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CENTRO

AN INTERNATIONAL JOURNAL OF ENVIRONMENT STUDIES IN THE MEDITERRANEAN

UNIVERSITY OF MALTA

Foreword

The present issue of CENTRO is dedicated entirely to a single topic: the biology of a saline marshland reserve in Malta, i.e. the Għadira Reserve. The Maltese Islands are generally poor in vegetation and rapid urban development during recent years, coupled with a very high population density, have seriously threatened the rather limited number of important natural habitats. Efforts to designate and conserve such areas as nature reserves have not always met with success. However, in the case of Għadira, which stands like an 'oasis' in the northern rocky part of the mainland, we were much more successful and for a number of years it was the only officially designated reserve in Malta. This reserve is a site of great scientific and educational interest. It is one of the few surviving habitats in the Central Mediterranean, which is utilised by a number of migratory birds as a temporary resting station on their migratory routes between Europe and Africa, and is a good wintering site for others.

During a one-day public Seminar held in April 1988 and organised by the Department of Biology of the University of Malta, a number of papers were presented which included new information on the natural environment of this site. These papers form the basic material for the present issue of CENTRO. In presenting this material at an international level, we hope to be making a significant contribution towards the better understanding of such saline marshlands in the Central Mediterranean as well as increasing the public awareness of their scientific interest and need for protection and good management.

The Editorial Board of Centro is planning to publish a number of future issues of this journal which will be similarly dedicated to single environmental themes. We welcome any suggestions from the ever - increasing number of our readers, for CENTRO suitable topics which would be directly relevant to the natural environment of the Central Mediterranean.

Professor Victor Axiak
General Editor,
CENTRO

11th December 1990.

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An Introduction to the Għadira Nature Reserve

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The Għadira Nature Reserve, which covers approximately six hectares, lies roughly 100 metres inland from the water's edge at Mellieħa Bay, while on the opposite side (to the west) the sea at iċ-Ċumnija, a rugged rocky coast, is about one km. distant.

On mid-sixteenth century maps the site is indicated as *Saline* and in fact at that time the area was one of the main producers of salt in Malta. With the building of the salt-pans at Qawra, the Għadira area started to be indicated on the maps as *Saline Vechie* or *Saline Vecchie*.

After a number of years of being unused as salt-pans the area was gradually being covered by soil carried down during the rainy season mainly from the extensive northern hill side.

When Għadira started to emerge as a site of natural scientific importance it consisted mainly of a clayey depression, dry in summer but flooded during the winter months, surrounded by a salt marshy plant community. This 'oasis' in the midst of a comparatively arid limestone environment, lying at sea level, and bounded by some cultivated fields and a rocky karstic area, provided a diversity of microhabitats quite rich in flora and fauna and an ideal spot for migratory birds.

In the mid-sixties the area was threatened by the building of a new coastal road, which was planned to go right through the centre of this natural niche. The Malta Ornithological Society, which at that time was incorporated with the Natural History Society of Malta, quickly alerted other bodies interested in conservation to this development and the Government took steps to revise its project and leave the pool intact. This decision was received with joy not only by the local small group of naturalists but also by foreign conservation organisations. This is how it was commented upon in the International Council of Bird Preservation's bulletin *The President's Letter* (No. 9 Sep 1966):

> "It was therefore with much satisfaction that a letter was received from the Office of the Prime Minister of Malta, dated 14th May 1966, stating that the plans for the

new Għadira Road ensure that the pond will be by-passed and left untouched. This action of the Government of Malta will be greatly appreciated in many other countries and is a valuable contribution to the international preservation of migratory birds."

In 1967 the Malta Ornithological Society published a report on the natural and historical features of Għadira and was presented to the House of Representatives requesting the conservation of the area and the creation of the first nature reserve on the islands.

In the mid-seventies the increasing popularity of the site as a weekend picnic area was posing a new threat to this ecological site. From late spring to early autumn cars were being driven onto the area, while the dry bed of the pool was frequently being used as a football pitch as well as a parking place.

In the meantime, the area was still being leased by Government for bird-hunting and this continued until 1978 when the area was legally declared a bird sanctuary. This occurred after the Government accepted the plans for the setting up of the reserve prepared by Mr Herbert Axell, a land-use adviser, who was brought over from the U.K. by the Malta Ornithological Society with the help of the Royal Society for the Protection of Birds, with whom he had served as warden of Minsmere Bird Reserve for several years.

His main plans involved widening the surface area of the pool, creating islands of different levels, digging a deep area which could be used as a reservoir at the back and digging a surrounding ditch, and using most of the spoils to build an embankment along the whole length of the ditch.

The work could start by hiring a contractor with an initial sum of US$25,000 donated by the World Wildlife Fund on the initiative of the Malta Ornithological Society. And the machines rolled onto the area in May 1980.

Due to the nature of the pool bed all the heavy engineering works had to be carried out in the dry season and in fact it was executed in three phases during three consecutive summers.

By August 1982 two thirds of the works were completed. Those of us who were involved in the project as well as all other local naturalists were shocked to see the infliction of huge scars in such an area but Mr. H. Axell's plans were quite convincing and when all works were finished and the rainwater washed the scars, nature took over again.

Apart from the habitat engineering work, a bird-watching hide was built with a donation from the Malta Bird Reserves Overseas Committee while a visitor's centre, which houses an interpretive room, was also built by the Malta Ornithological Society with a contribution by Mid-Med Bank.

The Malta Ornithological Society was also engaged in the organisation of voluntary work which included the planting of shrubs and trees, supplied by the Department of Agriculture, fencing and screening.

Soon the mud and brackish water became enriched with life and various species of migrant birds started to visit the reserve and stay for winter. And when it rained heavily and rainwater rushed towards the beach in a continuous stream the Grey Mullet *Mugil cephalus* swam towards the pool to find a new home. Several specimens of rare species of flora such as *Carex extensa* and *Pancratium maritimum* which were being exterminated from the bay area with the building of the new road, were transplanted in the reserve area and have thrived in the new environment.

Due to the unfortunate local circumstances regarding bird shooting, apart from digging the defensive ditch, the area had also to be fenced to keep intruders out.

With the posting of a warden at Għadira by the Government Environment Division, a lot of work such as tree planting, has been carried out, while school visits have been organised on a regular basis. The Għadira reserve, with its rich flora and fauna has been designed to help bring

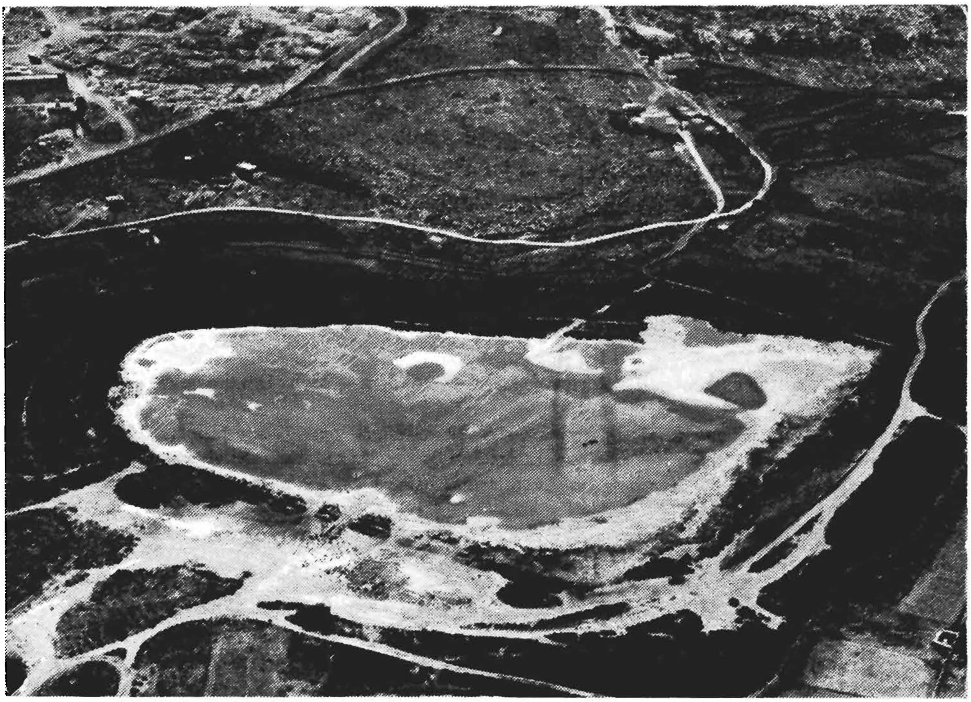

Plate 1: Aerial view from the N.E. of the pool at Għadira prior to the habitat engineering works which started in 1980. (Courtesy of the Department of Information, Malta)

Plate 2: A recent (Feb. 1991) aerial view from the S.E. of the Għadira Nature Reserve. (Photo: Joe Sultana)

about a change in mentality towards nature, birds in particular, especially in the younger generation. Here they can watch and study birds feeding quietly and compare them with the lifeless stuffed effigies in private collections.

Here they can observe closely how nature works and how beautiful nature is. Għadira is a living museum, which is already being used as a scientific and educational medium where various species can be seen to take advantage of a safe environment. Mammals such as the hedgehog *Erinaceus algirus*, reptiles such as the Occellated Skink *Chalcides ocellatus*, insects and other living organisms including an interesting salt-marsh flora combine to make Għadira a fine example of conservation. Here, conservation was not only made but was seen being made.

ANNOTATED LIST OF REPORTS ON GHADIRA IN CHRONOLOGICAL ORDER

1967 - **Report on the natural and historical features of Għadira** — Malta Ornithological Society.

This report includes mainly information about flora, fauna, geology and history of Għadira. It was presented to the Malta House of Representatives by the M.O.S. when the area was threatened by the building of a road. At that time the M.O.S. was associated with the Natural History Society of Malta.

1978 - **Għadira-proposals for development as a National Nature Reserve** - Herbert Axell.

This report, which includes details of the proposed development of the site into nature reserve, was presented to the Malta Government and to the Malta Ornithological Society.

1980 - **Report on Għadira prepared by the Natural Environment Study Section of the Society for the Study and Conservation of Nature** — C. Savona Ventura, S.P. Schembri, E. Lanfranco, P.J. Schembri, G. Lanfranco, J. Schembri.

This report was issued by the S.S.C.N. as it feared that some of the proposed changes to Għadira might be detrimental to certain animal and plant species found in the region. It outlines the general features of the area and stresses the scientific importance and uniqueness of the pool and its environs.

1980 - **Għadira National Nature Reserve** — H.E. Axell

This report was made after the first phase of the habitat engineering work was carried out in summer 1980. It outlined how the available funds should be used and what future work with excavating machines was necessary. This document was sent to the Malta Ornithological Society so that together with the Development Plan of 1978 it would be circulated to all concerned to facilitate discussion on the project.

1980 - **Għadira Malta: Development as a national nature reserve** — H.E. Axell

This paper was presented at the 12th Conference of the European Continental Section of the International Council for Bird Preservation — Malta November 1980. In his paper Mr Axell outlined the plans for developing Għadira as a national nature reserve.

1981 - **Second report on Għadira** — Society for the Study and Conservation of Nature

This report was issued by the Committee of the Society for the Study and Conservation of Nature and was based on a draft report prepared by P.J. Schembri. It outlines the diversity of habitats at Għadira and makes a number of recommendations aimed at reducing the negative impact of the habitat engineering works on the vista of the reserve.

1981 - **The Għadira Development Plan: a reappraisal** — M.A. Thake. A report which evaluates the feasibility of the second phase of Axell's Għadira Development Plan.

1982-83 - **Għadira — the making of a reserve — Parts I & II.** *Bird's Eye View* Nos. 5 (pp11 - 14) + 6 (pp4 - 8) — (J. Sultana ed.)

This report which appeared in two parts gives detailed information of all the work which was being carried out at Għadira to turn it into a nature reserve according to Axell's plan.

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The Għadira Reserve: Physico-chemical Characteristics of the Pool

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Introduction

The Għadira Reserve is the largest saline marshland in the Maltese Islands. It is a protected bird sanctuary and a review of its development may be found in Sultana (1990) and a more detailed description of the area is given in Borg *et al.* (1990)

This paper will present data on the physico-chemical parameters in the waters of this marsh as recorded from four fixed stations over a period of one year (May 1985 - April 1986). The purpose of this investigation was to provide information to the ecological study of the Għadira pool (Borg *et al.*, 1989) and thus to contribute towards the basic environmental information which is essential for the correct management of such reserved areas.

The present Għadira marsh complex consists of a central pool with a number of small artificial 'islands' *(Figure 1)*. The pool is surrounded by a embankment and a ditch to limit public access to the area. Furthermore, the ditch was designed to collect rainwater and drain it into a freshwater reservoir constructed on the west side of the pool at the farthest side from the sea. This reservoir was to supply the central pool with enough water throughout the year and thereby to prevent its drying up during the summer months (Axell, 1980). The Għadira marsh complex is separated from the sea (Mellieħa Bay) by a road and a narrow sandy beach which together are approximately 100m wide.

Methods

Four sampling stations were selected as indicated in *Figure 1*, namely:

Station 1: Ditch
Station 2: East side of the pool, nearest to the sea
Station 3: South side of the pool
Station 4: Reservoir

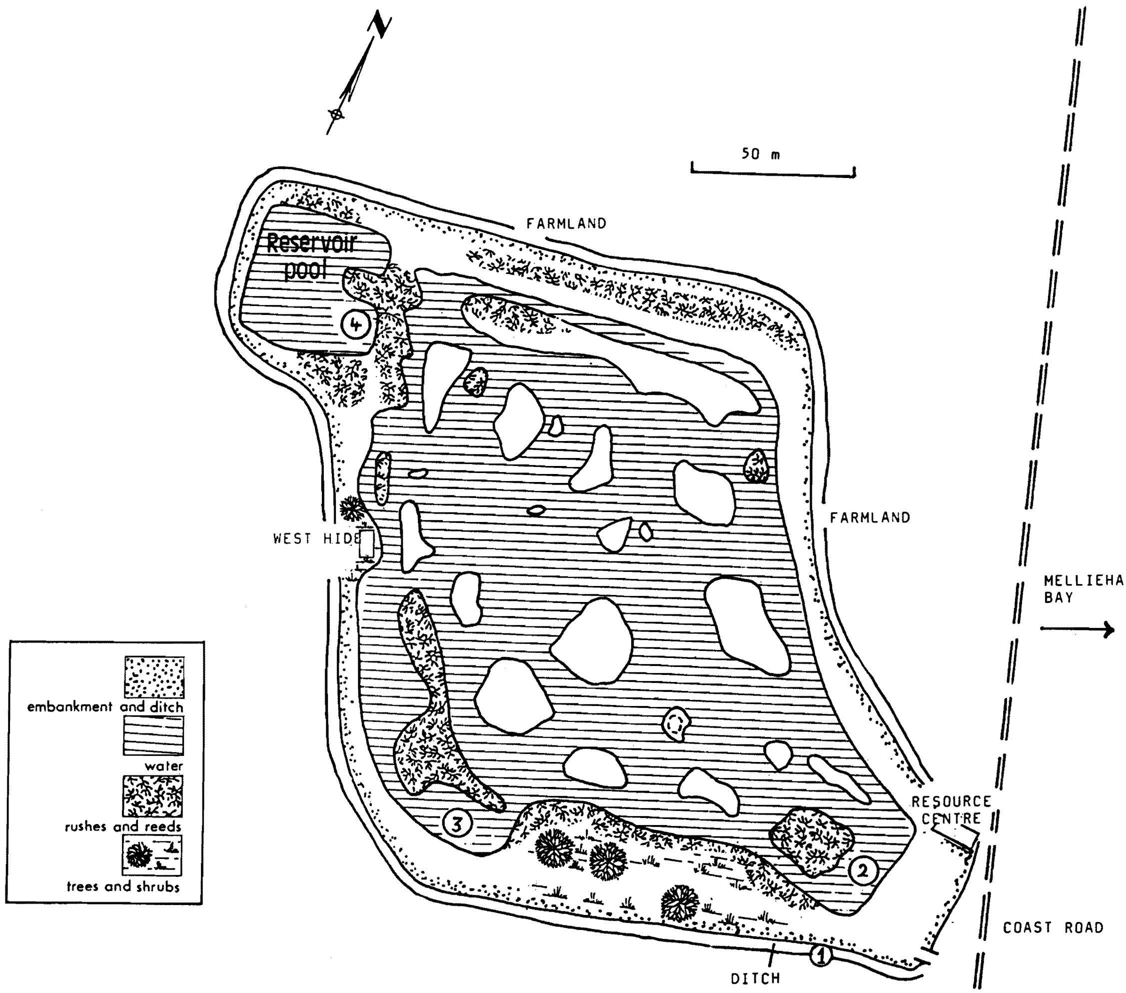

Fig. 1: The Għadira Reserve, showing location of stations for the monitoring of physico-chemical parameters.

We were not permitted to sample at the central region of the pool because of possible interference with bird activity.

At each station, monthly readings of water depth, temperature, salinity (as measured by a salinity/temperature meter Bridge Type M.C. 5) and dissolved oxygen levels (using a YSI Model 54A oxygen meter fitted with a probe model 5739) were taken at the surface and at the bottom. pH was measured using a Griffin field pH meter. Moreover, at each station, water samples were taken from the surface and from the bottom for analysis of suspended matter, chlorophyll *a* content, nitrates, nitrites and dissolved phosphates. These analysis were carried out by methods described by Strickland and Parsons (1972).

Results

The various parameters as measured at the surface at the four different stations from May 1985 to April 1986, are presented graphically in *Figure 2.* These parameters as measured at the

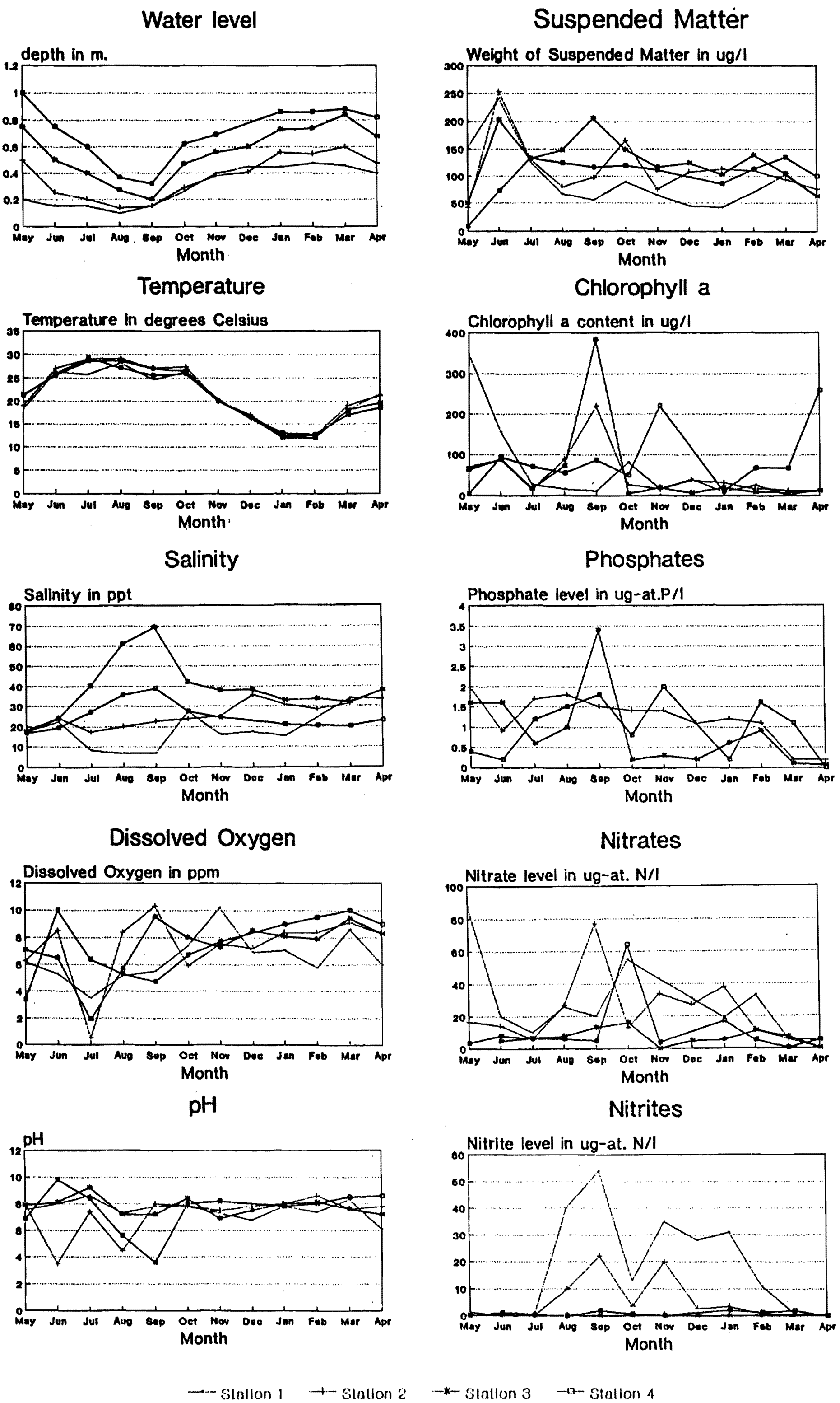

Fig. 2: The Għadira Reserve: Monthly values for the various physico-chemical parameters measured at four different stations.

bottom of each station did not differ significantly than those measured at the surface. This is due to the shallow waters at the four stations sampled, with the mean annual water depths varying from 30 to 70cm. *Table 1,* shows the mean annual values for each parameter at each station, together with the coefficient of variation for each. The latter is expressed as a percentage and shows the relative amount of variation between the different means. For example, while pH shows the smallest range of variation over the period of study, chlorophyll *a* and nutrients show very wide ranges of fluctuations.

The water depth at all four stations remained shallow throughout the year, and this partly explains the wide fluctuations in the other parameters. The lowest depths were recorded in August and September, when evaporation reached a maximum as water temperature peaked at 29 °C. A minimal water temperature of 12 °C was recorded in January/February.

Salinity fluctuations were especially high in *Station 1,* ranging from 7.00 to 33.9 ppt. Annual mean salinities within the pool itself, varied with location, so that while *Station 2,* was found hyposaline (26.3ppt), *Station 3* was hypersaline (38.9ppt). *Station 2* became hypersaline only in April, while *Station 3* remained hypersaline from August to December, with a maximum of 69.4 ppt being recorded in September. This was in fact the highest salinity recorded within the whole area during this study. The reservoir *(Station 4)* was generally brackish with salinities

TABLE 1. Mean values of parameters measured with coefficients of variation.

	Station 1		*Station 2*		*Station 3*		*Station 4*	
Water level (m)	0.3	51%	0.37	44%	0.56	36%	0.7	30%
Temperature (°C)	20.8	27%	21.7	28%	21.3	28%	21.5	30%
Salinity (ppt)	19.2	49%	26.3	25%	38.9	37%	25.0	28%
Oxygen (ppm)	6.5	27%	7.4	33%	7.4	28%	8.1	42%
pH	7.5	2%	7.2	2%	7.8	8%	7.6	22%
Susp. Matter (µg/1)	93.4	61%	112.0	48%	128.0	37%	120.0	36%
Chloro. a (µg/1)	62.0	162%	52.5	113%	58.0	183%	90.0	91%
Phosphates (µg-at P/1)	6.9	124%	1.2	48%	0.88	109%	0.98	71%
Nitrates (µg-at N/1)	29.6	80%	22.5	92%	28.0	261%	11.2	161%
Nitrates (mg-at N/l)	17.9	106%	5.3	148%	0.21	67%	0.89	90%
N/P ratio	14.0	78%	22.6	79%	35.0	142%	38.8	145%

fluctuating from 16.9 ppt in May to a maximum of 39.0 ppt in September.

Oxygen levels were generally high at all stations except in July, when near-anoxic conditions were recorded at *Stations 2* and *3*. These coincided with the warm summer period immediately after a phytoplankton bloom as reported below. Annual pH means were about 7.5 and as would be expected, pH fluctuations were minimal, the only exception being *Stations 2* and *4*, where pH values of 3.5 were sometimes measured.

Levels of total suspended matter as well as of chlorophyll *a* were generally high at all stations throughout the year. Most stations may be described as eutrophic with algal blooms being evident. Primary productivity as measured by chlorophyll *a* levels was minimal for all stations in July, October and January.

Nutrient levels were also high at all stations, with wide fluctuations being reported both for phosphate and nitrate concentrations. Annual mean N/P ration values ranged from 14 to 38.8, but the large coefficient of variations indicate that these mean values are of little significance. In fact, phosphate levels were generally high with N/P ratios being less than 10 for many months at all stations. Nitrite levels were surprisingly high in *Stations 1* and *2*, with maximum values of 40 and 20 μg-at N/1, respectively. Nitrates exceeded nitrate values in *Station 1*, during August September and January indicating strong reducing conditions during these periods.

An attempt was made to model phytoplankton primary productivity as measured by chlorophyll *a* content in terms of the other parameters within the main pool itself *(Stations 2 and 3)*. This was done by multiple regression analysis (Sokal and Rohlf, 1981). The purpose was to estimate and fit a structural model to 'explain' variation in the observations of chlorophyll *a* content, in terms of the other independent variables.

A study of the complete correlation matrices between the various parameters indicated that except for water level, temperature and salinity, most other variables were not well correlated with each other. This means that they may be considered to be independent of each other in most cases and may not be left out of a regression model to explain chlorophyll content. Factor analysis also supported this idea.

The 'best fit' multiple regression equation for *Station 2* was found to be the following:

$$[\mathrm{Chl}\,a] = 209.3 - 2.50\,X_1 - 5.33\,X_3 + 12.31\,X_4 + 5.64\,X_5 - 0.25\,X_6 - 46.37\,X_8 + 2.67\,X_9 - 5.60\,X_{10}$$

and for *Station 3*, this was found to be:

$$[\mathrm{Chl.}\,a] = 144.7 - 3.17\,X_1 - 9.51\,X_4 + 5.43\,X_5 - 1.08\,X_6 + 105.58\,X_8 - 0.48\,X_9 + 181.65\,X_{10}$$

where:

X_1 = water level in cm;
X_3 = salinity in ppt;
X_4 = dissolved oxygen in ppm;
X_5 = pH;
X_6 = suspended matter in μg/1;
X_8 = phosphate level in μg-at P/1;
X_9 = nitrate level in μg-at N/1;
X_{10} = nitrite level in μg-at N/1.

The first regression model accounted for 81.4% of the variance while the second model accounted for 96% of the variance of chlorophyll *a* jointly explained by the rest of the variables. Both models were statistically significant at $P<0.05$.

One must note that any variables left out of the predictor set are not necessarily unimportant. They may simply be correlated with other variables in the predictor set.

Discussion

The Għadira marsh may be considered as a small and highly complex microcosm. It is surrounded on one side by the sea and on the other sides by agricultural land, much of which is intensively cultivated. Three types of boundaries through which this microcosm interacts with the rest of the surrounding environment may therefore be identified. These are:

(a) that *with the atmosphere* (eg. rainfall, fallout of marine aerosol spray carried from the nearby sea and possibly of aerosol droplets of chemicals applied to the surrounding fields);

(b) that *with the bottom sediments* through which seawater may seep through from the nearby bay or through which ground water from the surrounding fields may reach the area;

(c) that *with surrounding surface land* through which agricultural water runoff may reach the marsh.

The relatively small volumes of water within the marsh and the complex nature of its interactions with the surrounding environment result in a wide range of fluctuations of most of the physico-chemical parameters of the pool water as measured in the present study.

A study of Lago Patria which is a small brackish lagoon near Naples (Italy) has similarly shown wide fluctuations in the physico-chemical parameters monitored, with comparable peak values of phosphates, nitrates, nitrites and chlorophyll *a* being reported (De Rosa and Rigillo Troncone, 1981).

The present study has made a contribution towards our understanding of the water budget within the Għadira marsh. During the period under investigation, no water was pumped into or taken from the reservoir *(Station 4)* to be utilised in the main pool. Therefore the input of water into the pool was only through rainfall, seepage and drainage from the surrounding land. Moreover seawater may have reached the pool through the ditch during sea incursions, especially during periods of high wave action. For example, the sudden increase in salinity in the ditch *(Station 1)* in October, occurring after a period of heavy rainfall and rough weather and can only be explained by incursions of seawater into the ditch. Seepage of seawater through the strata of compacted beach sand and soil was most evident during the summer months. Moreover, during these months, loss of water from the main pool resulted in the formation of isolated small pools, such as at *Station 3,* which attained the characteristics of rockpool with salinities higher than 38 ppt for at least six months of the year.

The high nutrient levels recorded in all stations at least during most months is probably due to agricultural run off from the nearby fields. This was confirmed by the fact that after heavy rains in September/October, nitrate contents in the ditch *(Station 1)* reached maximum levels.

Phytoplankton blooms were evident during two periods of the year, namely: May/June and August/September. The May/June algal blooms were apparently triggered by an increase in temperature, since nutrient levels were generally high and non-limiting. This was followed by a period of fast decomposition, with near-anoxic conditions in the main pool. During the subsequent summer phytoplankton bloom, macroalgal blooms of *Cladophora* sp. and *Enteromorpha intestinalis* among others, could also be seen to cover the water surface almost completely, especially in *Stations 2* and *3.*

Moreover, this study has shown, through a multiple regression analysis, that phytoplankton primary productivity in similar habitats is dependent on a large number of physico-chemical parameters which interact in a complex manner. Furthermore, the fact that different models had to be used to explain productivity in two stations within the main Għadira pool indicate that during the periodic drying up of some of its areas, isolated smaller pools are formed, each of which may be considered to be a self-contained microcosm. This further illustrates the complex nature of such small systems which are bordered by agricultural land and the sea.

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Ecology of the Għadira Pool Macrofauna (Għadira Nature Reserve, Maltese Islands, Central Mediterranean)

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ABSTRACT

Sediment and water samples were collected quantitatively from three stations in the pool within the Għadira Nature Reserve at monthly intervals over a period of 12 months (May 1985-April 1986). The macrofauna within these samples was sorted into species and counted to provide estimates of population density and abundance, and of their fluctuation with season.

Five species dominated the samples: *Ventrosia ventrosa* (Gastropoda), *Cerastoderma glaucum* (Bivalvia), *Orchestia gammarellus* (Amphipoda), *Lekanesphaera hookeri mediterranea* (Isopoda) and the larvae of an unidentified species of Chironomidae (Diptera). Other species present in lower numbers included: *Truncatella subcylindrica* (Gastropoda), *Ovatella myosotis* (Gastropoda), *Gammarus aequicauda* (Amphipoda), larvae of *Sratiomys longicornis* and an unidentified species of Syrphidae (Diptera), four different species of Hydrophilidae (Coleoptera), and the fish *Liza ramada* and *Aphanius fasciatus.*

Overall species richness was low but individual species reached very high population levels: the most abundant species were *Ventrosia ventrosa* and *Cerastoderma glaucum* with average population densities of 15,000-52,000 individuals/m^2 and 4000-4600 individuals/m^2, respectively, over the study period. Benthic diversity was higher than diversity in the water column. Population density of most species fluctuated with season. Three patterns were observed: strongly unimodal (as shown by *Orchestia gammarellus,* strongly bimodal (as shown by the chironomid larvae), and populations which were maintained throughout the year with occasional peaks (as shown by *Ventrosia ventrosa, Cerastoderma glaucum* and *Lekanesphaera hookeri*). Populations of different species peaked at different times and for a given species, populations in different stations peaked at slightly different times and reached different levels. In many cases, the timing and amplitude of the population peaks could be correlated with changes in the physico-

chemical parameters affecting the pool; however, different species were affected by different factors or combinations of factors. In some cases, low population densities could also be correlated with changes in pool chemistry, mainly low dissolved oxygen concentrations.

Spatial variation in the pattern and/or amplitude of population fluctuations was noted for certain species. In general, this seemed to be correlated primarily with the varying nature of the substratum, the degree of water level fluctuations and the blooming of micro- and macroalgae in the different parts of the pool.

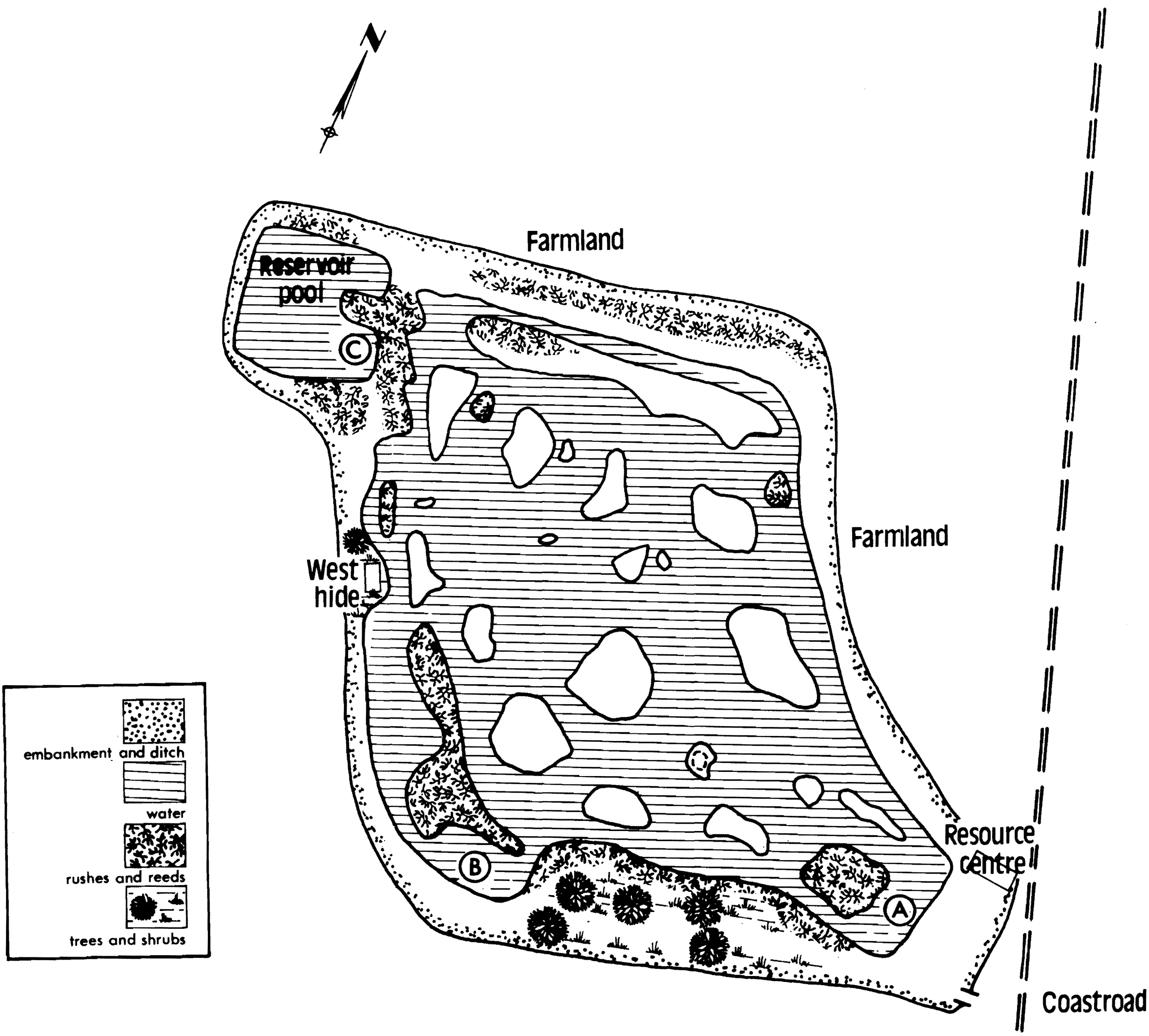

Fig. 1: Map of the Għadira Nature Reserve showing location of the three sampling stations.

Introduction

Saline marshland occupies less than 0.5% of the 190km coastline of the Maltese Islands. The Għadira marsh, situated on the northeastern coast of Malta at Mellieħa Bay, and covering an area of c.6 hectares, is the largest such habitat in the islands.

On the microtidal Maltese shores (mean tidal range 0.06m, spring range 0.15m; U.S. Dept. of Commerce, 1985), saline marshlands are maintained by seasonal changes in water level rather than by tidal fluctuations. These changes are controlled by the annual cycles of temperature and precipitation which define two ecological seasons: a wet season (October to March) during which falls c.70% of the total annual rainfall (which averages c.530mm) and with a mean temperature range of 11.0-18.0°C; a dry season (April to September) during which falls c.30% of the total annual rainfall and with a mean temperature range of 18.1-26.3°C (Mitchell, 1961).

The Għadira marsh is situated on the northeastern tip of a downthrown block of limestone between two SE to NW running parallel normal faults, which define Marfa Ridge to the north and Mellieħa Ridge to the south. The Għadira graben is tilted downwards to the northeast (Pedley *et al.*, 1976). The northeast shore of the graben is therefore surrounded by higher land on three sides and this has resulted in alluvial and colluvial deposits accumulating at Għadira. The saline marshland known as the Għadira marsh develops on these deposits. On the seawards side, this marsh is bounded by the sandy shore of Mellieħa Bay. A system of sand dunes develops at the back of the beach, forming a boundary between the marshland at Għadira and the beach. The marsh substratum consists of beach sand towards the northeast. The substratum becomes predominantly alluvial deposit towards the southwest.

Previous to 1980, a pool of water formed in the centre of the Għadira marsh during the wet season and then gradually dried up until by mid-summer, it was completely dry. Thake (1981) has discussed the dynamics of this process. According to his model, the pool formed partly by accumulation of rainwater, directly, and from surface runoff from the surrounding high ground, and partly by incursion of seawater directly from Mellieħa Bay during heavy seas and indirectly through seepage through permeable strata. During the dry season this water evaporated, the pool becoming progressively more saline until it dried up completely leaving a deposit of salt in the soil. The greater part of this salt was washed back to the sea by overflow from the pool during the following wet season.

In 1980 habitat engineering work was started in the Għadira area as part of a plan to turn the Għadira marsh and part of the surrounding land into a bird sanctuary with restricted access (Axell, 1980; see also Malta Ornithological Society, 1979, 1981, 1982, 1983a, b; Sultana, 1990) The main aim of the work was to deepen the central pool such that it would retain some water all the year round. Additionally, a ditch and embankment were constructed round the perimeter of the protected area, a reservoir was excavated to the west of the pool and several artificial islands were created within the pool itself. This work was completed by 1984. Although the protected area is legally a bird sanctuary (Government of Malta, 1980), it has functioned as a nature reserve since its inception (Sultana, 1990). The reserve was officially opened on 10 May 1988.

Few studies on the pool biota were made prior to the habitat engineering work in 1980 and in the main these consisted of non-quantitative species lists and habitat descriptions. These works have been summarised by Lanfranco (1967), Savona Ventura *et al.* (1980) and Schembri (1981).

The present work gives the results of a study of the pool macrofauna carried out after completion of the habitat engineering works as part of a larger study on the ecology of the Għadira Nature Reserve and is a companion paper to the study of Hili *et al.* (1990) on the physico-chemical characteristics of the pool.

Material and Methods

Samples were collected from the three stations indicated in Fig. 1. These stations were chosen as being representative of the different substratum types in the pool. Station A, the closest to the coast, had a bottom predominantly of sand, while the bottom at station C, which was situated in the 'reservoir' (originally designed to dilute the main saline pool with freshwater; Axell, 1980), was of hard, compact, clayey soil. Station B had a substratum intermediate between that of stations A and C.

Quantitative samples of the benthic and pelagic macrofauna were collected from each station at monthly intervals over the period May 1985 to April 1986. Benthic forms were sampled using a hand-operated corer of circular cross-section. The cores, which were take at randomly selected locations within a given station, had a surface area of $0.038m^2$ and variable depth depending on the compactness of the bottom sediment, but since all infauna was found to penetrate no deeper than 3cm, only the top 5cm of each core were processed. Cores were sieved through 2.0mm mesh and all animals retained were sorted by hand under a stereomicroscope, preserved in 70% ethanol, identified and counted.

Pelagic samples were taken using a 50cm diameter plankton net (mesh size 1.0mm) with an attached float in order to keep it just below the water surface. The net was transported a measured distance into the pool and towed to land by hand. When the water was too shallow to allow towing of the net without contact with the bottom, a known volume of water collected from the pool using a bucket was strained through the plankton net. Pelagic samples obtained in this way are indicated by an asterisk in Tables 2-4. All animals retained by the net were preserved in 70% ethanol, identified and counted.

No samples were taken from station C in December 1985 because of the presence of birds in the reserve, since the sampling procedure would have disturbed them.

Community parameters were calculated as described in Brower and Zar (1977). Data on the physico-chemical parameters of the pool were obtained from Hili *et al.* (1990).

Results

Species Survey

Table 1 lists the 13 macrofaunal species which occurred in our samples.

The Għadira hydrobiids belong to the *Ventrosa ventrosia* species complex as defined by Giusti and Pezzoli (1984). These gastropods occurred in both benthic and pelagic samples since although found mainly on the bottom sediment, they also crawled on strands of floating algae or beneath the waters' surface film. Although predominantly herbivores and deposit feeders, *V. ventrosa* were observed gathering on dead fish, presumably to scavenge. Both *Truncatella subcylindrica* and *Ovatella myosotis* occurred only in benthic samples, the latter however was absent from the reservoir. Although predominantly infaunal, some *Cerastoderma glaucum* were found in pelagic samples, as individuals occasionally attached themselves to strands of floating algae, mainly *Cladophora*.

Individuals of *Orchestia gammarellus* aggregated close to the pool edges especially in cracks and irregularities on the bottom but also on floating strands of *Enteromorpha intestinalis* during blooms of this alga. *Orchestia gammarellus* were thus present in both benthic and pelagic samples.This species was observed to mate in May. *Gammarus aequicauda* occurred only in the vicinity of station A where it was found just at the edges of the pool and under stones bordering the pool edge. This species was not present in the quantitative samples. Apparently, *Gammarus aequicauda* only invaded Għadira after the habitat modifications were made, presumably because of the year-round supply of saline water now available (Moore and Schembri, 1986).

Lekanesphaera hookeri mediterranea is better known under its older generic name of *Sphaeroma;* it has been recently transferred following a revision of this genus by Jacobs (1987). Individuals were observed either swimming in the water column or foraging on the bottom sediment, however, they were occasionally also found under stones in shallow water. Not unexpectedly, they occurred in both benthic and pelagic samples. *L. hookeri* were observed to feed on bottom detritus and to scavenge. Mating occurred in June.

The larvae and pupae of an unidentified species of chironomid were found in all three stations. All efforts to breed the larvae into adults failed so the species could not be determined. Just before eclosion the pupae floated to the surface, following which the adults emerged; empty pupae were collected from station C in July. A behaviour for which we have no explanation at present is the carrying of chironomid larvae by the amphipod *Orchestia gammarellus. Stratiomys longicornis* were represented in our samples by their aquatic larvae. A single stratiomyid pupa was collected in August in station C which perhaps suggests that emergence may take place at about this time. Four different species of hydrophilid beetles occurred in our samples. Although a number of beetles of the family Hydrophilidae have been recorded from the Maltese Islands (e.g. Cameron and Caruana Gatto, 1907), these records need confirmation and revision in the light of modern taxonomic knowledge of the group (S. Schembri, personal communication) hence no attempt has been made to identify the Għadira species pending such a review. The only other insect encountered in the pool at Għadira was a single pupa of a syrphid fly which was found at station A in October 1986; no specimens occurred in our samples, however.

Two species of fish occurred at Għadira, *Aphanius fasciatus* and *Liza ramada.* The former was deliberately introduced into Għadira (Cilia, 1986) following deepening of the pool. The other invaded the pool from Mellieħa Bay during heavy weather when waves crossed the 100m or so of beach separating the pool at Għaidra from the sea. *Aphanius fasciatus* occurred in pelagic samples from all three stations but *Liza ramada* did not occur in our quantitative samples, possibly because it is too fast and too large to be caught by our sampling gear. It is reported that an unspecified species of eel has also invaded Għadira in the same way as *Liza ramada* (C. Gauci, personal communication); we cannot however confirm this record from our present work.

Quantitative samples

The results of the pelagic and benthic quantitative sampling are presented in Tables 2, 3 and 4. Inspection of these tables shows that *Ventrosia ventrosa* is by far the most abundant species in the pool; at times population densities reached values as high as 280,000 individuals m^{-2} (e.g. August 1985 station A benthic sample, Table 2). This species occurred at all times of the year in all three stations. The next most abundant species were *Cerastoderma glaucum* and *Orchestia gammarellus,* however, while *C.glaucum* occurred in nearly all samples, *O.gammarellus* occurred at particular times of the year only, and occasionally at very high population densities (e.g. April and March 1986 benthic samples at stations A and B respectively, Tables 2 and 3). *Lekanesphaera hookeri* and the chironomid larvae were also fairly regularly represented in our samples, although at much lower population densities than the foregoing species. An additional two species, the gastropods *Truncatella subcylindrica* and *Ovatella myosotis,* were present throughout the year, at least in some stations, but always in low densities. The remaining species were only sporadically represented in our samples and also at very low densities.

Table 5 gives the mean monthly population density of the five most abundant pool species for each station. It is evident that station A supported higher population densities than the other two stations, both for each species individually (excepting *Cerastoderma glaucum*), and for all species considered together. *C.glaucum* reached its highest average density in station B although

Table 1

Classified list of the macrofaunal species collected from the pool at the Għadira Nature Reserve during the period May 1985-April 1986. Species marked with a dagger did not occur in the quantitative benthic and pelagic samples.

Mollusca: Gastropoda
Hydrobiidae
Ventrosia ventrosa (Montagu) (complex?)
Truncatellidae
Truncatella subcylindrica (Linnaeus)
Melampidae
Ovatella (Myosotella) myosotis (Draparnaud)
Mollusca: Bivalvia
Cardiidae
Cerastoderma glaucum (Poiret)
Crustacea: Amphipoda
Gammaridae
†*Gammarus aequicauda* (Martynov)
Talitridae
Orchestia gammarellus (Pallas)
Crustacea: Isopoda
Sphaeromatidae
Lekanesphaera hookeri mediterranea (Lejuez)
Insecta: Coleoptera
Hydrophilidae
Hydrophilidae sp. I
Hydrophilidae sp. II
Hydrophilidae sp. III
Hydrophilidae sp. IV
Insecta: Diptera
Chironomidae
Chironomidae sp.
Stratiomyidae
Stratiomys longicornis (Scopoli)
Syrphidae
†Syrphidae sp.
Chordata: Actinopterygii
Cyprinodontidae
Aphanius fasciatus Nardo
Mugilidae
†*Liza ramada* (Risso)

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average population densities at all three stations are hardly different. Apart from its overall lower macrofaunal population densities relative to station A and B, station C was characterised by a complete absence of *Ovatella myosotis* and by a very reduced density of *Orchestia gammarellus*.

The following community parameters were calculated separately for the pelagic (Table 6) and benthic (Table 7) samples: species richness *(s)*, the total number of macrofaunal species in the sample; Simpson dominance (λ), as a measure of the distribution of individuals amongst species; the inverse of λ (d_s) as a measure of diversity (*sensu* Hurlbert, 1971); and e_s, the associated evenness measure.

For all three stations, pelagic macrofaunal species richness was overall low, the highest mean value, that for station A, being only 2.92. Mean pelagic species richness was comparable for stations A and B (Mann-Whitney U-test, $0.20<P<0.30$), however, station C had a significantly lower value than either (Mann-Whitney U-test; A and C, $P<0.001$; B and C, $0.001<P<0.002$). For stations A and B, where pelagic species richness was high ($s = 4$ or 5, e.g. May, June and December at station A, June and December at station B; Table 6), the corresponding dominance values were also high while both diversity and evenness were low indicating that one very abundant species dominated the samples. Pelagic diversity and dominance showed very little variation from month to month in stations A and B as shown by the low standard deviations

Table 2

The number of individuals of each macrofaunal species collected from station A in the Għadira pool (see Fig. 1) during 12 monthly sampling trips between May 1985 and April 1986. Each cell entry gives the number of individuals collected in pelagic samples (upper figure; expressed per m³ of water) and the number collected in benthic samples (lower figure, expressed per m² of bottom). The asterisk marks those pelagic samples not collected by hauling (See Material and Methods section).

	May	Jun	*Jul	*Aug	*Sep	*Oct	*Nov	*Dec	*Jan	*Feb	Mar	Apr
	3,077	1,368	0	4,712	2,299	2,482	140	1	194	69	1,491	13
V. ventrosa	41,132	35,895	11,473	280,000	151,579	24,053	6,605	11,842	7,316	26,184	9,789	23,421
	72	14	0	80	34	0	0	0	0	0	0	0
C. glaucum	9,579	6,026	289	12,868	7,421	1,053	263	421	7,421	237	447	2,342
	0	0	0	0	0	0	0	0	0	0	0	0
T. subcylindrica	53	0	26	132	132	0	53	79	26	53	26	53
	0	0	0	0	0	0	0	0	0	0	0	0
O. myosotis	0	26	132	0	0	0	0	26	0	26	0	0
	74	0	0	0	0	0	1	33	252	194	346	0
O. gammarellus	8,053	0	0	0	26	26	26	5,026	4,632	6,211	1,316	22,395
	6	2	0	0	0	0	0	1	0	11	26	0
L.hookeri	79	79	0	0	0	0	26	26	53	0	0	4,605
	5	1	0	0	0	0	0	0	0	0	0	0
Chironomidae sp.	842	132	0	0	473	26	26	0	0	0	0	3,421
	0	0	0	0	0	11	0	0	0	0	0	0
Hydrophilidae sp. I	0	0	0	0	0	26	0	0	0	0	0	0
	0	0	0	0	11	0	0	1	0	0	0	0
Hydrophilidae sp. II	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	11	0	0	0	0	0	0	0	0	0
Hydrophilidae sp. III	0	0	0	0	0	0	0	0	0	0	0	0
	0	2	57	23	0	0	0	0	0	0	0	0
A. fasciatus	0	0	0	0	0	0	0	0	0	0	0	0

Table 3

The number of individuals of each macrofaunal species collected from station B in the Għadira pool (see Fig. 1) during 12 monthly sampling trips between May 1985 and April 1986. Each cell entry gives the number of individuals collected in pelagic samples (upper figure; expressed per m^3 of water) and the number collected in benthic samples (lower figure, expressed per m^2 of bottom). The asterisk marks those pelagic samples not collected by hauling (See Material and Methods section).

	May	Jun	*July	*Aug	*Sep	*Oct	*Nov	*Dec	*Jan	*Feb	Mar	Apr
	97	3,468	412	538	1,979	206	0	4,312	435	0	60	26
V. ventrosa	5,105	19,657	37,789	147,947	82,000	5,105	8,105	7,921	3,237	2,237	13,789	14,895
	0	287	69	23	0	0	11	11	0	0	0	0
C. glaucum	9,895	12,447	7,527	5,105	4,710	3,368	3,842	2,421	1,000	0	53	4,632
	0	0	0	0	0	0	0	0	0	0	0	0
T. subcylindrica	0	0	26	0	53	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
O. myosotis	0	0	79	53	26	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	1,910	217	23	0	0
O. gammarellus	1,342	0	0	0	0	0	0	79	26	342	29,579	263
	0	0	0	0	0	0	0	11	0	11	0	0
L. hookeri	26	0	53	0	26	0	0	158	0	0	0	105
	0	7	0	0	0	0	0	0	0	0	0	0
Chironomidae sp.	53	0	0	395	184	0	26	0	0	0	0	53
	0	0	0	0	0	0	0	0	0	0	0	0
S. longicornis	0	0	0	0	53	0	0	26	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae sp. I	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	2	0
Hydrophilidae sp. II	0	0	0	26	0	0	0	0	0	0	0	0
	0	1	0	0	0	0	0	0	0	0	0	0
Hydrophilidae sp. III	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	2
Hydrophilidae sp. IV	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	0	0	11	0	11	0	0	0	0	0
A. fasciatus	0	0	0	0	0	0	0	0	0	0	0	0

Table 4

The number of individuals of each macrofaunal species collected from station C in the Għadira pool (see Fig. 1) during 12 monthly sampling trips between May 1985 and April 1986. Each cell entry gives the number of individuals collected in pelagic samples (upper figure; expressed per m^3 of water) and the number collected in benthic samples (lower figure, expressed per m^2 of bottom). The asterisk marks those pelagic samples not collected by hauling (See Material and Methods section). No samples were collected during December 1985. Chironomidae collected in the July 1985 pelagic sample were all empty pupae (marked by dagger).

	May	Jun	*July	*Aug	*Sep	*Oct	*Nov	*Dec	*Jan	*Feb	Mar	Apr
	4	0	126	343	366	34	0	-	69	0	0	0
V. ventrosa	6,789	1,210	22,184	62,316	15,526	12,125	17,186	-	8,452	7,325	5,431	8,546
	0	0	0	0	0	0	0	-	0	0	0	0
C. glaucum	4,894	5,684	6,737	5,684	789	1,210	948	-	3,786	4,546	6,782	5,483
	0	0	0	0	0	0	0	-	0	0	0	0
T. subcylindrica	0	0	26	0	0	26	0	-	0	52	0	0
	0	0	0	0	0	0	0	-	0	0	0	0
O. myosotis	0	0	0	0	0	0	0	-	0	0	0	0
	4	0	0	0	0	0	0	-	0	0	1	0
O. gammarellus	1,737	0	0	0	0	0	0	-	0	0	120	877
	0	0	0	0	0	0	0	-	0	0	0	0
L. hookeri	105	0	0	26	26	0	26	-	0	0	215	418
	0	0	†69	0	0	0	0	-	0	0	0	0
Chironomidae sp.	79	0	0	500	26	26	0	-	0	0	79	26
	0	0	0	0	0	0	0	-	0	0	0.4	0.2
A. fasciatus	0	0	0	0	0	0	0	-	0	0	0	0

calculated (Table 6). Large monthly variations in these community parameters were however noted for station C. This was due to the large number of samples with *s* values of 1 or 0.

For the benthic macrofauna (Table 7), station A had the highest mean species richness whereas station C had the lowest value, although there was no significant difference between mean *s* for stations B and C (Mann-Whitney U-test, $0.50<P<0.60$). Variation in benthic species richness from month to month was also larger at these two stations than at station A (coefficients of variation: A=19.0%, B=41.3%, C=30.8%). Mean benthic diversity and dominance were very similar for all three stations (Table 7). Overall, diversity was low, dominance was high and evenness was low irrespective of the species richness, indicating that at all three stations one, perhaps two, species which were numerically much more abundant than all others, dominated the samples. For all three stations, there was considerable month to month variation in benthic community parameters (Table 7). In station A the January and April samples stood out because of their comparatively high diversity and evenness. In this station, during most months, one benthic macrofaunal species far outnumbered all others present, however, in the January and April sample, the benthos was codominated by two species, both of which reached comparably high population levels. The same explanation applies also to the high diversities measured for the January benthic sample at station B and for the January, March and April samples at station C.

As expected, fluctuations in population numbers occurred for most species. Three different patterns was observed: (i) strongly unimodal, as for *Orchestia gammarellus* (Fig. 2); (ii) strongly bimodal, as for the chironomid larvae (Fig. 3); and (iii) a population which was maintained throughout the sampling period and which showed occasional highs, as for *Ventrosia ventrosa*, *Cerastoderma glaucum* and *Lekanesphaera hookeri* (Figs 4-6). Due to their low frequency of occurrence in our samples, no definite trends could be discerned for the other pool species.

Orchestia gammarellus reached its single peak in the period March to May, the population becoming reduced in numbers, occasionally to zero levels, at other times (Tables 2-4). The population peaked in April in station A, in March in station B and in May in station C, in each case during that month when the water level is highest (Fig. 2).

The two population peaks shown by the chironomid larvae (Fig. 3) probably correspond to two periods of emergence. In station A the largest peak occurred in the spring months, with a smaller peak in autumn. In stations B and C, the largest peak occurred in late summer-early autumn, the spring peak being much lower.

Ventrosia ventrosa populations maintained fairly constant levels throughout the sampling period, except in the summer months when they peaked (Tables 2-4). These peaks probably originated from a concentration effect. As the pool dried during the hot summer months, motile benthic animals migrated away from the edges towards the deeper central regions of the pool which always held some water and consequently large numbers of *V. ventrosa* came to occupy a small area of bottom; the reverse process occurred as the pool filled up again following the first rains in September-October (Fig. 4). The same phenomenon was observed for *Cerastoderma glaucum* (Tables 2-4). In this case, however, a significant proportion of the population was not able to migrate fast enough to move with the receding water and perished. Large numbers of the dead shells of this species are uncovered each year as the waterline retreats.

Over and above the concentration effect, the populations of *C. glaucum* also peaked at those times when the levels of nitrates and phosphates in the ambient water were high (Fig. 5 and Hili *et al.*, 1990). In station A both the *C. glaucum* population and that of *V. ventrosa* experienced a large drop in numbers in July. This correlated with a massive drop in dissolved oxygen concentration (Fig. 4).

Lekanesphaera hookeri occurred practically all the year round in all three stations (Tables 2-4). Population levels were fairly constant throughout the sampling period with the exception of station A where the population showed a massive peak in April 1986 (Fig. 6) which had no

Table 5

The mean monthly population density of the five most abundant macrofaunal species in pelagic and benthic samples collected from three stations in the Għadira pool (see Fig. 1) over the period May 1985 to April 1986. Pelagic population densities are expressed per m^3 of water and benthic densities per m^2 of bottom.

Station	A		B		C	
	pelagic	benthic	pelagic	benthic	pelagic	benthic
V. ventrosa	1321	52441	961	28982	86	15190
C. glaucum	21	4031	32	4583	0	4231
O. gammarellus	75	3976	181	2636	0.45	249
L. hookeri	4	406	2	31	0	74
Chironomidae sp.	0.5	410	0.6	59	0	67

<u>**Table 6**</u>

Community parameters for the monthly pelagic samples collected from three stations in the Għadira pool (See Fig. 1) during the period May 1985 to April 1986. No samples were taken from station C in December 1985.

Station	A				B				C			
	s	d_s	λ	e_s	s	d_s	λ	e_s	s	d_s	λ	e_s
May	5	1.10	0.91	0.22	3	1.39	0.72	0.45	2	2.33	0.43	1
June	5	1.03	0.97	0.20	5	1.17	0.85	0.23	0	0	0	0
July	2	1.38	0.72	0.68	2	1.33	0.75	0.66	1	1.00	1.00	1.00
August	3	1.04	0.96	0.35	2	1.09	0.92	0.54	1	1.00	1.00	1.00
September	3	1.04	0.96	0.35	2	1.01	0.99	0.51	1	1.00	1.00	1.00
October	2	1.01	0.99	0.50	1	1.00	1.00	1.00	1	1.00	1.00	1.00
November	2	1.01	0.99	0.50	2	2.10	0.48	1.00	0	0	0	0
December	4	1.19	0.84	0.27	4	1.75	0.57	0.44	-	-	-	-
January	2	1.97	0.51	0.98	2	1.80	0.56	0.90	1	1.00	1.00	1.00
February	3	1.77	0.56	0.59	2	1.82	0.55	0.88	0	0	0	0
March	3	1.48	0.68	0.49	2	1.07	0.94	0.53	2			
April	1	1.00	1.00	1.00	2	1.16	0.86	0.56	2	1.13	0.88	0.39
Mean	2.92	1.25	0.84	0.51	2.42	1.39	0.77	0.64	1	0.56	0.53	0.74
s.d.	1.24	0.33	0.18	0.27	1.08	0.38	0.19	0.25	0.77	1.17	0.55	0.56

Table 7

Community parameters for the monthly pelagic samples collected from three stations in the Għadira pool (See Fig. 1) during the period May 1985 to April 1986. No samples were taken from station C in December 1985.

Station	A				B				C			
	s	d_s	λ	e_s	s	d_s	λ	e_s	s	d_s	λ	e_s
May	6	1.93	0.52	0.32	5	2.14	0.47	0.43	5	2.53	0.39	0.51
June	5	1.34	0.75	0.27	2	1.90	0.53	0.95	2	1.41	0.71	0.70
July	4	1.07	0.93	0.27	5	1.39	0.72	0.28	3	1.56	0.64	0.52
August	3	1.09	0.92	0.36	5	1.07	0.93	0.22	4	1.20	0.83	0.30
September	5	1.11	0.90	0.22	7	1.12	0.89	0.16	4	1.11	0.90	0.28
October	5	1.09	0.91	0.22	2	1.92	0.52	0.96	4	1.21	0.83	0.30
November	6	1.12	0.89	0.19	3	1.78	0.56	0.59	3	1.11	0.90	0.37
December	6	1.83	0.55	0.31	5	1.64	0.61	0.33	-	-	-	-
January	5	2.91	0.34	0.58	3	1.58	0.63	0.53	2	1.75	0.57	0.87
February	5	1.48	0.68	0.30	2	1.30	0.77	0.65	3	1.91	0.52	0.64
March	4	1.37	0.73	0.34	3	1.77	0.56	0.59	5	2.11	0.47	0.42
April	6	2.91	0.34	0.48	5	1.63	0.61	0.33	5	2.26	0.44	0.45
Mean	5.00	1.60	0.71	0.32	3.92	1.60	0.65	0.50	3.64	1.65	0.65	0.49
s.d.	0.95	0.67	0.22	0.11	1.62	0.33	0.15	0.26	1.12	0.50	0.19	0.19

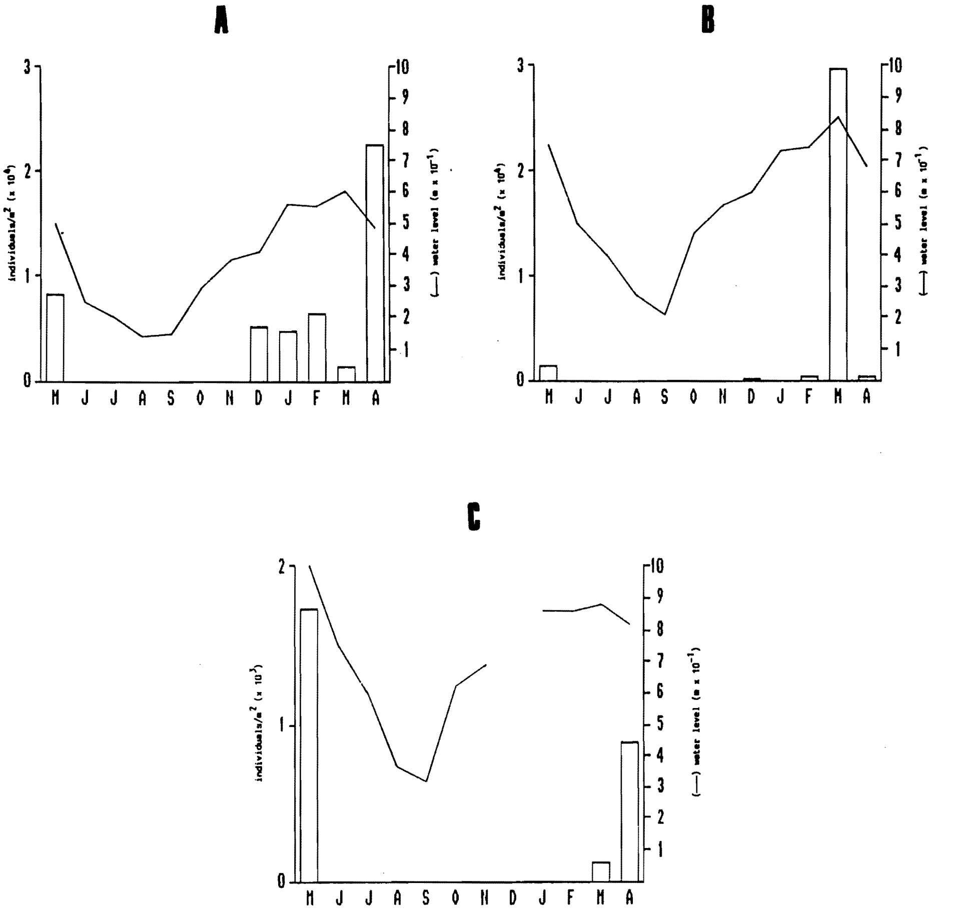

Fig. 2: Variation in population density of the amphipod ***Orchestia gammarellus*** *in each Għadira pool station (histograms) and variation in water level at each station (line graphs) during the study period.*

equivalent in the other two stations (Tables 2-4).

Discussion

European saltmarshes, including those of the European Mediterranean lands, have been recently surveyed by Dijkema (1984). Although miniscule, the Għadira marsh nonetheless exhibited vegetational communities and zonation patters typical of Mediterranean saline marshlands (as described by Beeftink, 1984 and Géhu and Rivas-Martinez, 1984) prior to the engineering works (Lanfranco, 1967; Savona Ventura *et al.*, 1980; Schembri, 1981). These halophilic communities were maintained by the seasonal fluctuations in soil inundation and water salinity, and what little data is available, points to the Għadira marsh as functioning as a saline marshland ecosystem (Schembri, 1981; Lanfranco, 1990). Following the habitat engineering works, the Għadira pool became a permanent rather than a transient feature and the saline marshland communities retreated to come to occupy that area of the pool edge and of the shores of the artificial islands affected by the inundation and desiccation cycle as the pool dries partially during the dry season and refills during the wet season; additionally, many non-saltmarsh

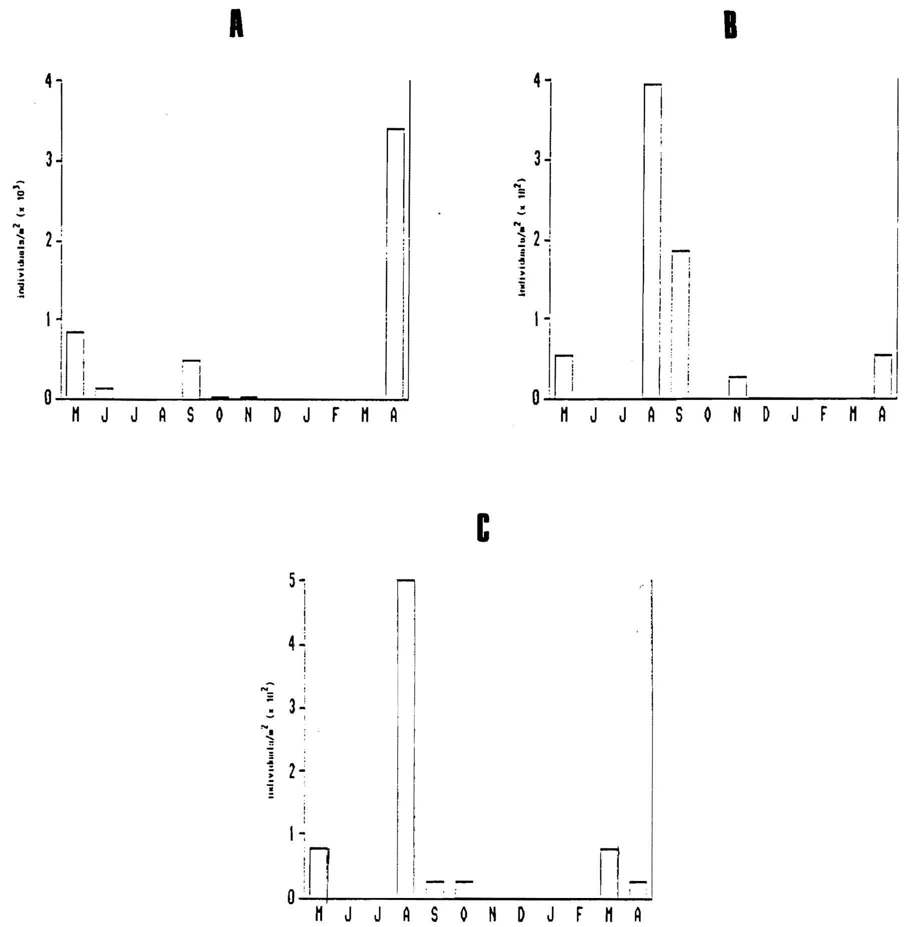

Fig. 3: Variation in chironomid population density in each Għadira pool station during the study period.

floristic elements were introduced into these communities as part of the habitat engineering works (Lanfranco, 1990). The pool as it now functions is more similar in character to a coastal lagoon such as those found on the southern Mediterranean coast (see survey by Kerambrun, 1986) than to the temporary pools which form in Mediterranean saltmarshes.

The general features of coastal lagoons have been reviewed by Phleger (1981) and Krumbein *et al.* (1981). In common with such environments, the Għadira pool has a lower macrofaunal species richness than either freshwater pools or the coastal marine environment in the same geographical area, and the species present are predominantly euryecious and able to tolerate large changes in ambient salinity, temperature and oxygen concentration. As for lagoonal environments elsewhere (Krumbein *et al.*, 1981), some individual species attain very high population densities. However, species richness at Għadira is much lower than is found in other Mediterranean coastal lagoons and salinas for which data exists (Halim and Guarguess, 1981; Kerambrun, 1986; Britton and Johnson, 1987). Three main factors probably contribute to this: (i) the Għadira pool is very small and has a low diversity of habitats; (ii) it receives no freshwater input other than from rain, therefore, salinity varies more or less homogeneously throughout the pool. In contrast, Mediterranean lagoons and salinas with higher species richness than Għadira

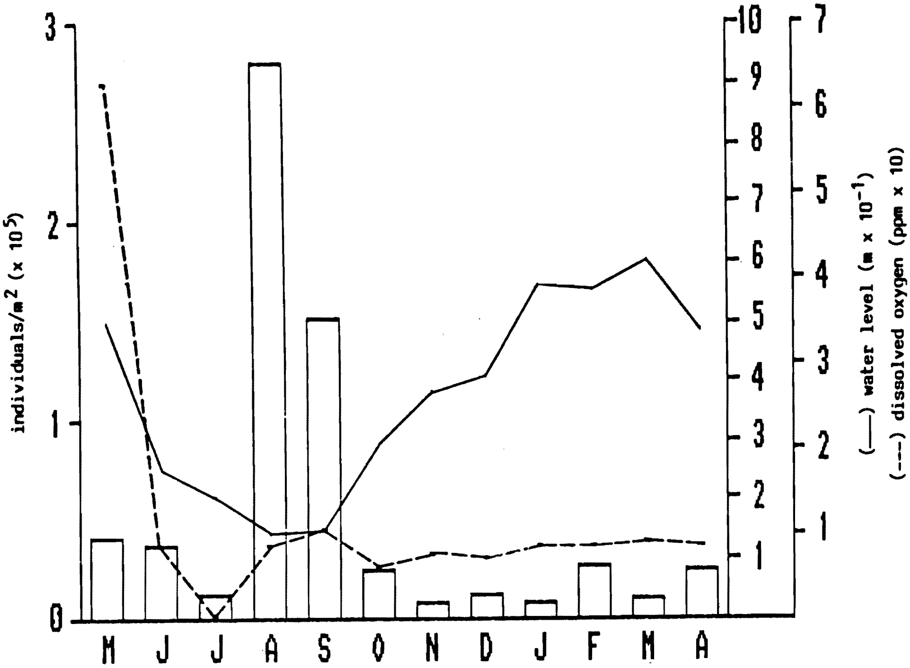

Fig. 4: Variation in population density of the hydrobiid gastropod Ventrosia ventrosa in Għadira pool station A (histogram) and variation in water level (solid line) and in dissolved oxygen concentration (dashed line) during the study period.

have a range of salinities present at all times of the year (Halim and Guarguess, 1981; Kerambrun, 1986; Britton and Johnson, 1987); (iii) the Għadira pool is completely cut off from the sea except for a drainage pipe which is mostly kept shut. Guelorget and Perthuisot (1983) have observed that the more a lagoon is isolated from the sea and the less the exchange of water with the marine environment, the poorer the biota of the lagoon, irrespective of salinity.

While some species have invaded the pool only after the habitat engineering works were completed (e.g. *Gammarus aequicauda;* Moore and Schembri, 1986), evidence exists that pool macrofaunal species richness has declined overall since the habitat modifications at Għadira were made. Pre-1980 records of marcrofauna from the Għadira pool include a number of species, amongst them dytiscid and hydrophilid coleopterans and tabanid and other dipterans (S. Schembri, personal communication; see also Savona Ventura *et al.*, 1980), which have not been encountered in our survey. It should be pointed out however, that since samples were taken only from a limited area of the pool, the possibility that species other than those listed in Table 1 also occur cannot be excluded.

The Għadira pool species are either detrivores, herbivores or scavengers, or else unspecialised omnivores. This probably correlates with the large amounts of detritic organic material accumulating in the pool and the rich microbial flora it must support and also with the seasonal blooming of both micro- and macro- algae. In particular, specialised predators are almost totally absent from the pool, however birds are important predators on the pool macrofauna (Gauci, 1990).

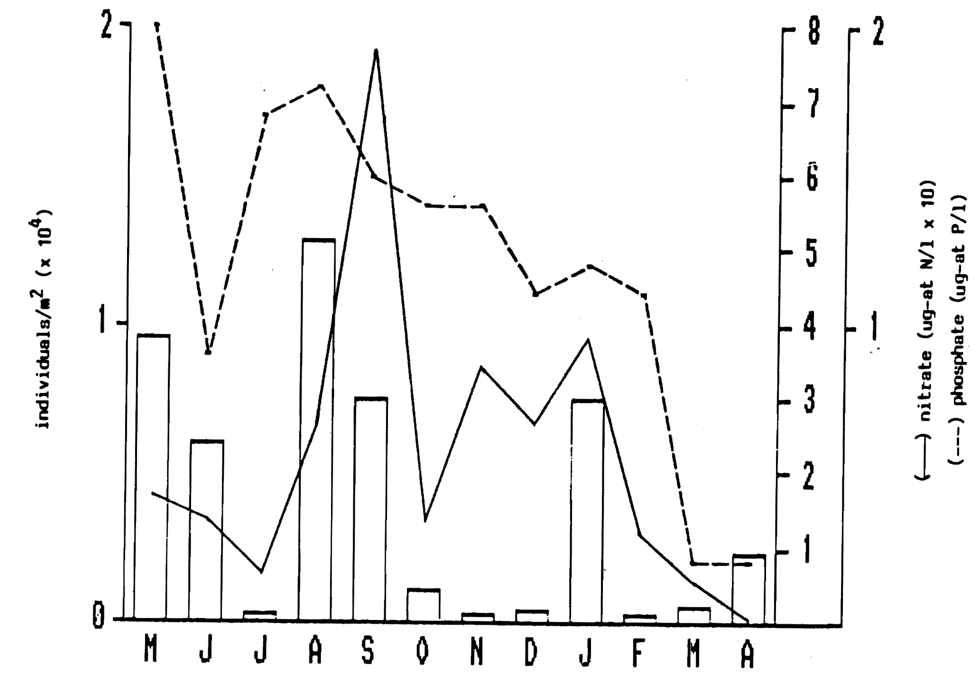

Fig. 5: Variation in population density of the cardiid bivalve Cerastoderma glaucum in Għadira pool station A (histogram) and variation in the concentration of dissolved nitrates (solid line) and phosphates (dashed line) during the study period.

In spite of the relative homogeneity of the pool habitat, interstation variation in overall species richness and in the average abundance of particular species was noted. Both parameters decline along a NE to SW gradient. This is probably correlated with the increase in the fine particulate content of the substratum and the decrease in amplitude of water level, and hence salinity, fluctuations along this gradient (Hili *et al.*, 1990). For example, the complete absence of *Ovatella myosotis* at station C is probably related to the different nature of the substratum at this station from that at stations A and B. It is not likely to be due to differences in the physico-chemical parameters of the reservoir water since fluctuations in these were well within the range of those observed in stations A and B where *O.myosotis* occurs (Hili *et al.*, 1990). The low numbers of *O. gammarellus* on the other hand are most probably due to the fact that in station C there were no blooms of the algae *Cladophora* sp. and *Enteromorpha intestinalis* on which the amphipods aggregated in the other stations; algal blooming in turn being related to the seasonal pattern of salinity changes.

Within each station, pelagic macrofaunal abundance was always much less than benthic macrofaunal abundance. This is to be expected as all species which occurred in our samples are strictly speaking benthonic, even if they do occasionally occur in the water column. This is true also for the killifish *Aphanius fasciatus* which, although never collected in our benthic samples, is still benthonic and when undisturbed spends much of its time foraging on the bottom sediment (Grech, 1989).

The community parameters calculated confirm that for all three stations and for both the pelagic and benthic macrofauna, the bulk of individuals collected belong to one, occasionally two, species, all others being very much less frequent.

The population fluctuations of most pool species are probably controlled mainly by extrinsic factors. Evidence for this comes from the observations that populations of the same species at different stations reached their peaks and troughs at slightly different times, while in some cases the timing and amplitude of these fluctuations could be correlated with changes in the abiotic and biotic factors affecting the pool. For example the population peaks of *Orchestia gammarellus* at all three stations occurred at times when the water level was at its highest (Fig. 2) and are probably related to the availability of water. Again, it is tempting to speculate that the observed population highs and lows of the filter-feeding *Cerastoderma glaucum* are related to the massive blooms and crashes of the pool microalgae and those of the macroalgae and their thycoplankton (see Lanfranco, 1990). Algal blooming may be an important factor controlling the populations of the Għadira pool fauna. Summertime eutrophication events which bring about deoxygenation of the water column with subsequent elimination of aquatic fauna are a common feature of Mediterranean brackish water bodies with a poor connection to the sea (Kelly and Naguib, 1984; Britton and Johnson, 1987).

On the other hand, some of the observed fluctuations were probably due to the concentration effect and may not represent real changes in population levels (e.g. *Ventrosia ventrosa* and *Cerastoderma glaucum*). As is predicted by the concentration hypothesis, the populations of both these species at station C did not experience such pronounced summer peaks as at stations A and B (Tables 2-4), seasonal fluctuations in the Għadira pool water level being least evident in the reservoir (Hili *et al.*, 1990).

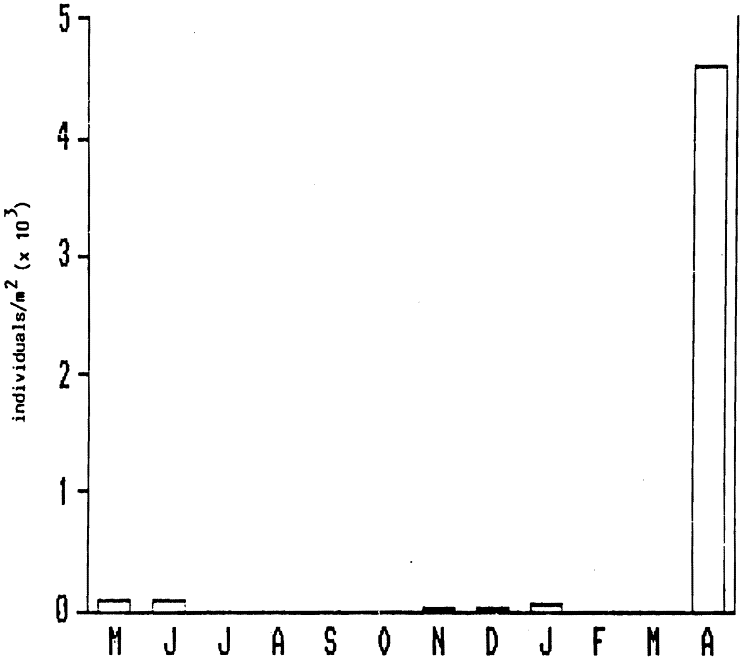

Fig. 6: Variation in population density of the sphaeromatid isopod Lekanesphaera hookeri mediterranea in Għadira pool station A during the study period.

For certain species, population fluctuations did not appear to be related to any obvious environmental change, for example, the massive population explosion of *Lekanesphaera hookeri* in April 1986 at station A. It is possible however that it was perhaps associated with the much larger populations of the alga *Enteromorpha intestinalis* found at this station.

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The Avifauna of the Għadira Nature Reserve

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Introduction

The Għadira Nature Reserve covers an area of about six acres of saltmarsh and has a protective, no-shooting zone of 500m radius around it. Excavation work, consisting of the removal of several tons of soil and the formation of islands in an open shallow pool, started in May 1980 and was continued for another three consecutive summers. A ditch was cut around the reserve, except on the seaward side. The soil excavated from the ditch was used to build an embankment running alongside it. The embankment has been successfully planted with Bianca *Atriplex halimus* on the outer part over-hanging the ditch. Several species of trees, but mostly tamarisk, *Tamarix sp.*, have been planted on and below the embankment. No planting has been carried out on the islands and natural colonisation has been taking place at a fast rate.

Habitats

The reserve and the area of land immediately surrounding it offer four types of habitats: wetland (the most important), agricultural, garigue and 'woodland'.

Wetland: This habitat makes up the bulk of the reserve's area. The main part consists of an open scrape with average water depth of 120cm in winter and 40 cm in summer and a number of low, saucer-shaped islands of varying sizes. There is little emergent vegetation, this consisting of the common reed *Phragmites australis* introduced at a few points around the shore. Algae are abundant during the the warmer months and in some years have almost completely choked the water surface to the extent that it had to be piled up in heaps. Another area of about one acre of open water without islands is situated at the western end. Here the water is deeper, averaging 120cm in summer and 200cm in winter. The shores are rather steep-edged and a strong reed bed is fast developing along three of its sides. Originally this area was intended to serve as a freshwater reservoir. Along extensive stretches of the ditch the common reed has also firmly established itself. Recently a small area of about thirty-five square metres has been excavated on dry ground and four shallow freshwater ponds have been built on a plastic base. Bulrush

Plate 3: Little Egret Agretta garzetta, a migrant which frequently visits the Għadira Nature Reserve.
Photo: Joe Sultana

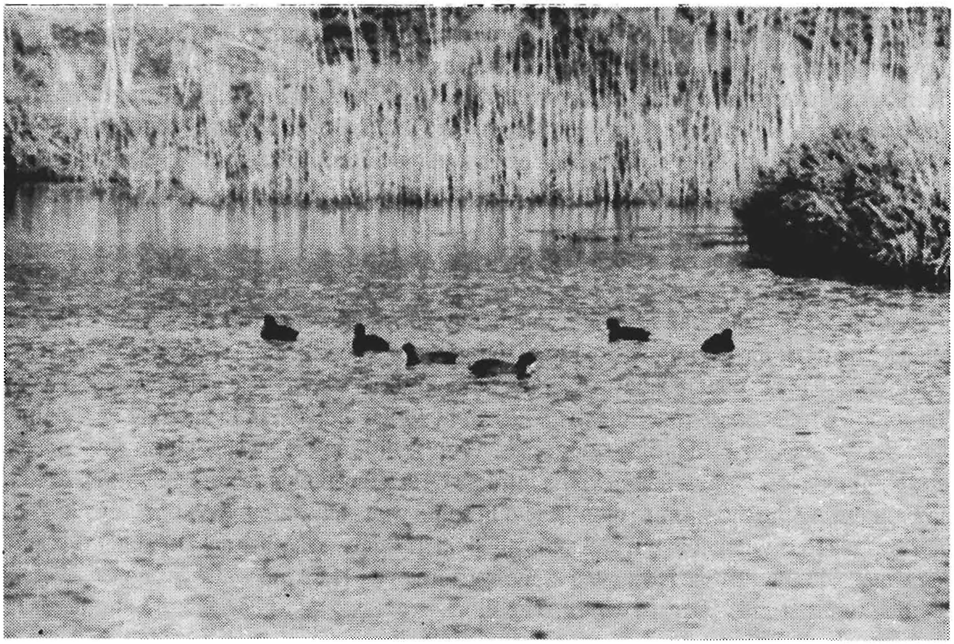

Plate 4: Coots Fulica atra; this species is a common winter visitor to the Għadira Nature Reserve.
Photo: Joe Sultana

Typha angustifolia, together with other aquatic vegetation, has been introduced into them.

Agricultural: Except on the seaward side, the reserve is surrounded by cultivated land which forms only a thin belt along the western and southern sides. All common crops grown elsewhere in the Maltese Islands are cultivated. Several small passerines feed on insects in these fields.

Garigue: This habitat occurs behind the reserve on the south-west side. It rises from behind the narrow fields and extends towards the cliffs on the opposite side of Mellieħa Bay.

Woodland: An established grove of tamarisk is found on the southern part of the reserve. On the northern side a larger grove, planted in the mid-seventies but now well established, consists of tamarisk, Aleppo Pine *Pinus halepensis, Acacia sp.* and *Eucalyptus sp.* The latter grove is used for roosting by small passerines wintering in the reserve. Egrets and herons also often roost there while on migration stop-overs.

The Avifauna

Being one of the very few marshland areas in the Maltese Islands, Għadira has always been a big attraction both for birds as well as for ornithologists. Despite its small size, its ornithological value can be gauged by the fact that two hundred species of birds have been recorded either in the reserve or flying over it since 1981 when a daily log was first kept. Up to 1982, 355 species of birds had been recorded in the Maltese Islands (Sultana, J. & Gauci C., *A New Guide to the Birds of Malta*, 1982). About eighty-five of the species recorded are birds depending on wetlands for food. The commonest are grebes, ducks, rails, moorhens and coots in winter; herons, egrets and waders in spring and autumn; and a small number of non-breeders of various species in summer. Several species which, owing to lack of suitable habitat, disturbance and persecution, as recently as 1982 *(loc. cit.)* had been recorded simply as passage migrants, are now wintering regularly in the reserve. These include Grey Heron, Water Rail, Moorhen, Coot and Kingfisher. Bird-ringing has shown that at least a proportion of birds surviving the summer, return to winter in the reserve, e.g. Water Rail - 30% and Kingfisher - 6%.

Grebes *Podicipediformes:* These feed on small fish caught by diving and also, on calm days, on mosquitoes and other insects picked up from the water surface. The Black-necked Grebe *Podiceps nigricollis* winters annually in small numbers. Up to eleven have been recorded together in one winter. The first birds sometimes arrive as early as the end of August and usually leave in early March. The Little Grebe *Tachybaptus ruficollis* is not regular but one or two winter during most years.

Herons and Egrets *Ciconiformes:* These feed mainly on fish, the larger herons feeding on mullet up to 25 cm in length and the smaller ones, as well as the egrets, take mainly Killifish. The Grey Heron *Ardea cinerea* and the Little Egret *Egretta garzetta* are the commonest, the former not infrequently wintering in the reserve. Little Egrets often spend up to a month off passage in spring. Non-breeding individuals of both species often stay well into June. Wintering and off passage birds become very territorial and frequently chase away both conspecifics and other species which attempt to land. Also regularly feeding in the reserve during migration times are Little Bitterns *Ixobrychus minutus*, Night Herons *Nycticorax nycticorax*, Squacco Herons *Ardeola ralloides* and Purple Herons *Ardea purpurea.*

Ducks *Anseriformes:* These occur mainly in winter in varying numbers. They feed on algae and on invertebrates, including molluscs. Most regular are Wigeons *Anas penelope* and Teals *Anas crecca* but Shelducks *Tadorna tadorna*, Mallards *Anas platyrhynchos*, Shovelers *Anas clypeata* and Pochards *Aythya ferina* are also present in most winters. In spring and autumn a few Garganeys *Anas querquedula*, Pintails *Anas acuta* and Ferruginous Ducks *Aythya nyroca* use the reserve for short stop-overs.

Birds of Prey *Accipiteriformes* and *Falconiformes:* They are usually seen flying over the reserve but Marsh Harriers *Circus aeruginosus*, Ospreys *Pandion haliaetus* and Kestrels *Falco*

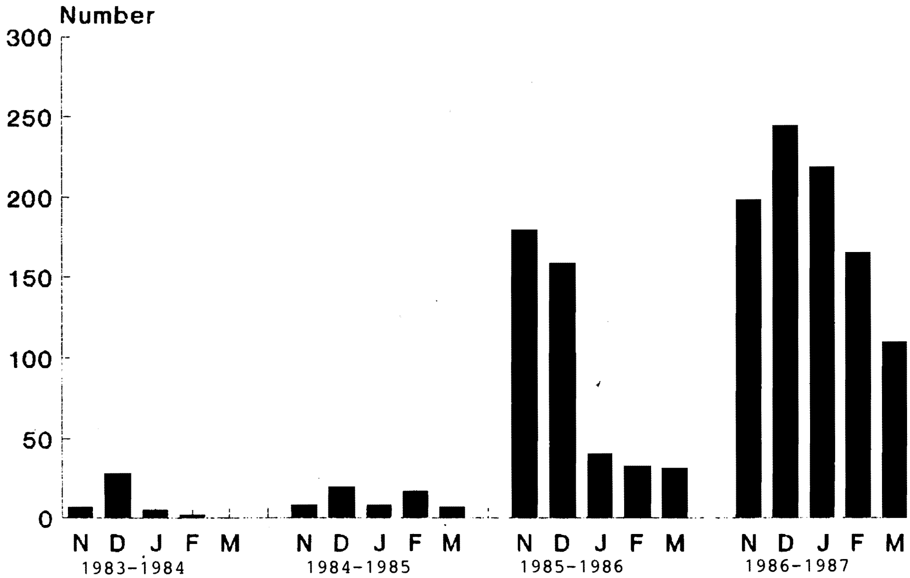

Fig. 1: Water Rail bird-days during four successive Winters.

tinnunculus have been recorded hunting over the scrape on several occasions.

Rails and crakes *Gruiformes:* These are numerous, especially in winter but, except for Coots *Fulica atra,* they are rather difficult to see as they are very secretive. They feed mainly on aquatic vegetation and on invertebrates, usually picked up at the water's edge. Moorhens *Gallinula chloropus* also regularly graze the fields adjacent to the ditch. Water Rail *Rallus aquaticus* and Moorhen numbers increased dramatically during the last four years when plant communities had colonised the ditches and other areas by the water's edge (Figs. 1 & 2). Moorhens presumably bred in 1986 as chick contact calls were heard in the dense bianca overhanging the ditch in July. Coot numbers are variable, depending on winter temperatures and other climatic conditions in Europe. The maximum in any winter has been thirty-seven (Fig. 3).

Waders *Charadriiformes:* Out of 36 species recorded at the Għadira Nature Reserve, 25 occur more or less annually. The peak period is in April-May in spring, and in August-September in

TABLE 1: Mean weight increase per day in waders.

Species	Spring		Autumn	
	No.	*inc./day (g)*	*No.*	*inc./day (g)*
Little Ringed Plover	1	1.02	-	-
Little Stint	4	0.83	257	0.60
Temminck's Stint	4	0.79	3	0.68
Dunlin	-	-	5	1.26
Curlew Sandpiper	2	1.45	-	-
Ruff	-	-	1	1.90
Wood Sandpiper	-	-	2	1.85
Common Sandpiper	4	3.06	7	0.97

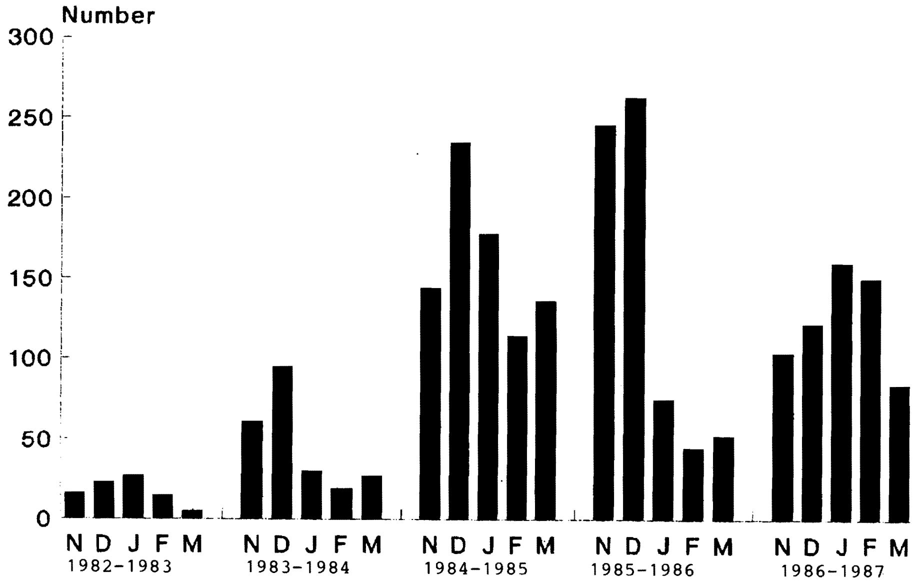

Fig. 2: Moorhen bird-days during five successive Winters. (In the winter of 1981-82 only one Moorhen was recorded).

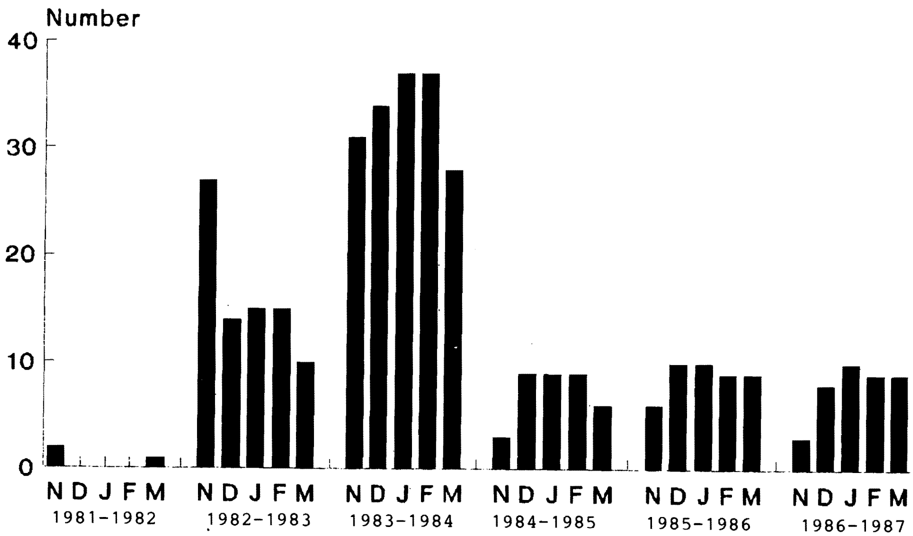

Fig. 3: Maximum Coot counts in six Winters (November-March)

TABLE 2: Mean length of stay and maximum stay in retrapped waders.				
Species	Spring		Autumn	
	Mean	*Max*	*Mean*	*Max*
Little Ringed Plover	-	5	-	-
Little Stint	2.94	6	5.81	29
Temminck's Stint	4.0	5	2.67	4
Dunlin	-	-	2.80	7
Curlew Sandpiper	4.0	6	-	-
Ruff	-	-	10.50	12
Wood Sandpiper	-	-	9.0	11
Common Sandpiper	4.0	5	10.43	20

autumn, but a few are present almost daily throughout summer while Little Stints *Calidris minuta* and Dunlins *Calidris alpina* winter in small numbers in some years. Waders take mainly invertebrate food, either picking it up from the water surface or exposed mud, or by probing in the mud in shallow water. Early in the morning they forage among the vegetation on the islands picking up small insects. A few species, mainly Spotted Redshank *Tringa erythropus* and Greenshank *Tringa nebularia,* also take small fish regularly. Curlew Sandpipers *Calidris ferruginea,* Ruffs *Philomachus pugnax,* Black-tailed Godwits *Limosa limosa* and Redshanks *Tringa totanus* feed heavily on molluscs which are abundant in the mud. The abundance of invertebrate food in the mud is obvious both by observing the rate at which food items are picked by the waders as well as from the rapid weight gains in birds trapped for ringing and subsequently retrapped *(Table 1).*

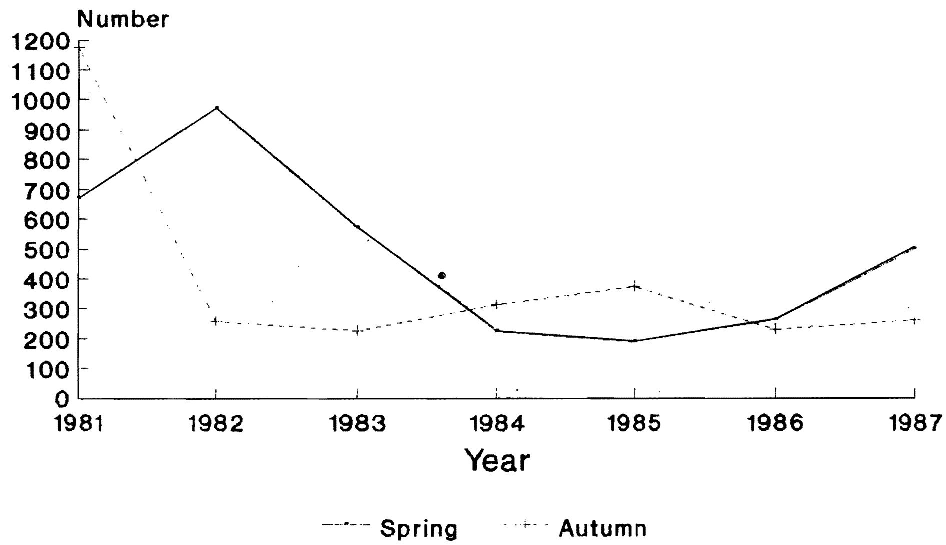

Fig. 4: Little Stint bird-day totals in Spring and Autumn for the years 1981-87

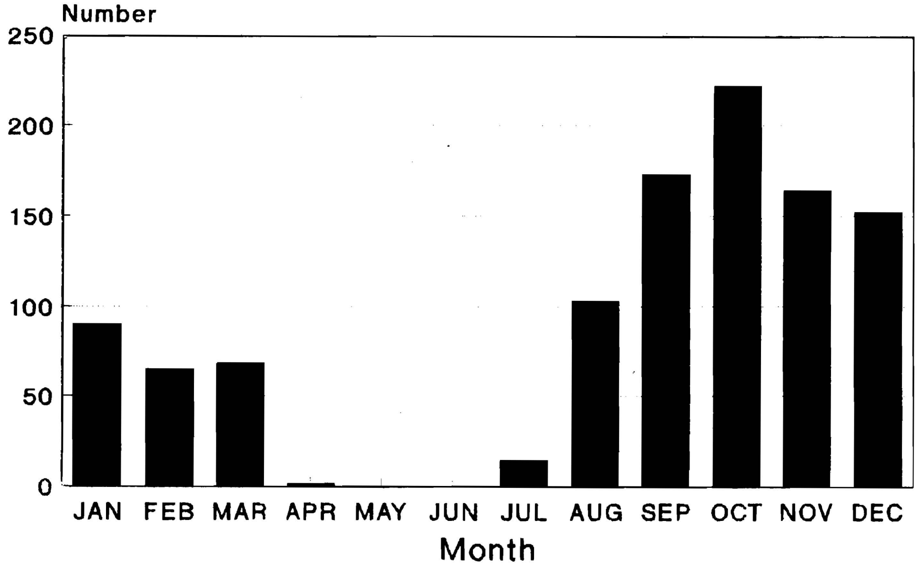

Fig. 5: Kingfisher bird-days; cumulative totals for the years 1981-87.

Table 2 shows the maximum and average length of stay in birds retrapped. As with most other birds, wader numbers vary from year to year according to weather conditions encountered during migration and, probably, also population levels. This is clearly demonstrated in Fig. 4 which shows the cumulative number of bird days in spring (March - June) and autumn (July - October) for the Little Stint, one of the commonest waders in the reserve.

Gulls and terns *Laridae* and *Sternidae:* Gulls rarely stay long in the reserve. The only species staying for any length of time is the scarce Slender-billed Gull *Larus genei* which, when present, feeds mainly on small fish which it seems to catch with ease. Sea-terns feed on fish caught by diving while marsh-terns catch insects by dipping. Terns usually stay for very short periods, occasionally for up to a week.

Other non-passerines: The most important is the Kingfisher *Alcedo atthis.* Not recorded at Għadira prior to 1980, it is now a regular migrant in autumn, wintering in most years (Fig. 5). It feeds on small fish caught by diving, usually from a perch overhanging water. Two (6%) of those ringed have been retrapped the following autumn/winter. The average elapsed time between ringing and retrapping is 35 days (N=27), the longest being of 214 days (1 Sep. - 3 Apr.) A pair was observed displaying in late March 1984 and this species is a potential breeder in future. Other species include Turtle Dove *Streptopelia turtur* and Cuckoo *Cuculus canorus* which rest for short periods in the reserve, Scops Owl *Otus scops,* mostly found roosting in the tamarisk grove, Swift *Apus apus* — commonly seen feeding by catching small insects in flight, Hoopoe *Upupa epops* and Wryneck *Jynx torquilla.* The Wryneck also winters in most years. It feeds almost exclusively on ants.

Larks *Alaudidae:* Skylarks *Alauda arvensis* are common migrants in autumn when several may rest on islands in the reserve. A few winter annually in the fields along the northern side of the reserve. Short-toed Larks *Calandrella brachydactyla* rarely settle in the reserve but regularly fly over in spring and autumn. A few pairs breed on the garigue to the south west of the reserve and can be seen and heard in display song-flight.

Swallows and martins *Hirundinidae:* are common in both spring and autumn, feeding on mosquitoes all around the reserve. Since 1987 Swallows *Hirundo rustica* started roosting in the reed-bed in the part known as the reservoir in autumn and also in spring from this year.

Pipits and Wagtails *Motacillidae:* Meadow Pipits *Anthus pratensis,* White Wagtails *Motacilla alba* and Grey Wagtails *Motacilla cinerea* winter in good numbers and feed on insects at the water's edge. Tree Pipits *Anthus trivialis* and Yellow Wagtails *Motacilla flava* are present, sometimes in large numbers, in spring and autumn, but Tawny Pipits *Anthus campestris* and Red-throated Pipits *Anthus cervinus* are more often seen flying over.

Chats and thrushes *Turdidae:* Most common are Robins *Erithacus rubecula* and Stonechats *Saxicola torquata* both of which pass through in large numbers in autumn and winter in the reserve. Several ringed individuals of both species have been retrapped 1-3 years later. Song Thrushes *Turdus philomelos,* Blackbirds *Turdus merula* and Black Redstarts *Phoenicurus ochruros* also winter in small numbers. Nightingales *Luscinia megarhynchos* and Redstarts *Phoenicurus phoenicurus* are common migrants in both spring and autumn, the former often heard in full song, especially in spring. Malta's national bird, the Blue Rock Thrush *Monticola solitarius,* often comes into the reserve in autumn and winter. In spring it can be heard singing along the nearby cliffs.

Warblers *Sylvidae:* Fan-tailed Warblers *Cisticola juncidis* and Sardinian Warblers *Sylvia melanocephala* are resident and breed in the reserve. Fan-tailed Warblers are polygamous and up to 30 females may breed in the reserve. Nest-building often starts at the end of January and nests may be found up to July. Usually up to 5 pairs of Sardinian Warblers breed in the reserve, each raising 2-3 broods from March to August. Cetti's Warblers *Cettia cetti* have become regular since 1986. Up to fifteen juveniles arrive in the reserve from mid-June to mid-September, some staying throughout winter. A pair bred for the first time in 1987. Chiffchaffs *Phylloscopus collybita* and Blackcaps *Sylvia atricapilla* winter, the former being very common. Several other species are common on migration, often spending a week or more in the reserve. The most numerous are Subalpine Warbler *Sylvia cantillans,* Whitethroat *Sylvia communis,* Garden Warbler *Sylvia borin,* Wood Warbler *Phylloscopus sibilatrix* and Willow Warbler *Phylloscopus trochilus,* with smaller numbers of Sedge Warblers *Acrocephalus schoenobaenus,* Reed Warblers *Acrocoephalus scirpaceus,* Great Reed Warblers *Acrocephalus arundinaceus* and Icterine Warblers *Hippolais icterina.* Reed Warblers occur mostly in autumn and two birds were retrapped 1-2 years later on subsequent migrations.

Flycatchers *Muscicapidae:* are mainly present in spring with only a few in autumn. Most numerous are Pied Flycatchers *Ficedula hypoleuca* and Spotted Flycatchers *Muscicapa striata* with smaller numbers of Collared Flycatchers *Ficedula albicollis* in spring and Red-breasted Flycatchers *Ficedula parva* in autumn.

Tits *Remizidae:* The Penduline Tit *Remiz pendulinus* has been recorded at the reserve during three years. In winter 1986/87 at least six wintered.

Shrikes *Lanidae:* The Woodchat Shrike *Lanius senator* is common in spring with smaller numbers in autumn. A few Red-backed Shrikes *Linius collurio* are seen mainly in autumn. Shrikes are quite conspicuous, perching at prominent points from where they survey the ground for beetles, grasshoppers, etc.

Finches *Fringillidae:* The Chaffinch *Fringilla coelebs* is the commonest in the reserve, a few regularly wintering. Other finches are frequently seen flying over but seldom use the reserve for resting or feeding.

Buntings *Emberizidae:* The Corn Bunting *Miliaria calandra* is resident with up to five pairs breeding in the reserve. Flocks, presumably migrants, also feed regularly on weed seeds in the reserve in late summer and autumn. The Reed Bunting *Emberiza schoeniclus* is an autumn migrant and winters in irregular numbers.

Appendix: Species recorded at the Għadira Nature Reserve during 1981-87, together with months of occurrence. The sequence and nomenclature follows the 'List of Recent Holarctic Bird Species' by Voous (1973, 1977)

Species	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Tachybaptus ruficollis	x	x	x	x						x	x	x
Podiceps nigricollis	x	x	x	x				x	x	x	x	x
Calonectris diomedea				x								
Puffinus puffinus							x					
Phalacrocorax carbo	x								x	x	x	x
Botaurus stellaris											x	
Ixobrychus minutus			x	x	x	x				x		
Nycticorax nycticorax			x	x	x			x	x	x	x	x
Ardeola ralloides			x	x	x	x		x	x			
Egretta garzetta	x		x	x	x	x	x	x	x	x	x	x
Egretta alba								x				
Ardea cinerea	x	x	x	x	x	x	x	x	x	x	x	x
Ardea purpurea			x	x	x			x	x	x	x	
Coconia nigra										x		
Plegadis falcinellus			x	x	x	x		x	x		x	
Platalea leucorodia			x						x	x		
Phoenicopterus ruber			x									x
Cygnus olor												x
Anser anser		x									x	
Tadorna tadorna	x										x	x
Anas penelope	x	x	x						x	x	x	x
Anas strepera											x	
Anas crecca	x	x	x			x		x	x	x	x	x
Anas platyrhynchos	x	x	x	x	x	x	x	x	x	x	x	x
Anas acuta	x	x	x	x			x	x	x	x	x	x
Anas querquedula		x	x	x				x	x	x		
Anas clypeata	x	x	x						x		x	x
Aythya ferina	x	x	x						x			
Aythya nyroca			x	x	x	x	x		x		x	x
Mergus serrator											x	x
Pernis apivorus					x				x	x		
Milvus migrans			x	x	x				x	x		
Neophron percnopterus				x								
Circus aeruginosus			x	x	x				x			
Circus cyaneus				x								
Circus macrourus									x			
Circus pygargus				x								
Accipiter nisus									x			
Buteo buteo									x			
Aquila pomarina											x	
Hieraaetus pennatus									x			
Pandion haliaetus			x	x	x				x		x	
Falco naumanni			x	x								

Species	J	F	M	A	M	J	J	A	S	O	N	D
Falco tinnunculus			x	x	x				x	x	x	x
Falco vespertinus					x							
Falco columbarius												x
Falco subbuteo				x	x				x			
Falco peregrinus							x					
Coturnix coturnix			x	x								
Rallus aquaticus	x	x	x	x				x	x	x	x	x
Porzana porzana	x	x	x		x			x	x	x	x	x
Porzana parva			x		x					x		x
Gallinula chloropus	x	x	x	x	x	x	x	x	x	x	x	x
Fulica atra	x	x	x	x	x	x	x	x	x	x	x	x
Grus grus	x		x							x	x	x
Haematopus astralegus				x				x	x			
Himantopus himantopus			x	x	x	x	x	x	x	x		
Recurivrostra avosetta			x	x	x			x			x	x
Burhinus eodicnemus				x								
Glareola pratincola				x	x							
Charadrius dubius	x	x	x	x	x	x	x	x	x	x	x	x
Chardrius hiaticula			x	x	x	x	x	x	x	x	x	x
Charadrius alexandrinus	x		x	x	x	x	x	x	x	x	x	x
Charadrius leschenaultii								x				
Charadrius morinellus										x		
Pluvialis apricaria	x								x		x	x
Pluvialis squatarola					x						x	x
Vanellus vanellus	x	x	x	x	x		x			x	x	x
Calidris canutus					x							
Calidris alba				x	x				x	x		
Calidris minuta	x	x	x	x	x	x	x	x	x	x	x	x
Calidris temminckii				x	x	x	x	x	x			
Calidris ferruginea			x	x	x	x	x	x	x	x		
Calidris alpina	x			x	x		x	x	x	x	x	x
Philomachus pugnax	x	x	x	x	x	x	x	x	x	x	x	
Lymnocryptes minimus	x	x		x					x	x	x	x
Gallinago gallinago	x	x	x	x	x			x	x	x	x	x
Gallinago media	x			x	x				x	x		
Scolopax rusticola	x										x	
Limosa limosa		x	x	x			x	x				
Limosa lapponica						x						
Numenius phaeopus								x				
Numenius arquata				x			x					
Tringa erythropus			x	x	x	x	x	x	x	x	x	
Tringa totanus	x		x	x	x	x	x	x	x	x	x	x
Tringa stagnatilis			x	x				x	x	x		
Tringa nebularia			x	x	x	x	x	x	x			x
Tringa ochropus	x	x	x	x	x	x	x	x	x	x	x	x
Tringa glareola			x	x	x	x	x	x	x	x	x	
Actitis hypoleucos	x	x	x	x	x	x	x	x	x	x	x	

Species	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Arenaria interpres					x							
Larus melanocephalus	x	x	x				x			x	x	x
Larus minutus		x	x								x	x
Larus ridibundus	x	x	x	x	x	x	x	x		x	x	x
Larus genei			x		x		x	x	x	x		
Larus audouinii		x										
Larus fuscus	x		x	x	x	x				x	x	
Larus argentatus	x	x	x	x	x	x	x	x	x	x	x	x
Rissa tridactyla			x									x
Gelochelidon nilotica			x	x	x	x	x					
Sterna caspia				x	x					x	x	
Sterna sandvicensis				x					x		x	x
Sterna albifrons					x			x				
Chlidonias hybridus				x	x	x						
Chlidonias niger					x			x	x	x		
Chlidonias leucopterus				x	x					x		
Columba palumbus												x
Streptopelia turtur			x	x	x	x	x	x	x	x		
Cuculus canorus				x	x			x				
Otus scops			x	x								
Asio flammeus			x							x		
Caprimulgus europaeus				x	x							
Apus apus			x	x	x	x	x	x	x	x		
Apus melba				x	x		x			x		
Alcedo atthis	x	x	x	x			x	x	x	x	x	x
Merops apiaster				x	x	x						
Coracias garrulus					x							
Upupa epops			x	x	x			x	x			
Jynx torquilla	x	x	x	x	x			x	x	x	x	x
Calandrella brachydactyla			x	x	x	x	x	x	x	x		
Lullula arborea												x
Alauda arvensis	x	x	x	x						x	x	x
Riparia riparia			x	x	x	x	x	x	x	x		
Hirundo rustica			x	x	x	x	x	x	x	x	x	x
Hirundo daurica				x	x							
Delichon urbica		x	x	x	x	x	x	x	x	x	x	x
Anthus novaeseelandiae										x		
Anthus compestris			x	x	x			x	x	x		
Anthus trivialis			x	x	x			x	x	x	x	
Anthus hodgsoni											x	
Anthus pratensis	x	x	x	x						x	x	x
Anthus cervinus			x	x	x				x	x	x	x
Anthus spinoletta	x	x	x							x	x	x
Motacilla flava			x	x	x	x	x	x	x	x	x	
Motacilla cinerea	x	x	x						x	x	x	x
Motacilla alba	x	x	x	x						x	x	x

Species	J	F	M	A	M	J	J	A	S	O	N	D
Troglodytes troglodytes											x	x
Prunella modularis	x	x	x					x		x	x	x
Cercotrichas galactotes					x							
Erithacus rubecula	x	x	x	x	x			x	x	x	x	x
Luscinia megarhynchos			x	x	x			x	x	x	x	
Luscinia svecica	x		x	x					x	x	x	
Phoenicurus ochruros	x	x	x	x						x	x	x
Phoenicurus phoenicurus			x	x	x			x	x	x	x	
Saxicola rubetra			x	x	x			x	x	x		
Saxicola torquata	x	x	x						x	x	x	x
Oenanthe oenanthe			x	x	x			x	x	x	x	
Oenanthe hispanica				x								
Monticola solitarius	x	x	x	x	x				x	x	x	x
Turdus merula	x	x	x						x	x	x	x
Turdus pilaris	x	x									x	x
Turdus philomelos	x	x	x						x	x	x	x
Turdus iliacus	x									x	x	x
Turdus viscivorus										x	x	x
Cettia cetti	x	x	x	x	x	x	x	x	x	x	x	x
Cisticola juncidis	x	x	x	x	x	x	x	x	x	x	x	x
Locustella lusciniodes			x	x				x				
Acrocephalus melanopogon										x	x	x
Acrocephalus schoenobaenus		x	x	x	x	x		x	x	x	x	x
Acrocephalus scirpaceus	x			x	x	x	x	x	x	x	x	
Acrocephalus arundinaceus			x	x	x	x	x	x	x	x	x	
Hippolais icterina				x	x	x		x	x	x	x	
Hippolais polyglotta				x					x			
Sylvia undata	x	x										
Sylvia conspicillata	x	x	x	x	x	x	x	x	x	x	x	x
Sylvia cantillans			x	x	x		x	x	x	x		
Sylvia melanocephala	x	x	x	x	x	x	x	x	x	x	x	x
Sylvia curruca				x				x	x	x	x	
Sylvia communis				x	x	x		x	x	x		
Sylvia borin				x	x	x		x	x	x	x	
Sylvia atricapilla	x	x	x	x	x	x			x	x	x	x
Phylloscopus inornatus										x	x	
Phylloscopus bonelli			x	x	x				x			
Phylloscopus sibilatrix			x	x	x			x	x	x	x	
Phylloscopus collybita	x	x	x	x	x				x	x	x	x
Phylloscopus trochilus			x	x	x	x		x	x	x	x	
Regulus regulus	x	x								x	x	x
Regulus ignicapillus	x	x	x							x	x	x
Muscicapa striata				x	x	x		x	x	x	x	
Ficedula parva										x	x	
Ficedula torquata			x	x	x					x		
Ficedula semitorquata				x								
Ficedula hypoleuca			x	x	x			x	x			
Remiz pendulinus	x	x	x							x	x	x

Species	J	F	M	A	M	J	J	A	S	O	N	D
Oriolus oriolus				x	x				x			
Lanius collurio					x				x	x	x	
Lanius excubitor			x									
Lanius senator			x	x	x				x			
Sturnus vulgaris	x	x	x	x	x		x	x	x	x	x	x
Passer hispaniolensis	x	x	x	x	x	x	x	x	x	x	x	x
Passer montanus	x	x	x	x	x	x	x	x	x	x	x	x
Fringilla coelebs	x	x	x	x	x	x	x		x	x	x	x
Serinus serinus	x	x	x	x	x	x	x	x	x	x	x	x
Carduelis chloris	x	x	x	x	x	x	x	x		x	x	x
Carduelis carduelis	x		x	x	x	x	x	x	x		x	x
Carduelis spinus											x	x
Carduelis cannabina	x	x	x	x	x	x	x	x	x	x	x	x
Coccothraustes coccothraustes										x	x	x
Loxia curvirostra							x					
Emberiza pusilla											x	
Emberiza schoeniclus	x	x	x							x	x	x
Miliaria calandra	x	x	x	x	x	x	x	x	x	x	x	x

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The Vegetation of the Għadira Nature Reserve

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ABSTRACT

The Għadira Nature reserve is one of the few salt-marshes still extant in the Maltese Islands. The indigenous vegetation is dominated by halophilic and salt-tolerant species such as *Phragmites australis, Inula crithmoides, Juncus acutus, Juncus subulatus, Triglochin barrelieri, Melilotus messanensis, Salicornia ramosissima, Suaeda maritima, Salsola soda* and *Parapholis filiformis.* Management of the reserve has resulted in the introduction of three main categories of plants (a) species from the adjacent dune such as *Elymus farctum, Sporobolus arenarius* and *Pancratium maritimum;* (b) species, mainly trees and shrubs, introduced in order to attract birds and (c) halophytic species introduced from other salt-marsh areas in order to protect them from extinction such as *Carex extensa, Halimione portulacoides* and a possibly undescribed species as *Limonium. Tamarix* species, especially *T. africana* and *Atriplex halimus* were introduced long before the establishment of the reserve but their numbers have been augmented as part of the reserve management policy. Another component of the vegetation is represented by weed species such as *Oxalis pes-caprae* and *Sonchus* cf. *oleraceus,* some of which have greatly increased in abundance.

The aquatic vegetation is represented by four macrophytes: the angiosperm *Ruppia drepanensis* (for which Għadira is the only known station in the Maltese Islands) and the green algae *Enteromorpha intestinalis, Cladophora* sp. and *Ulothrix* sp. The algae occur largely as floating algal mats supporting a characteristic thycoplankton the phytoplanktonic component of which is dominated by diatoms, dinoflagellates and chlorophytes.

Introduction

Saline marshlands are communities which become established on soft substrates inundated and/or permeated by water of high salinity.

Few saline marshlands exist in the Maltese Islands, these are located mainly at the mouths of valley systems e.g. Salini, Birżebbuġa, Marsa, St. Julians, Marsalforn (Gozo) or on low-lying coastal land where sea-water permeates the soil e.g. Għadira, Għadira s-Safra, Is-Simar, Marsaxlokk, (Schembri *et al.*, 1987).

All Maltese saline marshes have been greatly modified by human activity, partly for purposes of land reclamation e.g. Marsa or due to their proximity to urban or resort areas e.g. St. Julians, Marsalforn (Gozo), Marsaxlokk, Is-Simar. As a result few localities still support a discrete saline marsh vegetation while in most cases only the persistent appearance of a few saline marsh species such as *Phragmites australis* or *Atriplex prostrata* bely the former existence of a saline marsh community (Lanfranco & Schembri, 1986).

Għadira is one of the largest saline marshes in the Maltese Islands. The locality is now a Nature Reserve. For details of the former history of Għadira and events leading to its establishment as a Nature Reserve see Sultana (1990).

Very little literature exists pertaining specifically to the vegetation of Għadira. This consists entirely of reports leading to the establishment of Għadira as a Nature reserve (Lanfranco [G], 1967; Savona -Ventura *et al*, 1980; Axell, 1980; Schembri; 1981; Thake, 1981).

There has been no attempt to study the vegetation in detail beyond the floristic aspect. This paper is the result of a short-term preliminary survey on which a more detailed research programme can be built.

Materials and Methods

The flora growing within the confines of the reserve was investigated during a series of visits

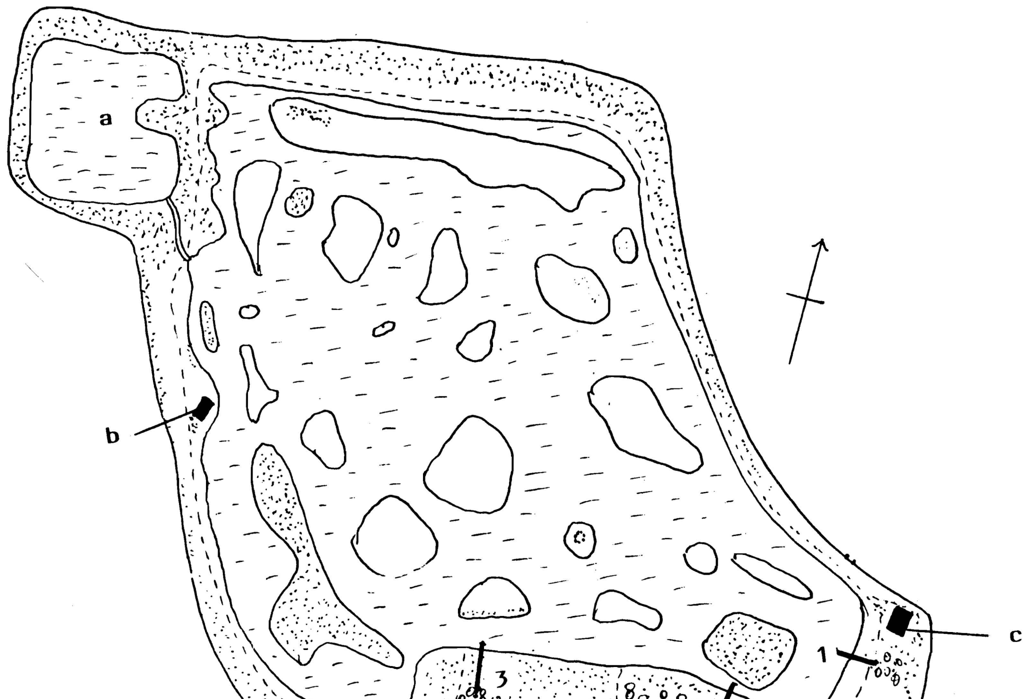

Fig. 1: Plan of Għadira Reserve showing position of transects 1; 2 & 3 (small circles = Tamarix trees; dots = reeds; rushes and low vegetation; dashes = water; broken line = main path; a = reservoir; b = hide; c = resource centre).

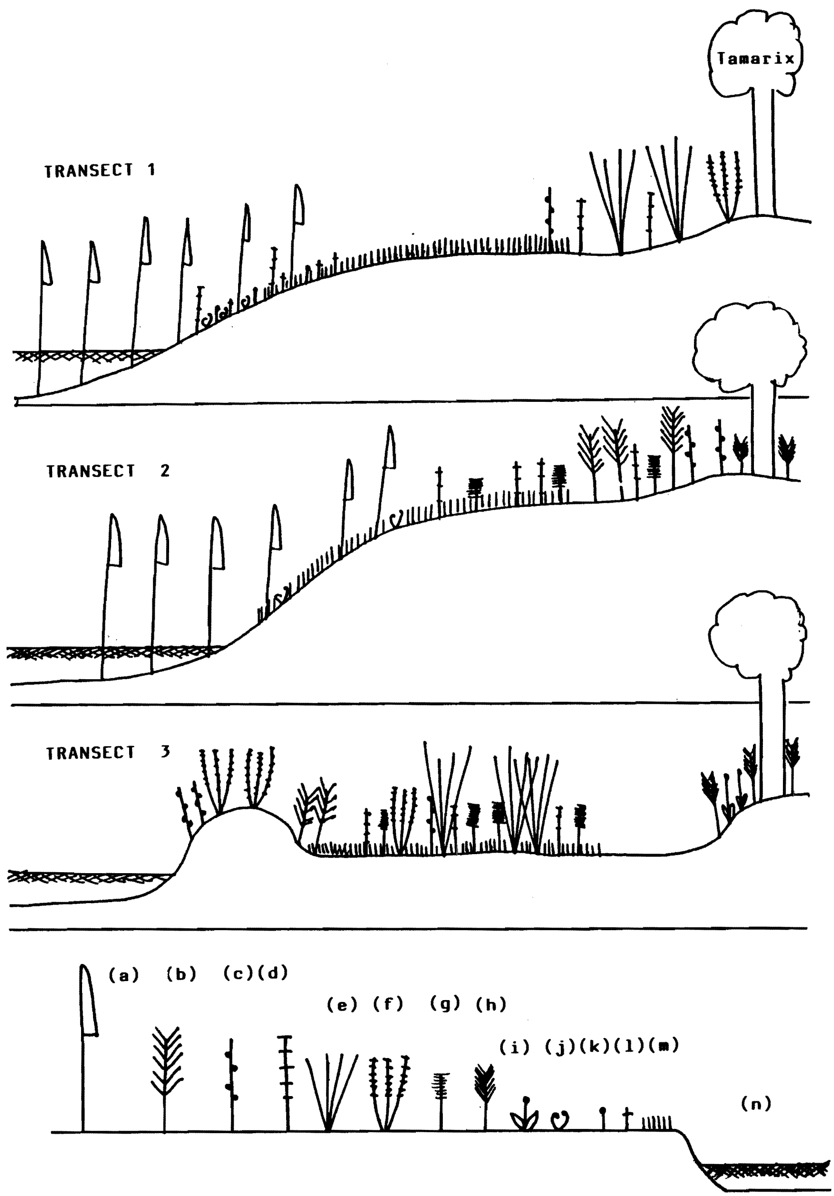

Fig. 2: Three representative transects. Baseline for transects 1 and 2 = 4 metres, that for transect 3 = 5 metres. Key to symbols: (a) = Phragmites australis, (b) = Sporobolus arenarius, (c) = Melilotus messanensis, (d) = Salicornia ramosissima, (e) = Juncus acutus, (f) = Inula crithmoides, (g) = Suaeda maritima, (h) = Bromus rigidus, (i) = Aethiorhiza bulbosa, (j) = Parapholis incruva, (k) = Salsola soda (seedlings), (1) = Juncus hybridus, (m) = Parapholis filiformis, (n) = algal mats (Cladophora with some Ulothrix). In transect 1 the following species were also present in the Tamarix undergrowth: Sonchus oleraceus, Oxalis pes-caprae, Elymus farctus and Sporobolus arenarius.

undertaken in the spring of 1988. Every species seen was recorded and its frequency and habitat noted. A complete list of the species is given in the appendix. Representative transects were taken (Figs. 1, 2). The aquatic vegetation was also noted. Water samples were taken from different parts of the site in order to examine the microbiota. Literature records were consulted (Sommier & Caruana Gatto, 1915; Borg; 1927; Borg, 1936; Lanfranco, 1967) as well as unpublished records by the author. Physico-chemical data used as a background for this study is based on Hili *et al.* (1990).

Non-Submerged Plant Life

The species growing within the confines of the reserve may be categorised as follows:

A. *Indigenous element:* Plants typical of saline marshlands and which also existed in the locality prior to the commencement of management activities. This component my be divided into three categories.

   (i) Species which, at least in the Maltese Islands, are confined to saline marshlands. The most characteristic are *Salicornia ramosissima, Triglochin barrelieri, Parapholis filiformis, Suaeda maritima, Juncus acutus* and *Melilotus messanensis.*
   (ii) Species which also occur in other types of saline habitats. Examples are *Inula crithmoides, Salsola soda* and *Parapholis incurva.*
   (iii) Salt-tolerant species which also occur in non-saline habitats but which, in the Maltese Islands, often reach their best development in saline conditions — not necessarily because of a predilection for saline substrates but more likely as a result of reduced competition by salt-intolerant species. Some of these also occur in freshwater marshlands. Examples are *Phragmites australis* and *Juncus subulatus.*
   (iv) species which are equally common in saline & non-saline substrates such as *Lotus ornithopodiodes* and *Medicago polymorpha.*

B. *Introduced species:* This component includes those species which become established as a result of habitat disturbance (i.e. weed species) and those which have been introduced deliberately as part of the reserve management policy. The following categories can be recognised:

   (i) Weed species, many of which occur in a variety of anthropic habitats. While most were also present prior to the establishment of the reserve, many have increased in extent as a result of the works carried out on the site in order to render it more attractive to bird life Characterisitic species are *Sonchus oleraceus, Bromus diandrus* and *Oxalis pes-caprae.*
   (ii) Species introduced from the adjacent dune community such as *Elymus farctus, Sporobolus arenarius* and *Pencratium maritimum.* Some of these are also part of the original vegetation where the reserve abuts on to the dune community.
   (iii) Species introduced in order to attract birds. These consist chiefly of indigenous and archeophytic trees and shrubs such as *Ceratonia siliqua, Myoporium tetrandrum* and *Punica granatum.*
   (iv) Halophytes introduced from other saline marshlands in order to protect them from possible extinction in their original sites. Examples are *Carex extensa* which was rescued from a nearby marsh which was destroyed when the Mellieħa bypass was under construction; *Halimione portulacoides* and a possibly undescribed species or subspecies of *Limonium* rescued from Ras iċ-Ċagħaq at Delimara where there was

a small but important marsh, now obliterated as a result of works in connection with the new power station. All of the introduced species have survived but, so far, there is no sign of propagation.

Two species deserving special mention are *Atriplex halimus* and *Tamarix africana*. Both are perhaps indigenous to the site but both have also been extensively planted. As indigenous species *Atriplex halimus* belongs to category A(ii) while *Tamarix africana* belongs to category A(iii) above.

Vegetation Structure

Part of the marshland perimeter is fringed with *Tamarix africana* which supports an undergrowth dominated by grasses, especially *Bromus rigidus* but also by other types of plants such as *Inula crithmoides* and *Aethiorhiza bulbosa*. Where the marsh abuts on the dune, species. such as *Elymus farctus* and *Sporobolus arenarius* also occur. Weed species, especially *Sonchus oleraceus* and *Oxalis pes-caprae* are abundant.

Clearings among *Tamarix* trees, especially along the south border are occupied by dense mats of *Triglochin barrelieri*, often mixed with *Melitlotus messanensis* and *Parapholis filiformis*.

Closer to the water's edge, dominant species are *Parapholis filiformis* and *Salicornia ramosissima* accompanied by *Suaeda maritima* all of which are annuals.

At the water's fringe is a population of *Phragmites australis* which is partly submerged during the wet season when the water level is high. This *Phragmites* belt is backed by a dense population of *Juncus subulatus* (a species which is also common in some freshwater marshes).

In late spring the receding waters permit germination of annual species such as *Salsola soda* (which reaches maximum development in summer), *Juncus hybridus* and *Parapholis incurva*.

On more permanent substrates there are populations of *Juncus acutus* and *Inula crithmoides*.

Submerged Vegetation

A. *The Macroflora*. Four species of submerged macroscopic plants were encountered during the present investigation. The only angiosperm was *Ruppia drepanensis*, a taxon of uncertain status which is endemic in the Mediterranean (Maire, 1952). Għadira is the only locality in the Maltese Islands where it is known to occur (Lanfranco, 1989). It grows in the main pool and in the reservoir but in greatly reduced quantity when compared to its abundance prior to the establishment of the reserve. The remaining three species are green algae. *Enteromorpha intestinalis* occurs mainly in the ditch. The main pool supports large populations of a *Cladophora* species which, in places, is accompanied by an *Ulothrix* species. Unpublished records by the author dating to the sixties and early seventies indicate the presence of a species of *Vaucheria* (Division: Xanthophyta) which was not encountered during the present study.

B. *The Microflora*. Most parts of the pool support a rich micro-flora Much of the material examined during this study is unidentified but it is still possible to indicate some of the major microfloristic components. In the ditch the most characteristic species were diatoms such as *Nitzschia longissima* and species of *Achnantes*, and *Pleurosigma* (s.1). Also abundant was the green monad *Pyramimonas*. Most abundant of the Cyanbacteria was a species of *Phormidium*. These were accompanied by numerous ciliates which included species of *Aspidiska*, *Lacrymaria*, *Vorticella* and *Vaginicola* and by microfauna especially gastrotrichs, rotifers, ostracods and cyclopoid copepods.

In the main pool one of the dominant species is an unidentified coccoid alga. also abundant were diatom species of *Achnantes*, *Navicula* (s.1.) and *Cocconeis* (this last epiphytic on

Cladophora). Blue-green algae were represented by species of *Spirulina* and *Chroococcus* while green algae were represented by species of *Pyramimonas* and (?) *Coelastrum*. Bacteria, notably spirochaetes, were abundant in the rotting algal mats. In summer there is an extensive development of pink halobacteria.

The reservoir does not support an abundant phytoplankton. The main species were an unidentified chlamydomonad and dinoflagellates, notably *Prorocentrum micans* and a species of *Gymnodinium*. A species of *Cosmarium* (Desmidiales) was also noted.

Discussion

The modification carried out on the Għadira site in connection with its conversion into a bird reserve have caused at least one major change in the nature of the habitat. In the pre-modification stage, Għadira supported a large, rather shallow pool which invariably dried up in summer while now there is a permanent water body — although the water level fluctuates widely throughout the year (Hili *et al.*, 1990). It is thus the aquatic biota which have been most profoundly affected by these changes. The principal change observed is the decline in the population of *Ruppia drepanensis*. This is regrettable in view of the rarity of this species. It is possible that this species favours waters which dry up periodically but, more likely, the main reason for its decline is the great increase in the population of a species of *Cladophora*. Prior to the changes undertaken on the site, the only macroscopic alga noted was a species of *Vaucheria* (not recorded in the present investigation). The waters of Għadira tend to become heavily eutrophic from late spring through summer, a phenomenon which, again, is mainly due to the great proliferation of the *Cladophora* which depletes the oxygen supply of the pool and dies off. In fact, during the hot months, much of the *Cladophora*, especially in the shallower parts, would be dead and in a state of putrefaction. An extensive development of pink halobacteria forms on these dead algal mats. The situation is relieved in the wet season when the pool is replenished by rain water.

There are no records of the microbiota of Għadira prior to this investigation. A remarkable characteristic is the co-existence, especially in the reservoir, of species with saltwater and freshwater affinities, e.g. *Cosmarium* sp. (freshwater) and *Prorocentrum micans* (saltwater).

Fewer qualitative changes seem to have occurred in the non-submerged vegetation. The floristic composition of the site is reasonably well documented in the standard floras (Sommier & Caruana Gatto, 1915; Borg, 1927) and the list given by Lanfranco [G] (1967) as well as numerous unpublished records by the author. A survey of the pool area was carried out in April 1974 as part of training in field work for pupils of the Hamrun Boys Secondary School, and supervised by the author. No species encountered during that survey has disappeared from the pool area except for the weed species *Urtica pilulifera*, which has also nearly disappeared from all over the Maltese Islands. The main change is the considerable proliferation of weed species, especially *Sonchus oleraceus*; to be expected given the considerable disturbance undergone by the site; as well as the deliberate introduction of new species as noted above.

Two rare species which were recorded from the pool area of Għadira have disappeared. *Chondrilla juncea* occurred in the area at least till the mid-1920's (Borg, 1927) but which is now confined - in very reduced numbers - to the area occupied by the Danish village outside the boundary of the reserve. *Crypsis aculeata* was recorded by Borg (1935) as plentiful. Neither of the above mentioned species has been seen in the pool area since the mid-1960s.

APPENDIX

Annotated List of Species

Hereunder are enumerated the plant species the presence of which (past or present) within the confines of the reserve has been verified by the author. This list is based on observations made during the present study and the information derived from the fieldwork carried out in 1974 by students of the then Hamrun Boys Secondary School under the author's supervision. The flora of the pool area before and after the modifications leading to the establishment of the reserve can thus be compared. Little use has been made of literature records since most of these do not specify from which part of Għadira the records originate. The dune habitat just outside the confines of the reserve carries a very different flora and many literature records refer to this latter habitat.

Key to symbols:

A = confined to saline marshes; B = growing mainly on a variety of saline substrates; C = dune species; D = frequent also on non-saline substrates; E = weed species; F = planted in quantity; G = planted in limited quantity; H = marked decrease at Għadira Reserve site since 1974; I = marked increase in Għadira Reserve site since 1974; J = very rare in Maltese Islands; K = extinct from Għadira Reserve site; L = endangered species introduced as a protection measure; S = submerged hydrophyte

A. VASCULAR PLANTS

(i) Gymnosperms

Pinus halepensis Miller	G

(ii) Dicotyledons

family: APIACEAE (= UMBELLIFERAE)	
Foeniculum vulgare Miller	D, E
family: ARALIACEAE	
Hedera helix L.	G
family: ASTERACEAE (= COMPOSITAE)	
Aethiorhiza bulbosa (L.) Cassini	D
Bellis annua L.	D,H
Centaurea nicaensis Allioni	D,H
Chondrilla juncea L.	A, J, K
Chrysanthemum coronarium L.	E
Galactites tomentosa Moench	E, I
Inula crithmoides L.	B
Reichardia picroides (L.) Roth	D
Sonchus oleraceus L.	E, I
Urospermum picroides (L.) Scopoli ex F.W. Schmidt	E, I
family: CACTACEAE	
Opuntia ficus-indica (L.) Miller	G
family: CARYOPHYLLACEAE	
Silene colorata Poiret	D
Spergularia bocconei (Scheele) Ascherson & Graebner	D,E
family: CHENOPODIACEAE	
Atriplex halimus L.	B,F
Atriplex prostrata Boucher ex DC.	B,E
Beta maritima (L.) Arcangeli	D,E
Halimione portulacoides (L.) Aellen	A,L
Salicornia ramosissima J. Woods	A
Salsola soda L.	B
Suaeda maritima (L.) Dumortier	A
family: CONVOLVULACEAE	
Cressa cretica L.	A, H
family: EUPHORBIACEAE	
Euphorbia pinea L.	D
Euphorbia terracina L.	C
family: FABACEAE	
Astragalus baeticus L.	E
Ceratonia siliqua L.	G
Cercis siliquastrum L.	G
Lotus ornithopodioides L.	D
Medicago littoralis Rohde ex Loiseleur	D
Medicago polymorpha L.	D,E
Melilotus messanensis (L.) Allioni	A
Psoralea bituminosa L.	D
family: FRANKENIACEAE	
Frankenia hirsuta L.	B
Frankenia pulverulenta L.	B,H
family: LAURACEAE	
Laurus nobilis L.	G
family: MALVACEAE	
Lavatera arborea L.	B,E
Lavatera cretica L.	D, E
Malva silvestris L.	D, E
family: MORACEAE	
Morus alba L.	G
family: MYOPORIACEAE	
Myoporium tetrandrum (Labillardiere) Domin	G
family: OLEACEAE	
Fraxinus angustifolia Vahl	G
Olea europaea L.	G
family: OROBANCHACEAE	
Orobanche pubescens D'Urville	D
family: OXALIDACEAE	
Oxalis pes-caprae L.	E
family: PITTOSPORACEAE	
Pittosporum tobira (Thunberg) Aiton fil.	G
family: PLUMBAGINACEAE	
Limonium sp. aff. *L. virgatum* (Willdenow) Fourreau	A, L
family: POLYGONACEAE	
Rumex buchephalophorus L.	D
family: PRIMULACEAE	
Anagallis arvensis L.	D,E, I
family: PUNICACEAE	

Punica granatum L.	G
family: RHAMNACEAE	
Rhamnus oleoides L.	G
family: ROSACEAE	
Eriobotrya japonica (Thunberg) Lindley	G
Rubus ulmifolius Schott	G
family: SALICACEAE	
Populus alba L.	G
family: SOLANACEAE	
Solanum nigrum L.	E, I
family: TAMARICACEAE	
Tamarix africana Poiret	B,F
Tamarix gallica L.	G
Tamarix parviflora DC.	G
family: URTICACEAE	
Urtica pilulifera L.	E,K
family: VERBENACEAE	
Lantana camara L.	G
Vitex agnus-castus L.	B, G

(iii) **Monocotyledons**

family: AMARYLLIDACEAE	
Pancratium maritimum L.	C,F
family: CYPERACEAE	
Carex extensa Goodenough	A, L
family: IRIDACEAE	
Gladioulus italicus Miller	D,E
family: JUNCACEAE	
Juncus acutus L.	
Juncus hybridus Brotero	D
Juncus subulatus Forsskaal	B
family: JUNCAGINACEAE	
Triglochin barrelieri Loiseleur	A
family: LILIACEAE	
Ornithogalum arabicum L.	D,I
family: POACEAE (= GRAMINEAE)	
Avena barbata Pott ex Link	D,E
Avena sterilis L.	D,E, I
Bromus diandrus Roth	D,E
Bromus madritensis L.	D,E,I
Bromus rigidus Roth	B
Crypsis aculeata (L.) Aiton	A,J,K
Elymus farctus (Viviani) Runemark ex Melderis	C,F
Festuca arundinacea Schreber	D
Horedeum leporinum Link	D,E
Hordeum marinum Hudson	B
Lagurus ovatus L.	D
Lolium rigidum Gaudin	D,E
Parapholis filiformis (Roth) C.E. Hubbard	A
Parapholis incurva (L.) C.E. Hubbard	B
Parapholis marginata Runemark	B
Phalaris minor Retzius	D,E
Phalaris paradoxa L.	
Phragmites australis (Cavanilles) Trinius ex Steudel	E
Piptatherum miliaceum (L.) Cosson	D,E
Polypogon monspeliensis (L.) Desfontaine	D
Sporobolus arenarius Duval-Jouve	C
family: RUPPIACEAE	
Ruppia drepanensis Tineo	H,J,M

B. ALGAE

(i) **Chlorophyta** (s.l.)

Cladphora sp.	I
Coelastrum (?) sp.	
Cosmarium sp.	
Enteromorpha intestinalis (L.) Link	
Pyramimonas sp.	
Ulothrix sp.	

(ii) **Xanthophyta**

Vaucheria sp.	H

(iii) **Bacillariophyta** (diatoms)

Achnantes sp.
Cocconeis sp.
Navicula sp.
Nitzschia longissima Ralfs
Pleurosigma (s.l.) sp.

(iv) **Pyrrhophyta** (Dinoflagellates)

Gymnodinium sp.
Prorocentrum micans Ehrenberg

(v) **Cyanobacteria** (blue-green algae)

Chroococcus sp.
Phormidium sp.
Spirulina sp.

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