in nature conservation. Extensive knowledge is also linked to time and money their it requires specialistic professionals and sufficient time. Concerning these two aspects BioHAB appeared to be more efficient. For evaluation changes spatially, especially after management activities, it is important that the area is well covered. In both PS projects 1998 and 2010 insufficient relevés were made to cover the full diversity. There information was missing, due to missing or inaccessible relevés, PS could not be performed properly. The advantages of PS over BioHAB are objectivity and maturity rules, more detailed information about changes in species composition that matters for nature conservation. For nature conservation purposes descriptions of only structure and dominance usually provide insufficient information.

5.2.2 Quantitative comparison

After super positioning the relevés on the BioHAB habitat map, seven natural GHC's were found: Helophytes (HEL), caespitose Hemicryptophytes (CHE), leafy Hemicryptophytes (LHE), Therophytes (THE), deciduous shrubby Chamaephytes

(SCH/DEC), evergreen mid Phanerophytes (MPH/EVR) and evergreen tall Phanerophytes (TPH/EVR). The third division level in the TWINSPAN resulted in eight different vegetation clusters (A-H). Table 5.2 shows the observed values for the extended chi-square test of independence. The observed values deviate significant from the expected values (p<0,001). Following the results presented in this table, evergreen mid Phanerophytes and tall Phanerophytes correspond strongly with TWINSPAN class C. Therophytes mainly correspond to TWINSPAN class G. As too few observations in the GHC classes HEL, CHE, LHE and SCH/DEC were made no meaningful interpretation of these cases is possible. In general it could be said that there is some prove that with sufficient sample size of each GHC, that correspondence with TWINSPAN vegetation classes is not random. Experiments with larger sample sizes should be performed to really say something about the effectiveness of BioHAB in comparison with PS.

	HEL	CHE	LHE	THE	SCH/DEC	MPH/EVR	TPH/EVR
A	2	0	0	0	0	0	2
B	2	0	0	0	0	0	0
C	0	1	0	0	1	12	7
D	1	1	0	0	1	3	0
E	0	0	0	3	0	0	0
F	0	0	0	3	3	0	0
G	0	0	1	8	0	0	0
H	0	0	1	0	0	0	2

Table 5.2: Observed values for the extended chi-square test for indepence in matrix format.

5.3 Synthesis

This study showed that drought is a persistent and increasing problem in the En Afeq Reserve. Evidently this is mainly caused by an increasing demand of water in the neighbourhood. With active water management it is possible to achieve management goals (see chapter 1.4.1) like; ‘to maintain the ecosystem structure and function integrity’ and ‘restore and maintain the naturalness of the landscape’. This is only possible for a part of the reserve; keeping the water level constant at one place means a drop of the water level at other places. The trend of increasing aridity is not expected to stop in the future and therefore it is essential that (water) management is frequently evaluated to keep tabs on concerning ecosystem services and wetland biodiversity. Proper management evaluation is performed by fitting the right monitoring tool to the management goals or information requests. When taking the management goals that were stated in 1999 for the En Afeq Reserve (*Olsvig-Whittaker et al, 1999*) as a guideline for the future, both tools used in this study can contribute to the process of evaluation. It is important to realize that the BioHAB tool is not suitable to evaluate goals as: ‘To maximize biodiversity’ or ‘To protect rare and valued species’. Which monitoring tool to choose is dependent on the weight that is given to the management goals. Besides this, the needed frequency of monitoring and the time that is available could also play a role in deciding which method to choose.

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Appendices

Appendix 1: Maps

Appendix 2: Species lists

Appendix 3: Twinspan output and synoptic table

Appendix 4: Ortho-photos

Appendix 5: Relevés: location and environmental variables

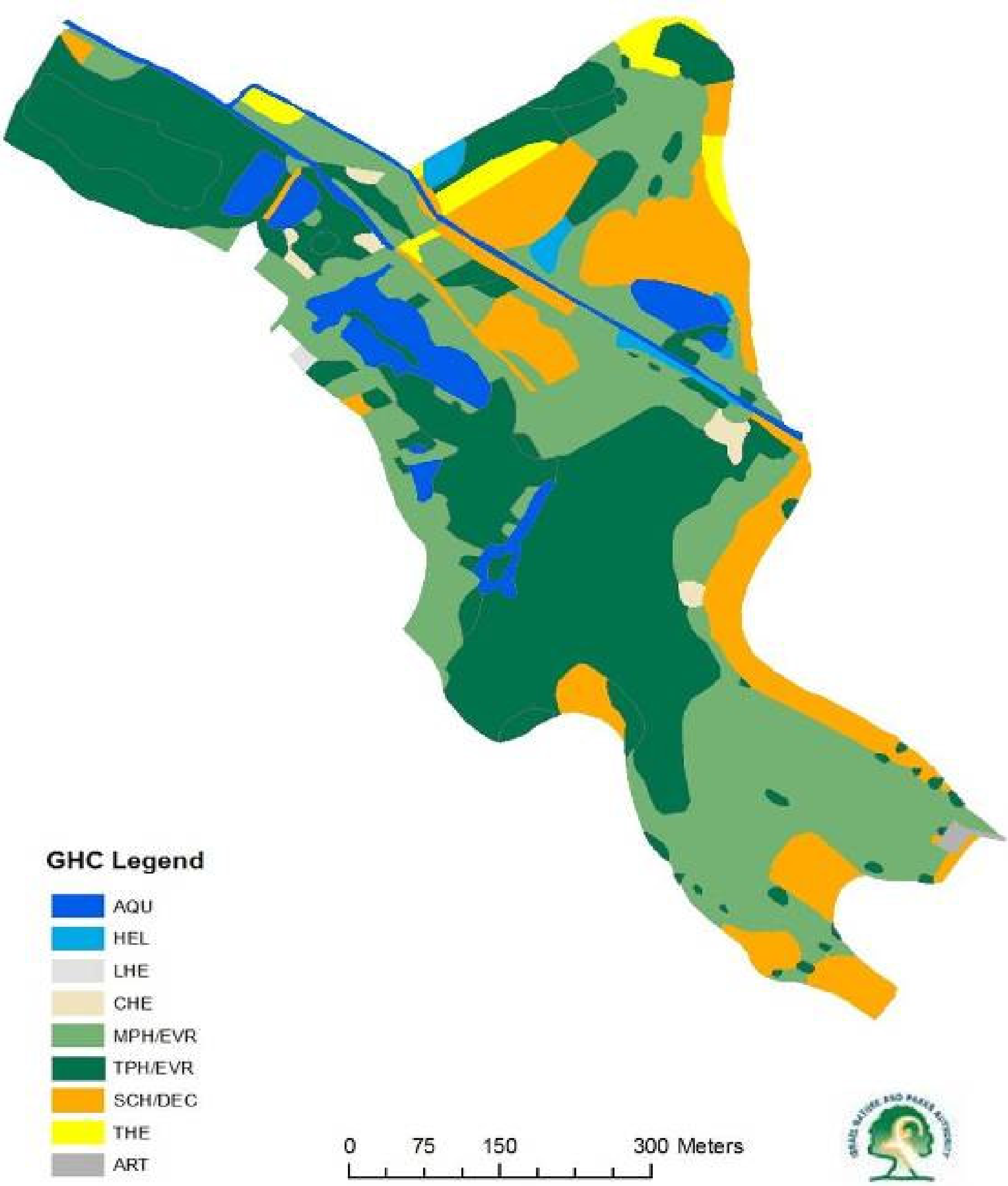
Appendix 6: BioHAB recording forms

Appendix 7: Photographs

Appendix 1.1

Habitat map En Afeq Reserve 1998

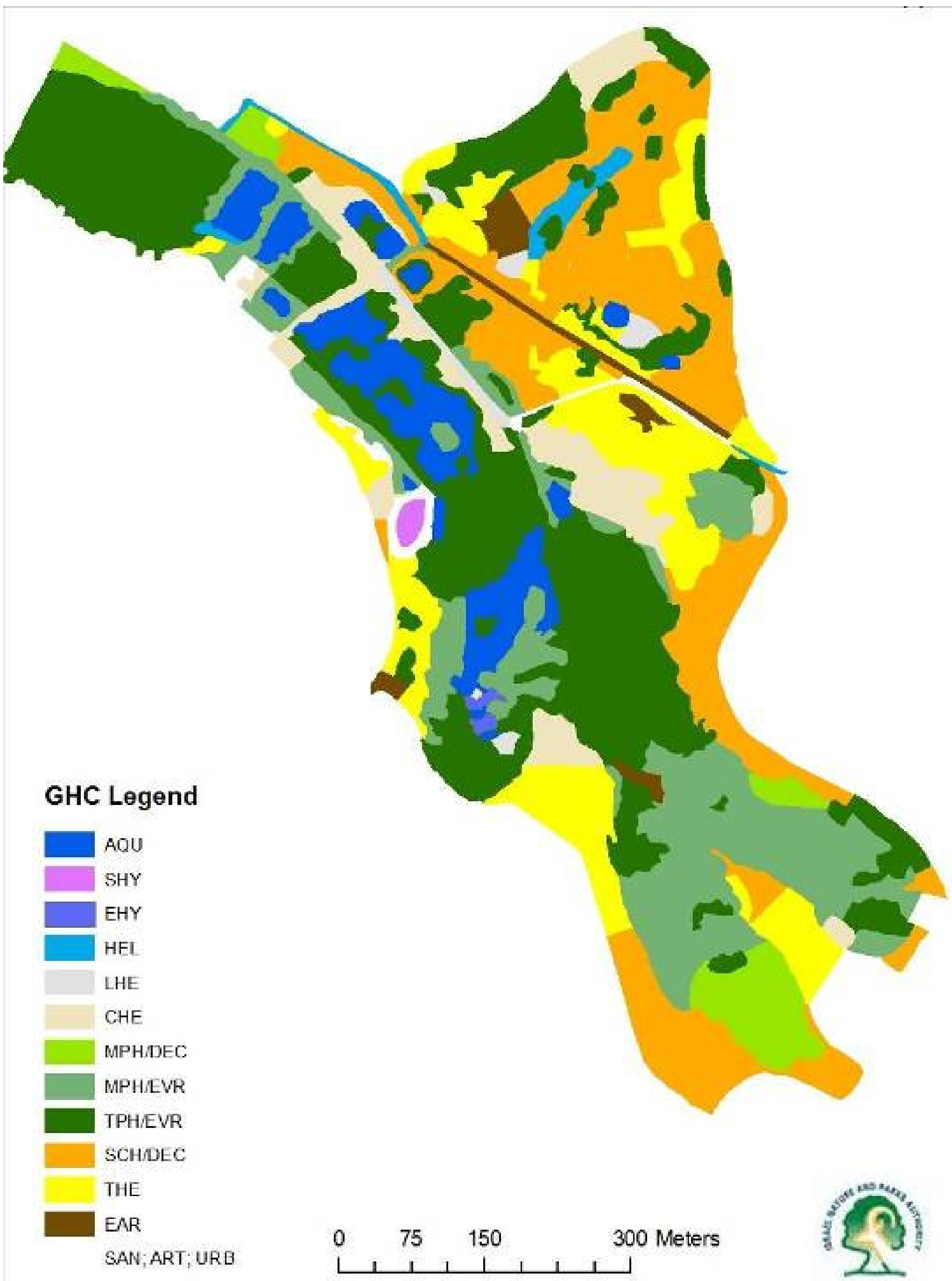
Based on GHC



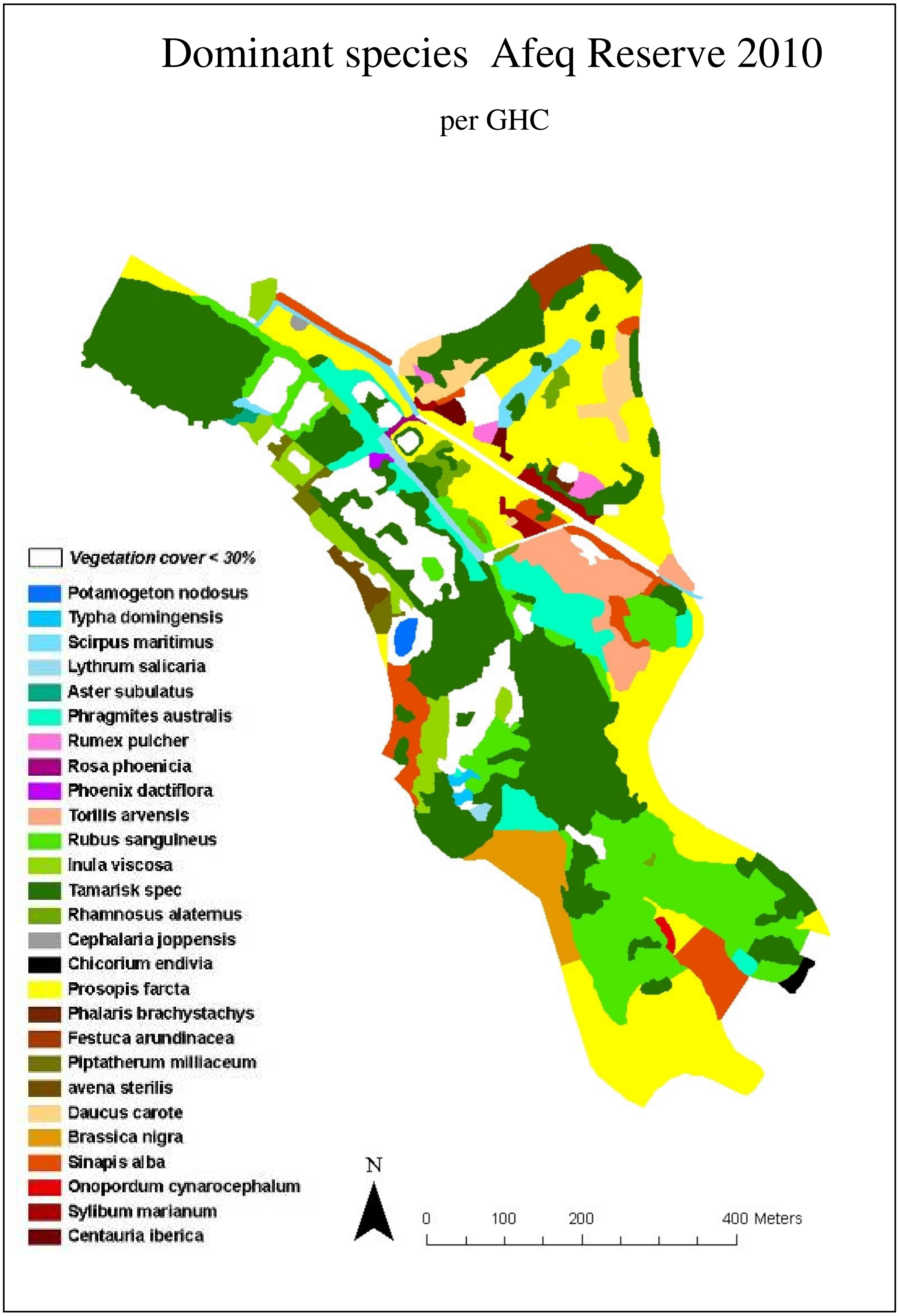
Appendix 1.2

Habitat map En Afeq Reserve 2010

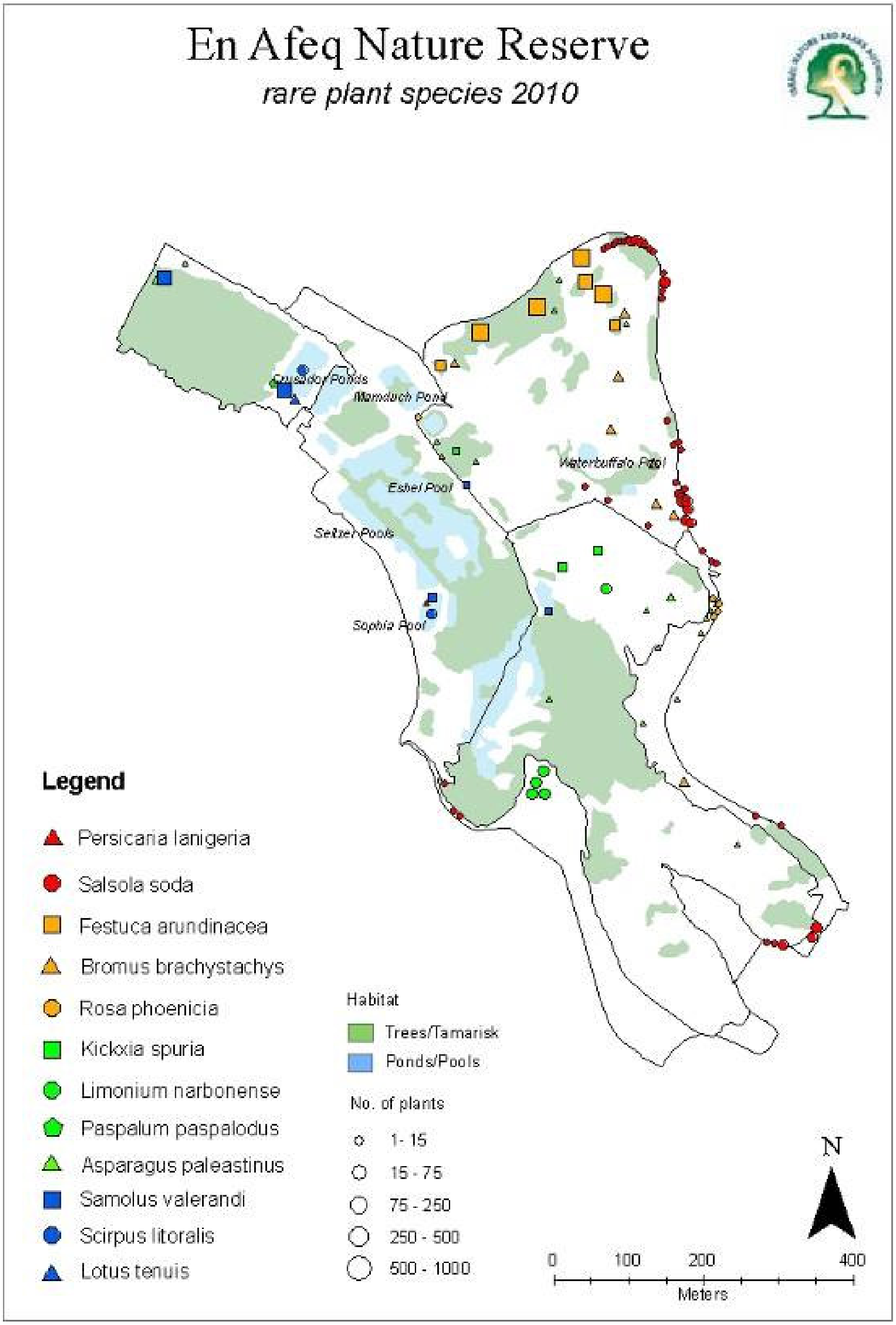
Based on GHC



Appendix 1.3


Dominant species Afeq Reserve 2010
per GHC
Vegetation cover < 30%
Potamogeton nodosus
Typha domingensis
Scirpus maritimus
Lythrum salicaria
Aster subulatus
Phragmites australis
Rumex pulcher
Rosa phoenicia
Phoenix dactiflora
Torilis arvensis
Rubus sanguineus
Inula viscosa
Tamarisk spec
Rhamnosus alaternus
Cephalaria joppensis
Chicorium endivia
Prosopis farcta
Phalaris brachystachys
Festuca arundinacea
Piptatherum milliaceum
avena sterilis
Daucus carote
Brassica nigra
Sinapis alba
Onopordum cynarocephalum
Sylibum marianum
Centauria iberica
N
0
100
200
400 Meters

Appendix 1.4


En Afeq Nature Reserve
rare plant species 2010
Crusader Ponds
Mamluch Pond
Waterbuffalo Pool
Eshel Pool
Seltzer Pools
Sophia Pool
Legend
Persicaria lanigeria
Salsola soda
Festuca arundinacea
Bromus brachystachys
Rosa phoenicia
Kickxia spuria
Limonium narbonense
Paspalum paspalodus
Asparagus paleastinus
Samolus valerandi
Scirpus litoralis
Lotus tenuis
Habitat
Trees/Tamarisk
Ponds/Pools
No. of plants
1- 15
15 - 75
75 - 250
250 - 500
500 - 1000
N
0
100
200
400
Meters

Appendix 2.1: Total species plant list 2010

This list shows all the plant species that were found and identified in 2010 during both the phytosociological and the BioHAB fieldwork in the En Afeq nature reserve.

Alhagi graecorum	Euphorbia helioscopia	Pimpinella peregrina
Amaranthus blitoides	Euphorbia valerianifolia	Piptatherum miliaceum
Amaranthus virides	Festuca arundinacea	Plantago lanceolata
Ammi majus	Ficus carica	Poa infirma
Annagalis arvensis	Foeniculum vulgare	Polygonum arenastrum
Apium graveolens	Galium aparine	Polygonum equisetiforme
Apium nodiflorum	Geranium sp.	Polygonum lapathifolium
Arum hygrophilum	Glinus lotoides	Polypogon maritimus
Asparagus aphyllus	Heliotropium europaeum	Polypogon monspeliensis
Asparagus palaestinus	Helminthoteca echioides	Potamogeton nodosus
Aster subulatus	Hordeum bulbosum	Prosopis farcta
Atriplex prostrata	Hordeum glaucum	Pulicaria dysenterica
Avena sterilis	Hordeum marinum	Ranunculus aquaticus
Beta vulgaris	Inula viscosa	Rapistrum rugosum
Brachypodium distachyon	Kickxia sieberi	Rhamnus alaternus
Brassica nigra	Kickxia spuria	Ridolfia segetum
Bromus brachystachys	Lactuca serriola	Rosa phoenicia
Bromus madritensis	Lavatera cretica	Rubia tenuifolia
Bromus sterilis	Limonium narbonense	Rubus sanguinues
Capparis spinosa	Lonicera etrusca	Rumex conglomeratus
Carduus argentatus	Lolium rigidum	Rumex dentatus
Carlina curetum	Lotus palustris	Rumex pulcher
Carthamus tenuis	Lotus tenuis	Salix acmophylla
Cephalaria joppensis	Lycopus europaeus	Salsola soda
Centaurea Iberica	Lythrum junceum	Samolus valerandi
Centaurium spicatum	Lythrum salicaria	Scirpus litoralis
Chenopodium ambrosioides	Malva nicaeensis	Scirpus maritimus
Chenopodium murale	Medicago polymorpha	Scolymus maculatus
Chrozophora tinctoria	Melia azedarach	Sinapis alba
Chrysanthemum coronarium	Melilotus siculus	Sinapis arvensis
Cichorium pumilum	Mercurialis annua	Smilax aspera
Clematis flamulla	Nasturtium officinale	Solanum nigrum
Convolvulus arvensis	Ononis alopecuroides	Solanum villosum
Crypsis schoenoides	Ononis spinosa	Sonchus oleraceus
Cuscuta campestre	Onopordum cynarocephalum	Sorghum halepense
Cynanchum acutum	Orobanche aegyptiaca	Stachys viticina
Cynoglossum creticum	Nerium oleander	Sylibum marianum
Cynodon dactylon	Notobasis syriaca	Tamarix spec.
Cyperus articulatus	Panicum repens	Torilis arvensis
Cyperus fuscus	Parietaria judaica	Tribulus terrrestris
Cyperus longus	Parkinsonia aculeata	Trifolium fragiferum
Datura innoxia	Paspalidium geminatum	Trifolium purpureum
Datura stramonium	Paspalum distichum	Typha domingensis
Daucus carote	Pennisetum cladestinum	Urospermum picroides
Dorycnium rectum	Persicaria decipiens	Urtica pilulifera
Echinochloa crus-galli	Phalaris brachystachys	Verbena officinale
Ecballium elaterium	Phalaris paradoxa	Verbascum sinuatum
Echinops adenocaulus	Phoenix dactylifera	Vicia narbonensis
Epilobium hirsutum	Phragmites australis	Vicia peregrina
Eryngium creticum	Phyla nodiflora	Xanthium spinosum
Eucalyptus camaldulensis	Physalis angulata	

Appendix 2.2: Rare species in the Na'aman stream area

These species were found during several field surveys in the past 12 years.

Alisma lanceolatum
Anacyclus radiatus
Aristolochia sempervivens
Arthrocnemum fruticosum
Asparagus palaestinus
Bromus brachystachys
Cyperus alopecuroides
Elaeagmus angustifolia
Elymus elongatus
Festuca arundinacea
Juncus inflexus
Kickxia cirrhosa
Kickxia sieberi
Kickxia spuria
Lepidium latifolium
Limonium narbonense
Lotus tenuis
Paspalum paspalodus
Polygonum senegalense
Plantago crassifolia
Rumex conglomeratus
Samolus valerandi
Schoenus nigricans
Sparganium erectum
Scirpus litoralis
Suaeda splendens
Teucrium scordioides
Vigna luteola

Appendix 2.3: Invasive species in the Na'aman stream area

Scientific name	Life form	En Afeq		Kareem		Nymphyt	
		Pres.	Abun	Pres	Abun	Pres	Abun
Melia azedarach	tree	x	Low	x	Med	x	Med
Eucalyptus camaldulensis	tree	x	Med	x	High	x	Low
Aster subulatus	annual	x	High	x	High	x	High
Datura stramonium	annual	x	Low				
Verbesina encelioides	annual			x	Low		
Pennisetum clandestinum	perennial	x	Low				
Xanthium strumarium	annual	x*	Low	x	Low		
Phytolacca americana	perennial					x	Low
Schinus terebinthifolius	tree			x	High	x	Med
Parkinsonia aculeata	tree	x**	Low				
Conyza canadensis	annual	x	Med	x	Med	x	Low

Appendix 2.4: Botanical garden plant species

Lavandula stoechas
Alisma plantago-aquatica
Asparagus palaestinus
Asphodelus ramosus
Aster tripolium
Cardopatium corymbosum
Cladium mariscus
Coridothymus capitatus
Cyclamen persicum
Elaeagnus angustifolia
Euphorbia microsphaera
Frankenia hirsuta
Halimione portulacoides
Ipomoea sagittata
Iris grant-duffii
Juncus articulatus
Juncus subulatus
Kickxia sieberi
Kickxia cirrhosa
Limonium graecum
Limonium meyeri
Lotus cytisoides
Lotus tenuis
Lupinus micranthus
Nymphaea caerulea
Ophrys carmeli carmeli
Orchis laxiflora
Paronychia palaestina
Plantago crassifolia
Rumex conglomeratus
Salsola soda
Samolus valerandi
Schoenus nigricans
Serapias vomeracea
Suaeda splendens
Trachomitum venetum
Vigna luteola

Appendix 3.1: Twinspan table

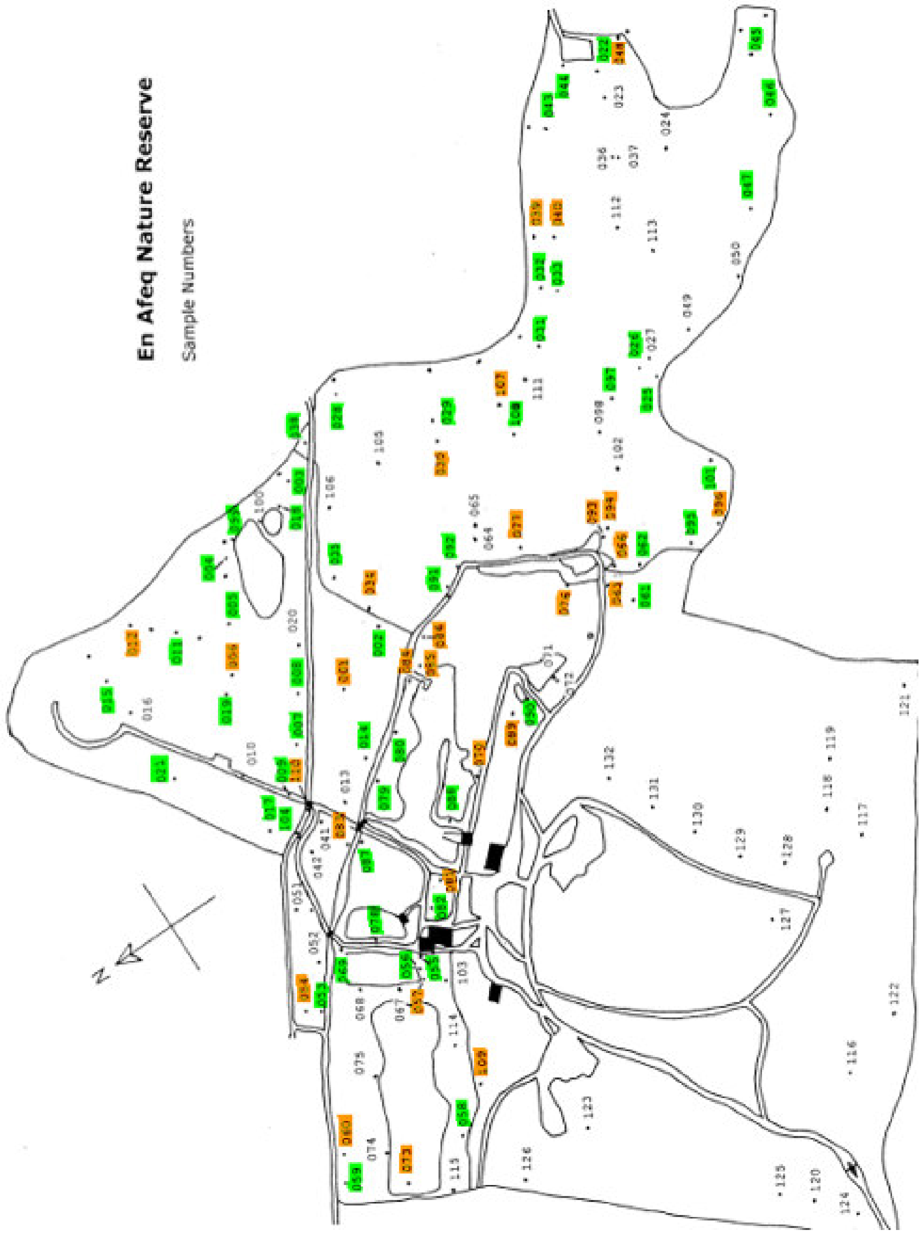
Appendix 3.2: Synoptic table

Appendix 4.1 Ortho-photo En Afeq 1995

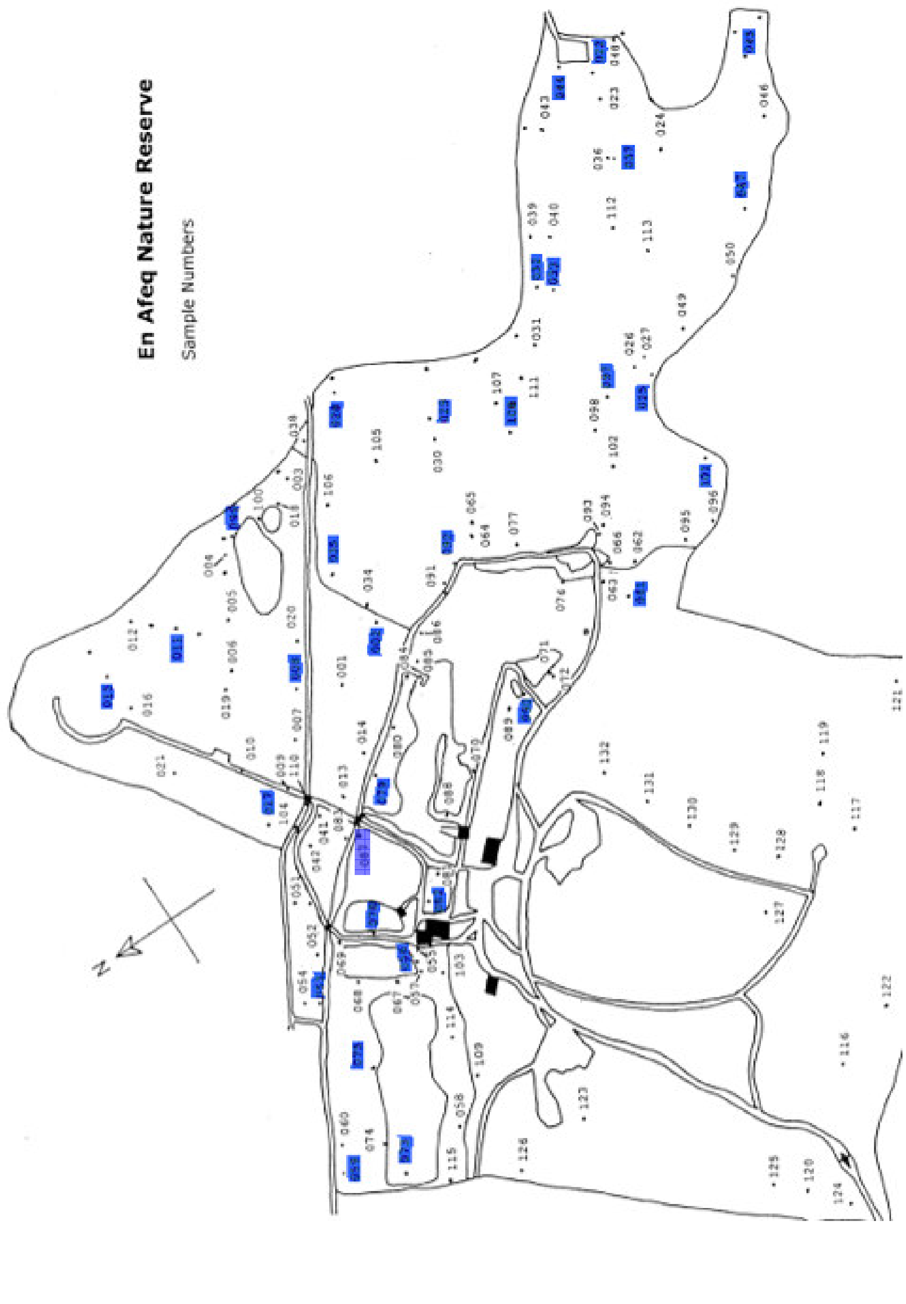
Appendix 4.2 Ortho-photo En Afeq 2002

Ortho-photo of 2002 with management measures between 1998 and 2002. The boundary of the reserve is shown by the yellow line. Areas where Tamarisk was cleared and ponds are dug and deepened are respectively shown in green and blue circles.

Appendix 5.1: Map of En Afeq with the location of relevés that where relocated during the 2010 phytosociological survey.



Appendix 5.2: Map of En Afeq with the location of relevés where soil samples were taken.



Appendix 6.1: Overview of all the phytosociological relevés of 2010 including moisture value and grazing pressure and intensity. The column *'Cluster_No'* shows in which vegetation ter the relevé is located according to the TWINSPAN analysis as described in chapter 3.1.3. The last column shows from which relevés soil samples were taken for the soil analysis (see chapter 3.1.5). The relevés coordinates are displayed in Appendix 6.2

Rel._No.	Altitude	Moisture	Grazing	Cow_Graz	Buf_Graz	Intensity	Cluster_No.	Soil_sample
1	4,5	1	1	0	1	2	9	20
2	5	1	1	0	1	1	9	28
3	6.5	1	1	0	1	1	8	-
4	6	1	1	0	1	1	9	-
5	6.5	1	1	0	1	3	8	29
6	7.5	1	1	0	1	2	8	-
7	6	1	1	0	1	1	9	-
8	7	1	1	0	1	2	5	-
9	6,5	1	1	0	1	3	8	-
10	5	1	1	0	1	3	8	-
11	5	1	1	0	1	2	9	21
12	5	2	1	0	1	3	2	-
13	5	1	1	0	1	1	6	-
14	5	1	1	0	1	3	8	24
15	6,5	1	1	0	1	1	4c	-
16	5,5	2	1	1	0	1	5	9
17	4,5	2	1	1	0	1	4c	7
18	6	2	1	1	0	2	4b	8
19	5	1	1	1	0	2	5	5
20	5	2	1	1	0	1	4b	6
21	5	2	1	1	0	1	4b	-
22	6,5	2	1	1	0	1	4c	-
23	5,5	2	1	1	0	2	4b	10
24	6,5	1	1	1	0	2	5	11
25	7	2	1	1	0	1	4a	25
26	6	2	0	0	0	0	4b	23
27	4,5	2	1	1	0	1	4b	-
28	6,5	1	1	1	0	2	5	22
29	5,5	2	1	1	0	2	4a	12
30	5	2	0	0	0	0	4b	-
31	6,5	3	0	0	0	0	3	13
32	6	1	1	1	0	2	6	3
33	5,5	2	1	1	0	2	5	2
34	5,5	1	1	1	0	2	8	18
35	6	2	1	1	0	1	6	1
36	5,5	2	0	0	0	0	6	26
37	5,5	2	0	0	0	0	3	-
38	4	2	0	0	0	0	4a	4
39	6,5	3	0	0	0	0	3	14
40	5,5	2	0	0	0	0	4a	-
41	5	2	0	0	0	0	4b	15
42	4,5	2	0	0	0	0	4c	-

43	7	2	0	0	0	0	4c	17
44	6,5	2	0	0	0	0	3	-
45	7,5	2	1	1	0	1	4b	-
46	6,5	2	0	0	0	0	3	16
47	5,5	2	0	0	0	0	4a	-
48	7	2	0	0	0	0	2	19
49	5,5	2	0	0	0	0	4c	-
50	6,5	2	0	0	0	0	5	30
51	5,5	2	0	0	0	0	4b	4
52	5	2	1	1	0	2	4a	-
53	5	2	0	0	0	0	3	27
54	5,5	1	0	0	0	0	4b	-
55[34]	4	3	3	0	0	0	-	31

[34] This relevé was not included in the phytosociological survey and did not belong to one of the 115 relevés of Burgerhart

Appendix 6.2: Coordinates and location of relevés. The coordinates are displayed in the Israeli coordinate system. Relevé number 55, indicated by the red circle was not included in the phytosociological survey. This relevé was especially assigned for soil sample analysis.

	E_coord	N_coord		E_coord	N_coord		E_coord	N_coord		E_coord	N_coord
1	211003	750459	**15**	211500	749740	**29**	211012	749976	**43**	210987	750335
2	211137	750531	**16**	211402	749558	**30**	211108	750172	**44**	211018	750296
3	211021	750427	**17**	211488	749710	**31**	211128	750127	**45**	211005	750341
4	211230	750514	**18**	211452	749800	**32**	211276	750079	**46**	210841	750368
5	211223	750440	**19**	211311	749898	**33**	211340	750117	**47**	210902	750295
6	211298	750255	**20**	211303	749885	**34**	211120	750250	**48**	210969	750153
7	211274	750270	**21**	211261	749946	**35**	211183	750248	**49**	210980	750440
8	211269	750346	**22**	211342	750591	**36**	210644	750593	**50**	210827	750509
9	211213	750369	**23**	211263	749645	**37**	210624	750473	**51**	211203	749987
10	211055	750391	**24**	211187	749826	**38**	210808	750401	**52**	211184	749867
11	211091	750368	**25**	211203	749821	**39**	210802	750410	**53**	210608	750546
12	211135	750418	**26**	211068	749846	**40**	210855	750465	**54**	210938	750390
13	211333	750205	**27**	211012	749886	**41**	210844	750426	**55**		
14	211271	750324	**28**	210984	749999	**42**	210944	750385			

Appendix 7a: BioHAB recording form for areal elements

Observers: Date: Location:

code	Field 1	Field 2	Field 3	Field 4	Field 5				Field 6	Field 7
α	General Habitat Category	Global/ Env. Qualifier	Site Qualifier	Man. Qualifier	Habitats/Species				Annex I	Farmland Class
					Full list of Habitats	%	Species	%		

Appendix 7b:

Appendix 8: Photographs