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PREFACE

This report is a compilation of the results and findings of the field research undertaken by A Rocha staff and visiting scientists to the Cruzinha field study centre in 2003. We are grateful to all those who have been part of the centre's life for a short or long period this year, and for their contributions to a better understanding of the Ria de Alvor and surrounding environments.

In 2003 A Rocha was contracted to survey areas of council-owned land entering into the proposed Bio-Parque initiative, implementing Natura 2000 in the Serra de Monchique. The botanical inventory and mapping is described in the abridged account included in this report. The fieldwork was immediately followed by the devastating forest fires of August and September, affecting 78% of the Monchique district, one of the key flashpoints of the country. Discussions have subsequently opened up on working towards more sustainable forestry policies in Portugal, and A Rocha hopes to contribute from its several years of research on the comparative biodiversity of different forest and woodland types in the south of the country. The monitoring of post-fire vegetation recovery in the Serra de Monchique will be an important part of our ongoing scientific contribution.

Another significant piece of work reported on here is the water quality study completed by Chris Boyes early in the year. This preliminary study has helped define relevant methodologies, whilst providing some initial data and questions for further study. By way of follow-up, another European Voluntary Service volunteer, Ben Carpenter, joined us in June to provide a first characterisation of the invertebrate communities of the estuary and marshes. The health of the aquatic ecosystem is in this way being explored, with relevance to future implementation of the European Water Framework Directive. As we look at possibilities for management of the water regime in the dyked marshlands, the work of Edinburgh University's Environmental Management MSc group, who for the second consecutive year spent a week with us in the Spring, became very relevant. An article based on a poster presentation of their work is included in this report.

The establishment of a Geographic Information System to support these studies and their application has long been considered a priority. This year the first phase of this development was realised through the award of ArcGIS software from the Conservation Grant scheme of ESRI. We took delivery of the system in time to benefit from the expertise of Stephanie and Eric Orndorff, A Rocha USA members who travelled over in the autumn to set up the system and provide training in its use. The next Observatory Report will provide an update on the building and use of the GIS, as well as the first map products arising from it. We are grateful to both the Orndorffs and ESRI for this development.

A Rocha's programme of bird studies continued through the year, with a weekly ringing session in the grounds of the centre, Storm Petrel ringing in the late Spring off Almadena (led by Rob Thomas with the help of Marielle Smith of Cardiff University), and fortnightly wader counts on the Ria de Alvor. We again benefited from the eagle eye of Willem Scheres, who visited us in April, and who in this report has provided a review of past seabird records from our study area. Complementing this is a more in-depth look at Gannet movements off the coast at nearby Carvoeiro by another frequent visitor from the north, Manfred Temme.

We look forward to the Ria de Alvor being confirmed as a European Natura 2000 site in 2004. In the meantime A Rocha has started to work towards a management plan as a means of implementing this legislation. The first part of this plan – a description and evaluation – was completed and became an integral part of the Lagos and Portimão's Intermunicipal Commission's report launched at a press event on World Wetlands Day, 1 February. We see this as a step forward, and intend to follow this process through the months ahead. Thank you for your interest in and support of our studies that help make the protection of this environment a possibility into the future. *The Editor*

ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF RE-INTRODUCING A TIDAL CYCLE INTO A DYKED AREA OF THE WESTERN ALVOR MARSHES, PORTUGAL

**Dr A. Vinten and the MSc Environmental Protection and Management groups
of 2001/2 and 2002/3, Edinburgh University**

The following is edited from a poster of the same title presented at the International Water Association DipCon 2003 Conference on Diffuse Pollution and Basin Management, University College Dublin, August 2003.

Introduction

The Western Alvor Marshes (Figure 1) lie between Lagos and Portimão in the southern Algarve, Portugal. The wetlands, situated at the confluence of the Farelo, Torre, Odiáxere and Arão Rivers, provide habitats for a diverse range of bird species. The wetlands are separated by a matrix of dykes which were built in the 1950s for rice cultivation and storm protection. In recent years there has been a decline in the number of nesting birds and waders recorded on the marshes. This is thought to be due to lack of food in the stagnant areas of the marshes, together with human disturbance of nesting sites. The inflow and outflow of tidal water is controlled by a sluice gate. Occasionally the sluice gate is jammed open by fishermen, leading to large and unexpected changes in water level. This leads to frequent flooding of plover nests. It is hypothesised that a regular tidal cycle would be preferable, not only because the nesting birds would avoid areas likely to flood but also because a decrease in stagnant areas would lead to an increase in the availability of aquatic invertebrates. This study assesses the potential environmental impact of this particular management option.

Topographical Study - impact on nesting birds

A topographical study of the Western Marsh areas was carried out to estimate the ground elevation with respect to vegetation types and area of open water. The results, shown in Figure 2, illustrate the effects of raising water levels on five main components of the marsh: water-covered areas, wet fringes, bare areas, low scrub and high scrub. Areas covered with low scrub are of particular importance due to their suitability to nesting birds, whilst high scrub, bare areas and wet fringes remain unsuitable. In contrast, wet areas provide suitable habitats for wading birds. It is therefore important to provide adequate areas for waders whilst preventing encroachment of nesting areas by seawater. The results show that a tidal influx of approximately 30 cm would not cause serious adverse effects on the nesting areas. A tidal in-flux greater than 30 cm would begin to reduce suitable nesting areas rapidly. This is a lot less than the tidal range in the surrounding estuary, so some active control would be needed.

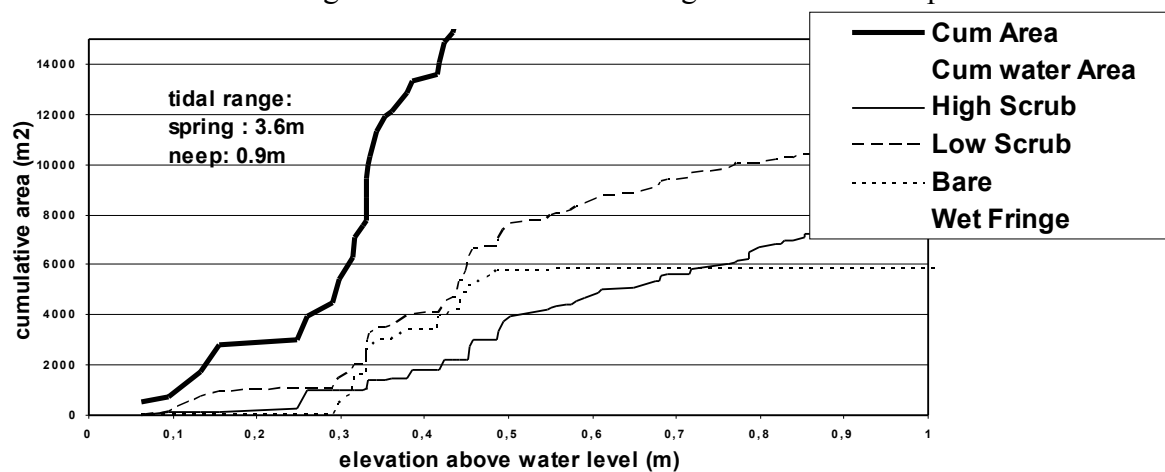
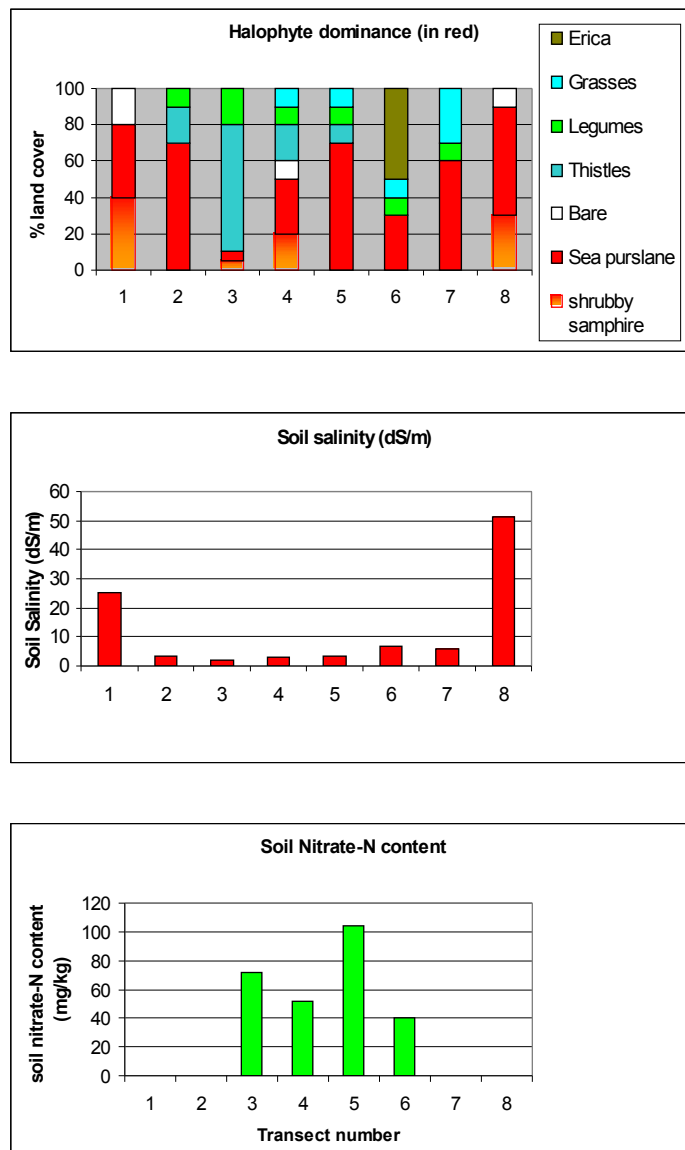
Figure 1 The Western Alvor Marshes.**Figure 2** The effect of raising water levels on the coverage of different components of the marshes.

Figure 3 Transect records of vegetation, salinity and nitrates.

Habitat features

Three vascular plants dominate the dyked salt marsh: Sea Purslane *Halimione portulacoides*, Shrubby Samphire *Arthrocnemum* spp and Sharp-pointed Rush *Juncus acutus*. A transect from SE to NW across one part of the marsh (see Figure 1) recorded vegetation, soil salinity and nitrate levels at 30 m intervals.

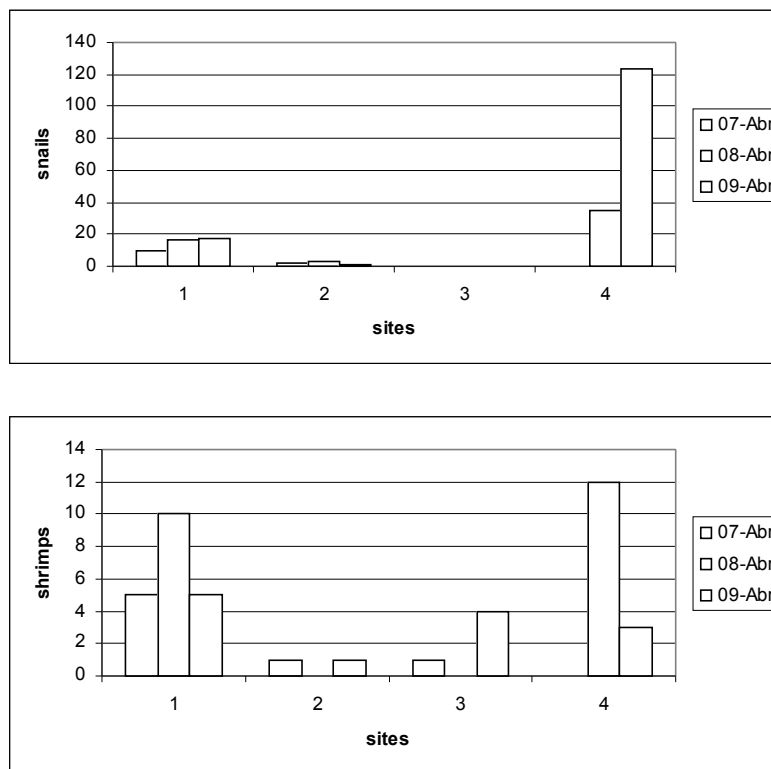
Halophytes dominate the fringes of the salt marsh island (Figure 3). However, grasses and non-halophytic plants become more common-place further from the salt water channel (with the exception of location 5). Soil salinity is highest near the salt water channels and in regions of halophyte dominance. Nitrates are found towards the centre of the salt marsh island. Local livestock are grazed in this part of the salt marsh which may explain the presence of such nitrates.

From point measurements made in the main channels (see values given in Figure 1) it appeared that the salinity of the water in the marsh did not significantly change.

Aquatic invertebrate survey

An investigation into the water quality of the area was carried out using traps in four different sites around the marshes. Two of these were relatively close to the sluice gate (see Figure 1) and the other two nearer to the opposite end of the dyked marsh. Samples were collected on three consecutive days and the numbers of snails and shrimps were recorded. High numbers were expected at sites 3 and 4, close to the sluice gate, due to the tidal inflow allowing circulation of seawater and inflow of organisms and food. In contrast, low numbers of species were expected to be found in the stagnant sites 1 and 2, further from the sluice gates. The results showed high levels of invertebrates at site 4 (closest to the gate), however site 3 recorded low levels. Results at site 2 were low as expected, however site 1 unexpectedly showed high numbers of shrimps.

Figure 4



Conclusion

From this initial survey work, the following conclusions are drawn:

- Introducing a tidal cycle would result in better water circulation, reducing stagnant and anoxic conditions. This would provide better feeding conditions for nesting birds and waders.
- Management of tidal inflow in relation to the topographical model could promote more suitable areas for both nesting and feeding waders.

Acknowledgements

We thank staff of A Rocha for their support and encouragement, and for providing the facilities for this project work.

A PRELIMINARY ASSESSMENT OF WATER QUALITY IN THE ALVOR ESTUARY

Chris Boyes and Will Simonson

Introduction

The aim of this study was to carry out a baseline assessment of water quality in the Alvor Estuary, in particular seeking to identify the presence of pollutants at levels potentially harmful to the health of the estuary ecosystem. A subsidiary aim was to research and test suitable techniques for water quality measurement, and make recommendations for further investigation and monitoring.

Water quality is critical not just to the aquatic flora and fauna of the estuary but the functioning of the whole biological system. The importance of the estuary for waders depends on the status of shellfish and other invertebrate populations, to give one example. The shellfish also support an important local fishing economy, especially the harvest of cockles, mussels and ragworms as fishing bait. For everyone's interests water quality is important to maintain and monitor.

At the same time, there are a number of potential threats to water quality, principally from organics generated by urban centres and livestock farming and brought into the estuary by its tributaries (Furtado, 1995). It is suspected that poor functioning of the waste water treatment works at Figueira has been responsible in the past for the release of untreated effluents in to the river. Untreated discharges from pig-farming enterprises is also a known problem elsewhere (eg Serra de Monchique) and is a potential issue in the catchment of the Alvor Estuary. Run-off of fertilisers from the intensively managed citrus orchards is another potential and significant source of nitrates, and fish-farms bordering the River Odiáxere are a source of organic products and nutrients, as well as increased oxygen demand.

Estuary water quality has yet to be studied within A Rocha's programme of research, and is generally subject to little systematic monitoring. It was included within an extensive ecological characterisation of the estuary undertaken in 1985/6 (Peneda, 1986), whose data are compared with the results of this current study. Throughout Europe, water quality of rivers, lakes, transitional and coastal waters is now regulated by the Water Framework Directive, with the overall aim of achieving a 'Good' status for all waters by 2015. It is hoped that A Rocha's initiation of water quality monitoring in 2002 can contribute to such aims, through a better understanding of local water quality issues.

Theoretical background to the measurement of water quality parameters

There follows an introduction to the key parameters used to assess the condition of an estuary, and the techniques employed to measure them; for a more detailed treatment please refer to the US EPA estuary monitoring manual (US EPA, 1993).

For most parameters, its biological importance, and importance in the interpretation of other parameters, will be explained; the issues surrounding the technicalities and feasibility of the available measurement techniques will then be discussed. The choice of parameters and techniques for use in this study of the Alvor Estuary will be explained throughout.

Table 1 Different water quality parameters: used in this study (*); observed, but not studied in depth (#)

Physical Measures	Chemical Measures	Biological Measures
Temperature *	Dissolved Oxygen *	Indicator bacteria *
Salinity *	Biochemical Oxygen Demand *	Submerged aquatic vegetation #
Turbidity * / Total Solids	Nutrients *	Other living organisms #
Marine debris #	pH *	
	Alkalinity	
	Toxins	

I Physical measures***Temperature***

Water temperature is one of the easiest measurements to make, and also one of the most important parameters of the aquatic environment to learn about. Water temperatures affect photosynthesis and respiration rates, oxygen and carbon dioxide levels and pH, solubility of gases, distribution of organisms with different temperature tolerances, chemical reaction rates, density of seawater in relation to freshwater, and therefore stratification and mixing to be found within the estuary. Water temperature is also required in the calculation of percentage dissolved oxygen saturation and salinity in the methods employed in this current study.

Salinity

Salinity is the measure of salts dissolved in water, usually expressed in parts per thousand (ppt). Estuaries usually exhibit a gradual change in salinity throughout its length, as freshwater from tributaries mixes with seawater from the ocean. Salinity also increases with depth unless the water column is well mixed. Together with water temperature, salinity is a primary factor in determining the stratification of an estuary.

Salinity is also an important factor when monitoring many key water quality variables. For example, salinity measurements are needed to calibrate Dissolved Oxygen meters and to calculate dissolved oxygen saturation.

Turbidity/Total solids

Turbidity is a measure of water clarity – it is not a measure of suspended solids present, nor the rate of sedimentation, but rather of the amount of light scattered or absorbed by suspended particles. Total Solids are a more direct measure of matter suspended or dissolved in the water. Both measures are useful indicators of the effects of run-off from construction, agricultural practices and discharges. Regular monitoring can help detect trends that might indicate an increase or decrease of erosion in the watershed.

Sedimentation is a priority concern in many estuaries, making turbidity monitoring important. Moreover, suspended particles can reduce dissolved oxygen levels and cause negative physical effects (smothering and light depletion) for bottom-dwelling organisms. They can be carriers of toxins.

Turbidity can vary enormously in time and space within an estuary environment, and hence even one or two years' data is insufficient to fully describe this variability. However, sources of erosion and turbidity can be detected in a few monitoring sessions. The ideal is to monitor weekly or bi-weekly, year round.

II Chemical measures

Dissolved Oxygen (DO)

Of all the parameters that characterise an estuary, dissolved oxygen (DO) is one of the best indicators of its health. DO is one of the most important factors controlling the presence or absence of estuarine species; as oxygen is crucial to most animals and plants an estuary with little or no DO cannot support healthy levels of animal or plant life. Oxygen enters the waters from the atmosphere, assisted by waves and currents, and through aquatic plant photosynthesis. It is also required for decomposition of organic matter. Low concentrations of oxygen can also lead to nutrients and toxins being released into the water column from sediments. (US EPA, 1993)

Biochemical Oxygen Demand (BOD)

Related to dissolved oxygen, biochemical oxygen demand (BOD) is a measure of the rate at which dissolved oxygen is depleted from the water by micro-organisms as they decompose organic matter, and by chemical oxidation of inorganic matter. The greater the BOD, the more rapidly dissolved oxygen is depleted, and the less is available to aquatic organisms. The consequences of high BOD are those of low DO levels: stress, suffocation, and death.

Sources of BOD include dead plant and animal matter, animal waste and human sewage, and effluents from food processing and wastewater treatment works. Although some waters are naturally organic rich, a high BOD often indicates polluted or eutrophic waters. (US EPA, 1993).

Biochemical oxygen demand was chosen to be measured in this study because of the potential sources of BOD in the Alvor Estuary, especially the Figueira wastewater treatment works (WWTW), fish farms, and marina (where sewage is possibly discharged from boats).

Nutrients

Nutrients are required by plants for growth, reproduction and fighting disease. However, high concentrations can stimulate excessive growth of algae (algal blooms), which when decomposed by micro-organisms leads to a depletion of oxygen in the water (eutrophication) and the associated effects of low dissolved oxygen levels on organisms. Increased algae can also reduce light levels reaching lower depths of water, affecting the photosynthesis of submerged aquatic vegetation. Submerged vegetation may be smothered by organic material from decomposing algae.

Anthropogenic sources of nutrients contributing to over-enrichment include fertiliser run-off from agriculture, golf courses and gardens, and effluent from WWTW and animal waste.

Nitrogen and phosphorus are nutrients of particular concern, and are monitored most commonly, because they are essential for the growth of aquatic plants and the amount of these delivered to estuaries has increased significantly.

Nitrogen and phosphorus are found in estuaries in a number of forms, depending on their source and the environmental conditions. For nitrogen: nitrate, nitrite, NO_x, ammonium, unionised ammonia and urea. For phosphorus: organic phosphate, orthophosphate, total phosphorus and polyphosphate.

Dr Vinten of Edinburgh University suggested that nitrogen in the form of nitrates is the most important to measure, as it is related to run off from fertilisers, and ammonia is also good to measure because of the presence of fish farms and WWTW in the Alvor estuary. Phosphates are of secondary importance to nitrogen in estuaries.

It was decided to measure nitrogen in the forms of nitrates and ammonia. Nitrate concentrations may be elevated due to runoff of fertiliser from citrus orchards, golf courses and by sewage if the

WWTW is not functioning correctly. Ammonia concentrations may be elevated by discharges from the fish farms, WWTW and runoff from agricultural land or farms having livestock.

pH

pH is an important chemical parameter of aquatic systems, as it can have direct and indirect (eg through affecting toxin release) effects on living organisms. Most estuary organisms prefer conditions within pH of approximately 6.5-8.5. Unanticipated increases/decreases in pH can be indicators of acid rain and industrial pollution. It can fluctuate on a diurnal and seasonal basis. Photosynthesis removes carbon dioxide from water, increasing pH. In areas with many plants, a significant difference can be found between dawn and six hours later, and one can also detect a difference in the growing season.

Alkalinity

This is a measure of the capacity of water to neutralise acids. The ability to resist pH change (eg from rainfall or wastewater) is critical to aquatic life. pH will vary between fresher and saline parts of an estuary. Alkalinity was not measured in this current study, as to some extent it would be inferable by the monitoring of pH.

Toxins

Substances that are toxic for aquatic life include heavy metals, and pesticides that run off from agricultural fields. Sewage is one source of heavy metals, and which are likely to accumulate in an estuary environment. Both metals and pesticides require laboratory analysis of water samples, although bioassays (for example with brine shrimps) is a possibility.

III Biological measures

Indicator bacteria

Human illness can result from drinking from or swimming in waters containing pathogens, or eating shellfish from these waters. Direct testing for pathogens is very expensive and impractical, and one or more indicator species or groups are used instead:

- Total coliforms are not so useful for testing recreational or shellfishing waters, as their presence does not necessarily indicate faecal contamination.
- Faecal coliforms are a more faecal-specific indicator, being a sub-group of total coliform bacteria. These are widely used, and were included in this study.
- *E. coli* is a single species within the above group, and was also used as an indicator in this study.
- Enterococci, like *E. coli*, are a group of species primarily found in the intestinal tract of warm-blooded animals, but testing for them requires a professional laboratory.

Potential sources of faecal bacteria within the Alvor Estuary are the waste water treatment works at Figueira, and the more dispersed pig farming units across the upper catchment.

IV Additional physical and biological observations made

Other simple observations can be made at sampling which help interpret the water sampling results and provide a more complete picture of the environmental health of the estuary. In this study the following observations were included:

- Water surface conditions – affects mixing of waters and dissolved oxygen
- Presence of surface scum, foam, debris and dead organisms – for example, the presence of dead fish might signify oxygen depletion
- Presence of animals in or out of the water – fish, wildfowl, cattle, etc

- Water colour and odour, and phytoplankton density – unusual odours might indicate water quality problems that are not visible
- Air temperature – a standard measurement taken in environmental monitoring programmes
- Water depth and tidal state – attempts were made to keep these constant (see methods section).

Methods (1)- Techniques for measurement

I Physical measures

Water Temperature

A plastic armoured, non-mercury thermometer was used to measure the temperature of water from the estuary. Measurements were taken: in the estuary directly, ideally more than 10cm below the water surface or halfway to the bottom in shallower waters (US EPA, 1993), though this was not always ensured; or from a bucket of 8L or more water taken from the estuary, as per recommendations (US EPA, 1993). The thermometer was read to the nearest 0.5 °C graduation, after allowing the thermometer to equilibrate to the water temperature (3-5 minutes). It is certified as accurate to +/- 0.5 °C, against US National Institute of Standards and Technology (NIST) standards.

Air Temperature

An aquarium-type thermometer – checked for accuracy against the Armoured thermometer – was used exclusively for measuring the air temperature at each sampling site (thus avoiding the difficulty of drying the Armoured thermometer). It was kept out of direct sunlight in a cardboard tube covered by aluminium foil. Readings were taken after leaving time for the thermometer to equilibrate to ambient air temperature – usually 10 minutes or just before leaving the sampling site.

Weather Observations

An indication of the amount of rain falling on the catchment area in the 7 days prior to sampling, and hence the degree of surface runoff, was gained from daily rainfall measurements made at Cruzinha. A simple tapered plastic rain gauge was mounted on a pole 1m from ground level in the most open area available, as recommended by the US EPA estuary monitoring manual (US EPA, 1993). Measurements were taken at 0900 UTC daily.

Details of weather conditions on each day of sampling were also recorded:

- General conditions e.g. occurrence of rain, mist, haze
- Wind strength and direction - estimated using Beaufort scale and compass
- Cloud cover – clear, partly cloudy, mainly cloudy or overcast

Salinity

Salinity is measured by either physical or chemical methods. The former are quicker and more convenient, and include conductivity (measured with a probe and meter), density (calculated by measuring the water's specific gravity, using a hydrometer), and refractivity. The chemical methods involved tests of chlorinity (chloride concentration) which is related to salinity.

In this study we chose to use a hydrometer, which is simple, inexpensive and highly consistent. The hydrometer was used to determine the specific gravity of a sample of estuary water, and the armoured thermometer used to measure its temperature. Knowing specific gravity and temperature, a value for salinity was obtained from a conversion table supplied with the hydrometer. Measurements were carried out in the field, although it is possible to take a water sample for analysis up to 7 days later (US EPA, 1993).

Turbidity

There are four commonly used methods of measuring turbidity: secchi disk, turbidity meter, transparency tube, and turbidity field kit. In this study turbidity was measured in Jackson Turbidity Units (JTU) using a transparency tube made by LaMotte. This is a small transparent plastic tube with a flat base.

Turbidity was recorded to the nearest 10 JTU as it was occasionally necessary to interpolate between the comparison values shown on the 'turbidity chart'. Measurements were made in open but shaded conditions, avoiding direct sunlight by turning one's back to the sun. Ideally the water sample would be taken from mid-depth, as far from the shore as is safe, away from stagnant water, and avoiding collecting sediment from the bottom (US EPA, 1993) although this was not always ensured.

Water depth

A plastic pole marked in centimetres was used to measure the depth of water at the place where samples were taken, except at Alvor marina (Site 9) and the estuary mouth jetty (Site 1) which were always deeper than 1m. Water depth was taken to aid the interpretation of other measurements such as temperature.

II Chemical measures

Dissolved Oxygen

Dissolved oxygen (DO) may be measured using an electronic meter or chemical test kits employing Winkler titration. Test kits were chosen for this study due to their adequate performance and lower cost which, for the number of tests carried out in this study, make them cost effective compared to electronic meters. The test kit is available with the reagents as powder in packets or liquid in dropper bottles. The 'all liquid reagents' version was chosen, at no extra cost, because of the greater ease of using dropper bottles than packets of powder, especially in field conditions with wind etc.

It was not felt necessary to go to the extra expense and effort of taking multiple samples at different depths as 'for most monitoring programmes and most water quality parameters...samples taken from the estuary's surface will suffice' (US EPA, 1993).

Dissolved oxygen was measured using a test kit (LaMotte #5860) which uses the azide modification of the Winkler titration method. The azide modification removes interference due to nitrites which is a common problem in estuarine waters (US EPA, 1993).

Immediately after a water sample is taken in a bottle, reagents are added to 'fix' the sample which ensures that no further oxygen can be introduced to it. The titration test for oxygen can then be done in the field, or up to 8 hours later if kept refrigerated and in darkness (US EPA, 1993). The amount of dissolved oxygen in the sample is determined at the end of the titration procedure – a reagent is added to turn the sample from a blue colour to clear, and the amount of reagent required translates directly into the amount of dissolved oxygen present in the original water sample. The result is read to the nearest 0.2 mg/L.

Biochemical Oxygen Demand

To determine Biological Oxygen Demand (BOD) two water samples are taken and one is immediately tested for dissolved oxygen concentration. The other sample is incubated at 20°C in total darkness for 5 days, and then tested for dissolved oxygen concentration.

$$\text{BOD, mg/L} = (\text{DO of immediately tested sample}) - (\text{DO of incubated sample})$$

For samples with much organic pollution, it is possible for the DO level to have decreased to zero during the incubation period. Since it is not known when the zero point was reached, it is not

possible to calculate the BOD. In this case it is recommended to collect another sample and dilute it by a factor which results in a final DO level of at least 2 mg/L. Special dilution water containing the nutrients necessary for bacterial growth must be used for the dilutions, and it takes some experimentation to determine the appropriate dilution factor for a particular sampling site. (US EPA, 1993)

An incubator is usually required for the incubation, which are quite costly, although Dr Vinten of Edinburgh University suggested that a sample could be kept at room temperature in a laboratory where the temperature varies little throughout the day. The results would differ from those of the standard test by perhaps 10%, but would be comparable to each other.

The BOD samples were kept in the Exhibition Room for 'incubation' for 5 days, and the temperature was monitored with a maximum/minimum thermometer. On the first occasion, the room temperature was favourable: varying only from 18.5-20.5°C. Although on the second occasion, weather conditions meant temperatures varied from 10-30°C.

Due to the extra expense and complication of using dilution water, should there have been any zero DO concentrations after the incubation, the BOD would not have been determined, but would have been recorded as "greater than X mg/L", where X = DO of the immediately tested sample.

Nutrients

Nutrients may be measured with a spectrophotometer, a colorimeter, test kits, and by analysis at a professional laboratory.

For measuring nitrates in this study, test strips and an electronic reader were loaned by Edinburgh University. The test strips are wetted and the reaction zone stays white if nitrate is not detected, or become a shade of violet to pink if it is.

Ammonia in water is present in two forms: the ionised ammonium ion (NH₄⁺) and un-ionised ammonia (NH₃). Together they comprise total ammonia. Commercially available test kits measure total ammonia-nitrogen, which is the amount of nitrogen present as a component of NH₄⁺ and NH₃ molecules.

A test kit using the salicylate method (#5864 from LaMotte) was used to measure total ammonia-nitrogen. Reagent tablets are added to a sample of water which turns yellow-green to blue-green depending on the level of ammonia-nitrogen detected. This is then compared with a colour chart in order to determine the corresponding amount: 0.1, 0.25, 0.5, 1.0, 2.0 or 4.0 mg/l total ammonia-nitrogen.

pH

A Hanna Instruments 'Checker' pH meter was used to measure pH, except after October when it became unserviceable. It had a measuring range of 0 – 14 pH, resolution of 0.01 pH and accuracy of +/- 0.2 pH. Details of its use are given in Annex 1.

III Biological measures

Indicator bacteria

Testing for *E. coli* and total coliforms was done using Coliscan Easygel, which is a self-contained kit with all the supplies required: sterile disposable collection bottles and 1mL droppers; bottles of Coliscan Easygel growth medium; and specially coated Petri dishes. It is a simple pour-plate method in which colonies of *E.coli* and coliforms that grow are identified from differences in colour. Coliscan is appropriate for measuring colony counts only above 20 colony forming units

per 100mL (100 cfu/100mL) since there is no filtration step to concentrate the bacteria and the maximum volume of water able to be tested is 5mL (US EPA, 1993).

A sample of water is added to the bottle of liquid Coliscan medium, mixed, and poured into a special Petri dish coated with a substance that causes the medium to gel. The plate is then incubated at 35°C for 24 hours, or at room temperature for 48 hours or longer. E.Coli and coliform colonies which have grown can then be counted: purple-blue colonies are E.Coli, other coliforms are pink, and non-coliform organisms are teal green, light blue or colourless.

Additional observations

To aid the interpretation of other collected data, various other observations were made at each site:

- Water surface state - calm, rippled, with waves, with whitecaps
- Water colour – nature if of note
- Water odour, or odour present in the area
- Phytoplankton – presence and relative density
- Presence or signs of:
 - Surface scum or foam
 - Floatable debris
 - Oilslick
 - Erosion
 - Dead organisms
- Wildfowl, sheep/cattle, dogs, schools of fish

Methods (2) Sample Sites

Choice of sample sites

Sample site locations should be chosen according to the purpose of monitoring (US EPA, 1993):

- to determine the significance of potential sources of pollution, sample sites should be clustered where point and non-point sources enter the water – upstream, downstream, as well as the point of entry, to provide comparative data;
- to obtain data on overall water quality, which over time may reveal trends, a sufficient number of sites should be chosen, scattered throughout the estuary that will give a representative indication of water quality status over that time.

As the aims of this study – to identify pollutants and sources affecting the Alvor estuary, and gain a picture of water quality in general – included each of the above purposes, a variety of sites were chosen to facilitate both. Locations were chosen carefully in order to gain the most valuable data coverage with a minimum number of sites, so as to be cost efficient in terms of testing supplies and time constraints. A total of thirteen monitoring sites were chosen.

Sites that were chosen specifically to evaluate potential sources of pollution were located near:

- Mesquita cement works
- Fish farms
- Figueira wastewater treatment works (WWTW)
- Penina golf course
- Alvor Marina

One site was located specifically to monitor water draining from the shellfishery beds, as chemical and bacterial contamination of shellfish for human consumption can have harmful effects on health. Other sites provided control data on the qualities of the water entering the estuary: those located near the tidal limit on each of the four tributaries, and one on the seaward side of the estuary jetties.

For control data on water entering the estuary at its mouth, it would be desirable to sample from water entering on the flood tide prior to sampling at the other locations in the estuary. However, water entering from the sea is denser and sinks below the less dense estuary water, and to sample below the overlying layer requires specialised sampling equipment. Therefore, as an acceptable alternative to directly sampling water entering from the sea, it was decided to sample seawater from the seaward side of the western jetty at the mouth, (with the other samples around low or ebb tide) in order to give a representation of the qualities of water likely to have entered the estuary on the preceding flood tide. Sampling sites were also chosen on the basis of their ease of access and length of time to reach the site from the preceding site sampled from, as sampling at each location must be undertaken at a fixed time (see below).

A suite of eight common parameters, and other complimentary observations, which give a general picture of water quality, was tested at all sites but one (which had a slightly reduced range of parameters tested). Additionally, dissolved oxygen was tested once or twice at eight sites; BOD was attempted twice for Site 9; indicator bacteria was tested on all sampling occasions at five sites of specific concern, and once at a further five sites. Full details of site locations and parameters tested are provided in Figure 1 and Table 2.

Figure 1 Aerial photograph showing locations of sample sites and potential pollution sources.

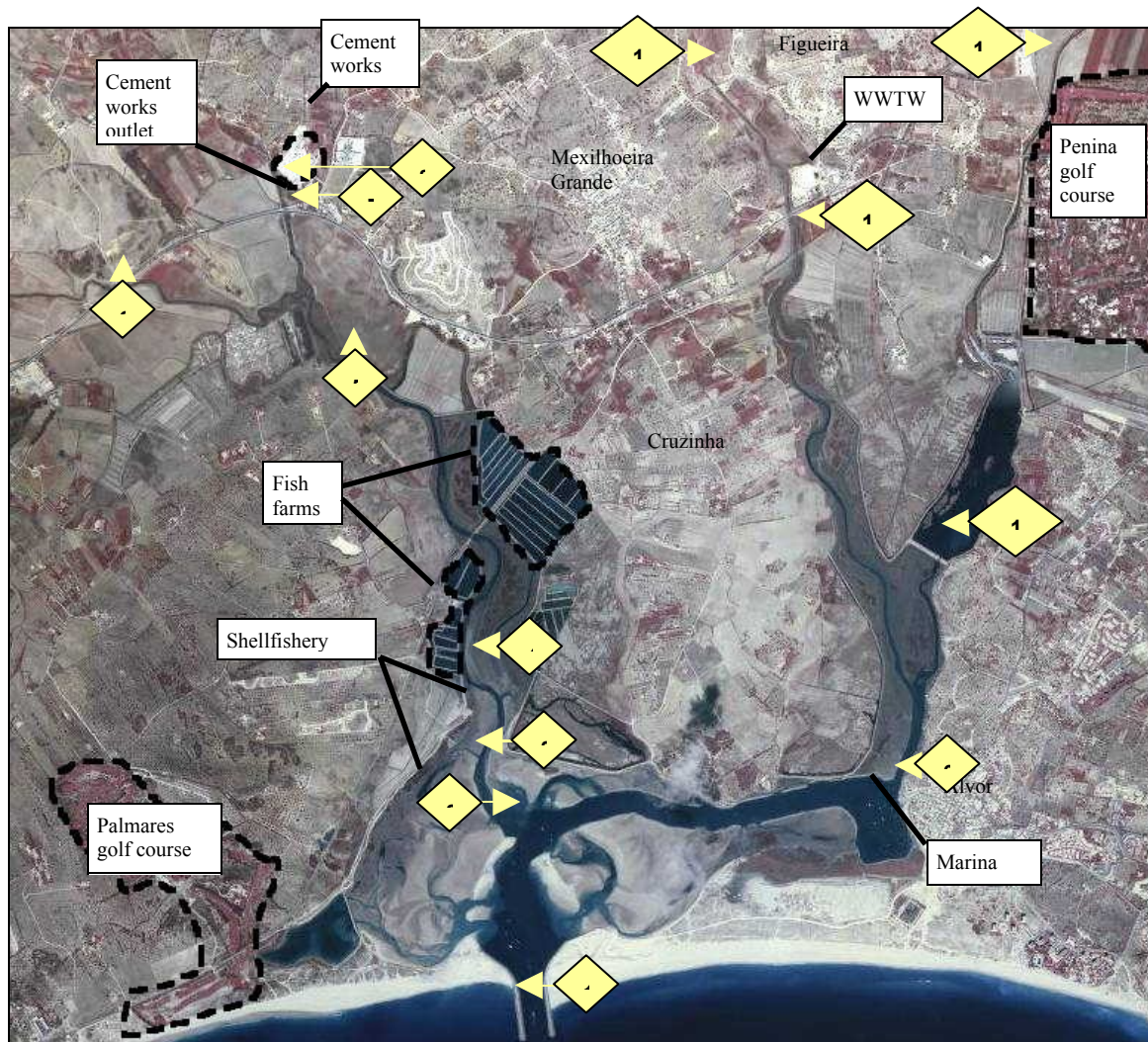


Table 2 Details of sample sites, parameters tested, and function.

Site no.	Description	Co-ordinates (UTM)	Parameters tested	Function
1	Seaward side of western jetty at estuary mouth	29 533806 E 41 08485 N	Common suite (turbidity, water depth & temp, air temp, salinity, pH, nitrate, ammonia), indicator bacteria	To provide data on qualities of the water entering the estuary at flood tide. Indicator bacteria tested as effluent from waste water treatment works (other than Figueira) could be present in the sea water.
2	Spit of sand at low tide protruding into main estuary channel	29 533978 E 41 09470 N	Common suite	To provide data on water in the main estuary channel after the R. Odiáxere and R. Alvor have met.
2 (alt)	As above, but approximately 100m away	29 533862 E 41 09471 N	Common suite	As above. Used as an alternative to the above site, which was unusually submerged at low tide in November.
3	Large rivulet at low tide draining from shellfishery	29 533585 E 41 10228 N	Common suite & indicator bacteria	To provide data on water from shellfisheries, especially indicator bacteria, as of public health interest.
4	Just downstream from outlet of fish farm	29 533585 E 41 10228 N	Common suite	To provide data on water quality impacts downstream of the outlets from the fish farms, especially ammonia content.
5	Point downstream from where R. Arão and Odiáxere join; upstream of fish farms	29 533037 E 41 11881 N	Common suite, indicator bacteria (once) and dissolved oxygen (once)	To provide data on water qualities after the R. Arão and Odiáxere join, and serve as a control for data taken downstream of the fish farms.
6	Downstream side of bridge over R.Odiáxere; near tidal limit	29 31696 E 41 12307 N	Common suite, indicator bacteria (once) and dissolved oxygen (once)	To provide data on qualities of the water entering the estuary via R. Odiáxere.
7	Just downstream from cement works outlet	29 532580 E 41 12710 N	Turbidity, water depth, water temp., air temp., salinity & pH	To provide data on water quality impacts downstream of the cement works outlet channel, especially pH and turbidity.

8	Upstream side of bridge over R. Arão; upstream of cement works, near tidal limit	29 532569 E 41 12759 N	Common suite, indicator bacteria (once) & dissolved oxygen (once)	To provide data on qualities of the water entering the estuary via R. Arão, and serve as a control for data taken downstream of the cement works.
9	Pier at Alvor marina	29 535872 E 41 09466 N	Common suite, indicator bacteria, dissolved oxygen (twice) & BOD (twice)	To provide data on water quality at Alvor marina, possibly affected by sewage discharges from craft, especially turbidity, nitrate, ammonia, dissolved oxygen, BOD & indicator bacteria.
10	By railway bridge over R. Farelo; downstream of Figueira WWTW	29 535295 E 41 12567 N	Common suite, indicator bacteria & dissolved oxygen (once)	To provide data on water quality impacts downstream of the wastewater treatment works, especially turbidity, nitrate, ammonia, dissolved oxygen & indicator bacteria.
11	Downstream side of bridge over R. Farelo; upstream of WWTW, near tidal limit	29 534911 E 41 13303 N	Common suite, indicator bacteria & dissolved oxygen (once)	To provide data on qualities of the water entering the estuary via the R. Farelo tributary and serve as a control for data taken downstream of the WWTW.
11 Up	Slightly upstream of bridge		Indicator bacteria (once) & nitrate (once)	As there is a drainage channel discharging water on the upstream side of the bridge, which was thought might be from the WWTW, in November it was decided to do additional bacteria and nitrate tests upstream of this. Raised water levels in subsequent months meant that this was not repeatable.
12	Upstream side of dam on R. Torre; downstream of Penina golf course	29 536116 E 41 10914 N	Common suite, indicator bacteria (once) & dissolved oxygen (twice)	To provide data on water quality impacts downstream of Penina golf course, especially nitrate & ammonia.
13	Just farther upstream than northernmost edge of Penina golf course, near tidal limit of R. Torre.	29 536628 E 41 13478 N	Common suite, indicator bacteria (once) & dissolved oxygen (once)	To provide data on qualities of the water entering the estuary via R. Torre, and serve as a control for data taken downstream of Penina golf course.

Frequency of sampling

The frequency at which samples should be taken also depends on the purpose of monitoring (US EPA, 1993). To detect pollution from point sources ideally requires very frequent sampling eg daily or even hourly; other parameters indicating estuarine conditions over long periods of time may be sampled only seasonally. Some recommendations for frequency of sampling are given in Table 3.

Table 3 Recommendations for frequency of monitoring (US EPA, 1993).

Measurement	Recommendation
Turbidity	'...should sample water for turbidity on a weekly or biweekly basis ... since turbidity often increases sharply during and immediately following a rainfall, [it is useful] to take additional turbidity readings shortly after the storm ...'
Nutrients	'... should sample nutrients on a weekly basis, although biweekly sampling will still yield valuable information.'
Indicator bacteria	'... should monitor bacteria on a weekly, biweekly, or monthly basis. In addition it may be extremely helpful to monitor during or immediately after storm events.'
Dissolved oxygen	'Sampling once a week is generally sufficient to capture the variability of D.O. in an estuary.'

The manpower and supplies available to this study, however, meant that sampling could only be repeated monthly which, though not ideal for some parameters, it was felt would still provide valuable data.

Timing of sampling

Sample time with respect to tides

At each location (except Site 1) sampling was undertaken at a time just before that of low tide for that location in the estuary. At this time water has flowed past in a seaward direction for as long as possible, seawater content will be at a minimum, and the concentration of potential pollutants from land based sources in the catchment area should be greatest and more likely to be detected. Approximate times for low tide (relative to the time published for Portimão) at each sample site were found by, or calculated from, observations of water depth, speed and direction of flow during a tidal cycle at points throughout the estuary. Complete results can be found in Annex 2. The sampling time determined for each site relative to Portimão low tide is given in Table 4.

It can be seen that low tide becomes later with distance upstream, which provides for different sampling times.

Table 4 Sampling time for sites, relative to published Portimão low tide time.

Site no.	Sample time relative to Portimão low tide (mins)
2	+ 10
3	+ 50
4	+ 70
5	+ 120
6	+ 180
7	+ 150
8	+ 180
9	+ 20
10	- 50
11	- 25
12	+ 50
13	+ 80

Sample time with respect to time of day (sunlight)

Sampling results can fluctuate during the course of a day. For example, because aquatic plants photosynthesise and release oxygen during the day, and respire and take in oxygen during the night, dissolved oxygen concentration in the water can vary significantly, especially in areas with dense vegetation. Dissolved oxygen concentrations are lowest at sunrise and highest in the afternoon. Correspondingly, carbon dioxide concentrations vary as aquatic plants remove it from the water for photosynthesis during the day, and release it during respiration at night, and this changes the pH of the water; reduced carbon dioxide significantly increases pH. (US EPA, 1993). To avoid recording data that largely describes daily fluctuations it is important to sample at about the same time of day at each site.

Tests involving visual comparison, especially turbidity, may be affected by light conditions and are best conducted with the sun overhead.

For these reasons, it was decided to standardise sampling times to midday; sampling at each site would occur at approximately the same time relative to noon UTC. Sampling dates were chosen on which Portimão low tide was at such a time as would mean midday would occur approximately midway through the sampling schedule. However, standardising sampling times relative to sunrise would have been more suitable, as there is a direct relationship between this and the opportunity plants have had to perform photosynthesis.

Consideration of holding times

In the scheduling of sampling, consideration was also taken of the maximum length of time that samples taken for later testing in the laboratory may be held: dissolved oxygen and biochemical oxygen demand samples may be held for a maximum of 8 hours until titration is performed; water samples for indicator bacteria testing can be refrigerated for up to 6 hours before plating.

Sampling schedule

In order to allow enough time to conduct sampling at each site, and for travelling between them, it was necessary to spread the schedule over 3 days as follows:

Day 1 – Sites 2, 3, 4, 5, 6; Day 2 – Sites 12, 13, 7, 8; Day 3 – Sites 10, 11, 9, 1

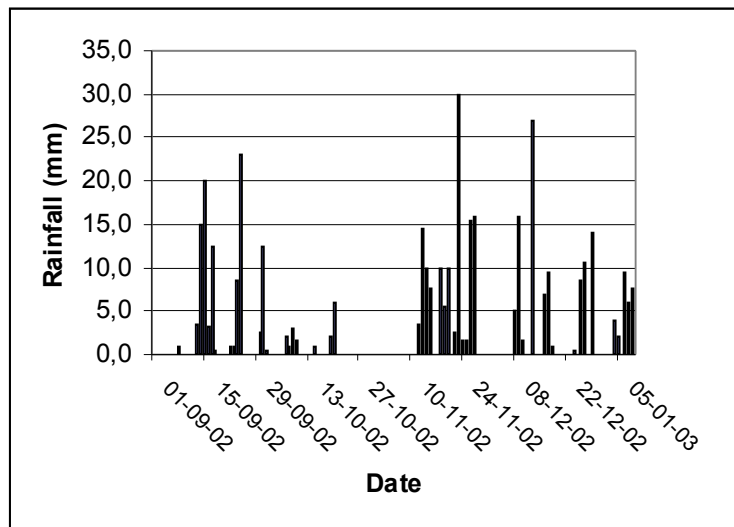
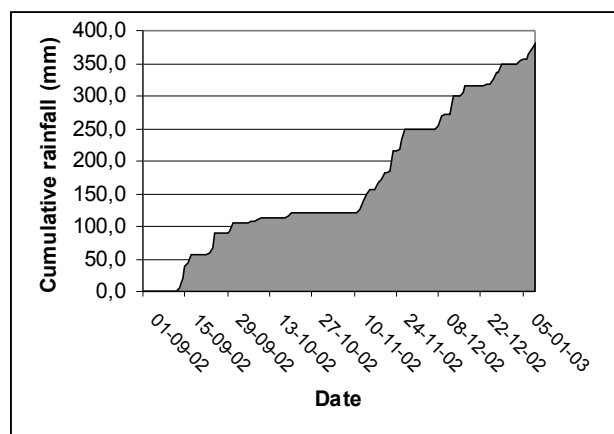
Results and discussion

A total of 315 measurements were successfully taken for 9 water quality variables. Practical limitations sometimes prevented sampling at a particular site. For example, site 3 was not sampled in September because the tide was coming in, potentially affecting the results and creating a danger of being cut off. Site 7 was not sampled in November and January because the sluice gate was closed and there was a lack of flow.

Physical measures

Weather observations

Rainfall measurements recorded at Cruzinha during the study period are shown in Figures 2 and 3. September, November and December were wetter than average months (comparison with data from Faria *et al.*, 1981), but October was unusually dry (Table 5). Rainfall has obvious effects on fluvial water flows and so is relevant to the interpretation of the water variable measurements described below.

Figure 2 Rainfall as recorded at Cruzinha during the monitoring period.**Figure 3** Cumulative rainfall over the study period.**Table 5** Monthly total rainfall compared with average values from Faria *et al.* (1981).

Month	Rainfall (mm)	
	2002	Average (Praia da Rocha 1941-1970)
September	91.8	17.2
October	29.5	47.8
November	128.0	72.2
December	100.5	74.2

Water temperature

A total of 49 water temperature measurements were made (Table 6). Temperature varied considerably, with a range of 12.0 to 27.0°C and an average of 18.7. These values compare with a range of 12.5 to 24.9 recorded by Peneda (1986) at high tide. The greatest range in temperature at any one site was recorded in the River Farelo (13°C at site 10). Monthly averages (September, October, November and January) were 24.3, 20.1, 16.4 and 14.0°C, showing the seasonal cooling of the water over this period. Interestingly, this trend was not apparent for the months of November and January in the case of the River Odiáxere; measurements from sites 2 to 9 in these months being almost identical. No other obvious trends were detected.

Table 6 Temperature measurements.

Sampling site	Temperature (°C)				
	Sept	Oct	Nov	Dec	Mean
1	24.0	20.0	19.5	15.0	19.6
2	22.5	19.5	15.5	15.0	18.1
3	-	20.5	15.0	15.5	17.0
4	24.5	20.0	15.0	14.5	18.5
5	27.0	21.0	14.5	14.5	19.3
6	25.5	22.5	14.5	15.0	19.4
7	26.5	20.5	-	-	23.5
8	24.5	19.5	16.0	14.5	18.6
9	23.5	22.5	18.0	13.0	19.3
10	25.5	18.0	18.0	12.5	18.5
11	21.0	19.0	18.0	12.0	17.5
12	25.0	18.5	16.0	13.0	18.1
13	22.5	20.0	16.5	14.0	18.3
Mean	24.0	20.0	19.5	15.0	18.7

Salinity

A total of 48 salinity measurements were taken with an encountered range of 0 to 37.8 ppt, the highest values (comparable with the sea) taken at sites 1 and 2 just outside or within the estuary mouth (Table 7). The very low or zero salinities were expectedly found at the upper river sites, and a clear gradient of salinity observable along the Odiáxere and Farelo Rivers from lower to upper estuary (Figures 4 and 5). The much lower average salinities of November and January compared to the earlier months reflect the greater flow of freshwater resulting from the significant rainfall in November (see Figure 3).

Table 7 Salinity measurements.

Sampling site	Salinity (ppt)				
	Sept	Oct	Nov	Jan	Mean
1	37.8	37.7	35.5	35.0	36.5
2	31.4	37.0	31.2	35.7	33.8
3	-	37.2	16.7	35.8	29.9
4	29.3	35.3	13.5	29.0	26.8
5	15.6	29.1	2.4	5.6	13.2
6	10.4	14.1	-	10.9	11.8
7	15.4	21.0	-	-	18.2
8	1.4	23.8	0.6	0.0	6.4
9	34.4	35.9	10.9	10.5	22.9
10	20.2	17.4	1.0	0.0	9.6
11	13.7	2.6	1.0	0.0	4.3
12	24.2	32.7	9.9	2.1	17.2
13	0.2	23.3	2.0	0.8	6.6
Mean	19.5	26.7	11.3	13.8	17.8

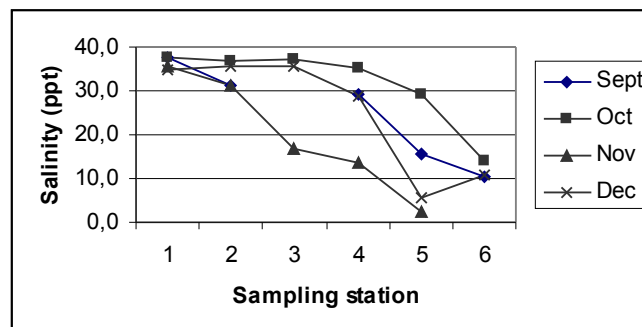
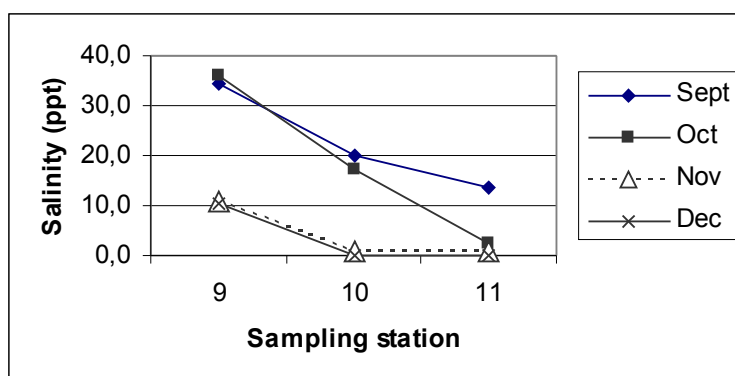
Figure 4 Salinity gradient along Odiáxere.

Figure 5 Salinity gradient along the Alvor and Farelo Rivers.

Turbidity

The 49 turbidity measurements are presented in Table 8 and show a range of 0 to over 100 JTU. The exceptionally high turbidity readings were all made in November and January, when the high rainfall would have been washing soil off the slopes of the catchment and into the rivers feeding the estuary. Resuspension of river sediments by the high energy currents would also be expected. The estuary was of brown appearance during this period, with the river notably swollen at sites 8, 10 and 11, and a storm-water plume of at least 100m out to sea visible from site 1. The high turbidity values were generally in the upper reaches of the estuary, before the mixing with seawater would have some diluting effect. It is interesting, for example, that the turbidity at site 2 in the lower estuary never rose above 40 JTU. Zero turbidity was always recorded at the seaward site 1 protected by the jetty from the turbid stream of the ebbing tide, indicating that contributions to turbidity in the estuary were entirely fluvial.

Table 8 Turbidity measurements.

Sampling site	Turbidity (JTU)				Mean
	Sept	Oct	Nov	Jan	
1	0	0	0	0	0
2	20	20	40	10	22.5
3	-	20	60	10	30
4	20	20	60	10	27.5
5	60	20	70	10	40
6	60	40	80	10	47.5
7	60	20	-	-	40
8	60	40	70	100	67.5
9	0	0	80	60	35
10	60	40	>100	80	70
11	20	0	>100	80	50
12	20	10	0	90	30
13	60	20	>100	60	60
Mean	36	20	57.5	37	38.75

The presence of seasonally high amounts of suspended solids is of concern for the populations of benthic invertebrates, and also for the fish nurseries, especially when sedimentation onto the estuary bottom is taking place and leads to the smothering of bottom-dwelling organisms and fish eggs. Further effects are likely on phyto-plankton and zooplankton. It is suggested that turbidity should be monitored on an ongoing basis and related to mortality of certain shell-fish species as well as the status of populations of macrophytes, eg *Zostera* species. With the forest fires of summer 2003 and the resulting processes of soil erosion with the following autumn and winter rains, there is the potential for greater impact on the health of the estuary system in the future.

Chemical measures

Dissolved oxygen and BOD

Twelve Dissolved Oxygen (DO) measurements were made across 10 of the sampling sites, in November and January with the exception of one measurement in October. The results are given in Table 9, all of which fall within acceptable limits for a healthy estuarine system. A minimum value of 5mg/l is considered necessary to fully support aquatic life (EPA, 2002). This is also the DO Environmental Quality Standard (EQS) for sensitive saltwater life (eg fish nursery grounds) included in UK Marine SACs guidance. All but one measurement (4.8mg/l) encountered in this study are above that level. However, it is also true that dissolved oxygen is most likely to be depleted in the warmer months when hypoxia and anoxia can bring serious problems for estuary animals and plants. Whilst the current study produces useful baseline data, DO monitoring from the Spring through the Summer would be more relevant for investigating this potentially limiting factor. It is worth noting that the year-round DO monitoring of Peneda (1986) in the Ria de Alvor did not show DO levels falling outside of critical limits.

Table 9 Dissolved Oxygen measurements.

Sampling site	Dissolved Oxygen (mg/l)		
	Oct	Nov	Jan
2	-	-	5.9
4	-	7.9	-
5	-	8.7	-
6	-	-	8.4
8	-	-	8.9
9	4.8	-	8.0
10	-	6.5	-
11	-	7.6	-
12	-	8.6	9.0
13	-	7.9	-
Mean	4.8	7.9	8.0

BOD tests were attempted twice during this investigation, although technical difficulties mean the results were unreliable. Both were attempted for samples from Alvor Marina (Site 9).

In the first instance, during the immediate DO test for one of the samples, too much acid was added in an attempt to remove brown particles (only one extra drop is permitted (US EPA, 1993) which were subsequently found to be insoluble material. The BOD was calculated to be effectively zero – 0.1 mg/L, and the DO test results can be read only to the nearest 0.2 mg/L) – and this is unlikely to be the case. The temperature variation during incubation was quite favourable: 18.5-20.5°C.

In the second instance, the temperature of the sample kept for 5 days was not adequately controlled – ranging from 10-30°C – having been placed on the top of the ‘incubator’ being used for bacteria testing. The temperature inside the incubator was approximately 35°C and it was hoped that the top would be sufficiently heated to keep the water sample close to 20°C. However, fluctuations in the lab temperature due to the onset of very cold weather interfered with this.

Nutrients

Nitrate levels from 47 measurements are given in Table 10. The levels are undetectable or below 10 mg/l in all but two instances which were at site 11. This site was designed to test the quality of water being issued into the river by the WWTW, but in October a reading of 10 mg/l was obtained both upstream and downstream of the inlet, suggesting another source. Some additional nitrate tests were made in a drainage ditch next to the Penina golf course at site 13 in November (10 mg/l) and January (0 mg/l), and the enclosed lagoon below the Palmares golf course in January (0 mg/l). There is patchy evidence, therefore, for significant nitrate contributions from at least some of the expected sources (citrus orchards, golf courses and sewage from the WWTW), but the situation for the estuary as a whole is of levels well below those of concern. This is despite monitoring having been undertaken during the winter season when the highest nitrate levels are to be expected (Peneda, 1986). It is however suggested that regular monitoring is carried out in the future, to detect any problematically high inputs as was recorded on the Ribeira da Torre upstream of Montes de Alvor, for example, by Furtado (1995) supposedly as a result of fertiliser use on the Penina golf course and Abicada peninsula.

Table 10 Nitrate measurements.

Sampling site	Nitrates (mg/l)			
	Sept	Oct	Nov	Jan
1	0	0	0	0
2	0-10	0	0	0
3	-	0	0	0
4	0-10	0	0	0
5	0-10	0	0	0
6	0	0	0	0
7	-	-	-	-
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	10	10	0	0
12	0	0	0	0
13	0	0	0	0

The results for total ammonia nitrogen (ionised ammonium and unionised ammonia) are given in Table 11. 37 measurements are included; a further 6 readings could not be determined with any certainty. In five of these cases, the test-tube contents' yellow colour did not match any of the colours in the key, but will be indicative of levels below the lowest recordable level; they are given as 'Low' in the table.

The presence of nitrogenous compounds in surface water generally indicates pollution. Ammonia nitrogen is the most common form of nitrogen from an effluent involving the biological breakdown of animal waste products. In the Alvor Estuary, potential sources of Ammonia nitrogen include the WWTW, fish farms and effluent from pig farming. The presence of the highest ammonia nitrogen levels at sites 4 (downstream of fish farm) and 10 (downstream of WWTW) would seem to confirm two of these inputs as significant. In October and November it was noticed that there was a particularly large flow of water from the fish farm at site 4. In October this coincided with a recorded ammonia nitrogen level of 2mg/l.

There are no known local quality guidelines on ammonia nitrogen levels to relate the values obtained in our study. A proposed General Quality Assessment (GQA) rating for England and Wales consists of a four tier system with the class boundaries at 0.86, 4.7, and 8.6 mg/l, (UK Marine SACs project, 2003). This would place approximately 25% of our values as class B and the rest at class A, indicating a reasonable to good water quality for this variable.

Table 11 Total ammonia nitrogen measurements.

Sampling site	Ammonia N (mg/l)			
	Sept	Oct	Nov	Jan
1	<0.1	≤0.1	0.1	-
2	0.5-1.0	0.1-0.25	≤0.1	-
3		<0.1	≤0.1	-
4	1.0-2.0	2.0	≤0.1	0.1
5	1.0	0.25	<0.1	<0.1
6	Low	0.1	<0.1	Low
7	-	-	-	-
8	0.10-0.25	0.25	≤0.1	Low
9	0.1	0.1	0.25	≤0.1
10	0.5	0.5-1.0	?	Low
11	≤0.1	<0.1	0.25?	≤0.1
12	0.25-0.5	<0.1	0.1(?0.25)	-
13	0.1	≤0.1	0.1	Low

Ammonia in water is present in two forms: the ionised ammonium ion (NH_4^+) and the un-ionised ammonia (NH_3) which is toxic to fish and other aquatic life. The proportion of each depends on temperature, salinity and pH, with high pH values driving the ammonia into its toxic un-ionised form. Given the relatively high pH values recorded in the estuary in September and October (see below) this is of some concern. During the course of the current study there was anecdotal evidence from shell-fish workers of there being a high mortality of clams in September. Could this have been the result of ammonia toxicity?

Conversion tables such as that given in Table 12 are available for calculating amounts of toxic ammonia. This has been undertaken for the months of September and October for which pH data is available, by taking the figures given in Table 11 (where necessary median values), and by assigning each measurement to the two temperature and two salinity classes. In this way we arrive at the estimates given in Table 13.

Table 12 Percentage of ammonia nitrogen in the un-ionised form (NH_3) in seawater and freshwater at different pH and temperature. Taken from www.lamotte.com.

pH	Temp			
	20		25	
	Seawater	Freshwater	Seawater	Freshwater
7.5	0.963	1.24	1.39	1.73
7.6	1.21	1.56	1.75	2.17
7.7	1.52	1.96	2.19	2.72
7.8	1.90	2.45	2.74	3.39
7.9	2.39	3.06	3.43	4.24
8.0	2.98	3.83	4.28	5.28
8.1	3.73	4.77	5.32	6.55
8.2	4.65	5.94	6.61	8.11
8.3	5.78	7.36	8.18	10.00
8.4	7.17	9.09	10.10	12.27
8.5	8.87	11.18	12.40	14.97

Table 13 Estimated percentage and total amount of NH_3 in the estuary waters. Figures in bold are above proposed EQS concentration (see text for explanation).

Sampling site	September		October	
	% NH_3	NH_3 (mg/l)	% NH_3	NH_3 (mg/l)
1	6.61	0.0033	2.39	0.0012
2	2.39	0.0179	2.39	0.0041
3	-	-	5.78	0.0029
4	2.19	0.0329	0.963	0.0193
5	2.17	0.0217	1.9	0.0048
6	-	-	3.06	0.0031
7	-	-	4.77	0.0000
8	14.97	0.0254	4.77	0.0119
9	4.28	0.0043	1.9	0.0019
10	2.17	0.0109	1.96	0.0147
11	1.56	0.0008	0.4	0.0002
12	10.1	0.0374	7.17	0.0036
13	4.65	0.0047	1.56	0.0008

The results would seem not to show any harmful levels of un-ionised ammonia (as a reference, one fish species, silver perch, survives in up to 0.1 mg/L of NH_3 – data from NSW Fisheries), as the most alkaline waters did not coincide with the highest levels of total ammonia nitrogen. For UK estuaries, an Environmental Quality Standard of 0.021 mg/L as an annual average has been proposed (UK Marine SACs project, 2003). Four of our values fall above this, but these are point measurements and a sequence of measurements from which to obtain an average are needed. It is clear that the nitrogen cycle at the Alvor Estuary, particularly in relation to the ammonia chemistry, requires further monitoring and investigation.

pH

pH was measured in the months of September and October only; thereafter the meter broke and could not be replaced in time to continue the monitoring. The 25 measurements are given in Table 14. Estuarine pH levels are typically 7.0 to 7.5 in the fresher upper reaches, and 8.0 to 8.6 in the saline lower reaches (US EPA, 1993). The pH of oceanic waters is typically 8.2 (UK Marine SACs project, 2003), as recorded at site 1 in September. The alkalising effect of seawater is due to natural buffering from carbonate and bicarbonate dissolved in the water. The situation presented by these results looks more complex with, for example, the highest values of all being in the upper estuary (sites 7 and 8) where the cement works is known to issue grey plumes of ground calcium carbonate and will have an obvious effect.

Table 14 pH measurements.

Sampling site	pH	
	Sept	Oct
1	8.20	7.90
2	7.93	7.90
3	-	8.35
4	7.75	7.51
5	7.57	7.81
6	7.79	7.88
7	8.58	8.16
8	8.53	8.12
9	8.09	7.83
10	7.56	7.69
11	7.58	7.02
12	8.36	8.42
13	8.17	7.65
Mean	8.00	7.86

Biological measures

Indicator bacteria

24 measurements of total coliform bacteria were made (Table 15). Sampling for these and *E. coli* (a further 24 measurements given in Table 16) was mostly concentrated around suspected point sources of faecal coliforms, in particular the WWTW and fish farm. Many of the results had to be treated with some degree of caution, given the difficulty in counting and distinguishing the colour of colonies in the petri dishes, but the results – with one exception – show no evidence of pollution by faecal coliforms. It is likely that the coliform bacteria are predominately soil-derived.

That one exception was the recording of 166 colonies of *E. coli* per 100 mL at site 11, near an outlet from the WWTW, in September. A sewage smell in the air was noted by CB during sampling. It seems that whilst contamination of the estuary by faecal coliform bacteria is not generally prevalent, here was one example of it happening from a point source. It is interesting to note that in October at the same site, samples up- and down-stream of the inlet from the WWTW rose from 3767 to 5650 coliforms per 100 mL respectively.

Contamination by faecal coliforms has apparently been a problem in the past. The year-long microbiological assessment of the estuary made by Coelho (1986) showed that for three months (March 1985, October 1985 and January 1986), both total and faecal coliform levels exceeded guideline limits (quoted as 500 and 100 colonies per 100ml respectively) on the Alvor River (but not Odiáxere River). In the case of faecal coliforms, levels of over 500 were recorded. Moreover, these were at high tide conditions, which Coelho showed to have bacteria levels typically ten times lower than at low tide. The concentration of these bacteria in the bivalve populations was also analysed and demonstrated to be high.

Improvements to the WWTW, local septic tanks and the waste disposal of pig farming enterprises may help to explain an apparent reduction in bacterial contamination, but further research is recommended here.

Table 15 Measurements of total coliforms.

Sampling site	Total coliforms (per 100 mL)			
	Sept	Oct	Nov	Jan
1	500	0	-	-
2	-	-	-	0
3	-	100	47000	0
4	-	-	-	0
5	-	-	-	2000
6	-	-	-	800
7	-	-	-	-
8	-	-	-	18300
9	1033.3	167	<10,100	300
10	2366	4900	>42,000	1000
11	8933	3767	>42,000	600
12	-	-	-	11300
13	-	-	-	15500

Table 16 Measurements of *E. coli*.

Sampling site	<i>E.coli</i> (per 100mL)			
	Sept	Oct	Nov	Jan
1	0	0	-	-
2	-	-	-	0
3	-	0	0	0
4	-	-	-	0
5	-	-	-	0
6	-	-	-	0
7	-	-	-	-
8	-	-	-	0
9	0	0	?	0
10	0	0	0	0
11	166.7	0	0	0
12	-	-	-	0
13	-	-	-	0

Conclusions

The current study has successfully researched, selected and tested methodologies for the testing of water quality in the Alvor Estuary. The estuary system and its aquatic environment is complex in space and time, and this presents a considerable challenge to the characterisation of its physical, chemical and biological quality. Whilst the monitoring over a four month period is insufficient to understand all these complexities and the most significant factors affecting the aquatic environment, this study has made an important step forward, not least in collecting some reference data for future comparison and of relevance to the implementation of the European Community Water Framework Directive and its aim to achieve good water status for all river basins by 2015. In so far as the data go, they provide evidence for a generally healthy estuary system, but nevertheless contain some warnings of potential problems that tie with what is known of human activities and land uses in the catchment that are able to impact on water quality.

The relatively high levels of total ammonia nitrogen is one example that needs further careful study, as does the seasonal volume of suspended sediments highlighted by the high turbidity sometimes recorded in this study. It would be extremely valuable to conduct surveys of benthic macroinvertebrates and fish (or fish breeding) in relation to possible turbidity impacts. The turbidity data, together with the estimation of areas of bare soil in the catchment, could be used to calculate soil erosion losses. The current study has not treated the potential presence of pesticides and their residues in the estuary waters, and this is another relevant area of future study, especially given the intensity of the regimes of citrus production in the catchment. An analysis of pesticide presence in the Ria Formosa National Park identified the presence of a large variety, but at amounts below guideline levels (Marques da Silva & Guia, 1990).

It would also be valuable to make another attempt at BOD measurements, and to increase the number of dissolved oxygen readings, since these are critical variables – in particular as they indicate the presence of organic enrichment, which is one of the most likely and possibly most damaging forms of pollution in the estuary.

We propose that water quality monitoring needs to become an ongoing, regular commitment, in the interest of the biological communities of the estuary as well as the resident and visiting human populations. The potential significance of bacterial pollution highlights this. The monitoring requires cost effective and practicable methodologies, possibly involving biological indicators, the search for which will be an important follow-up study. A small number of carefully chosen benthic macroinvertebrates could be monitored to provide a measure of water quality that is integrated in

time and also integrates different water quality parameters, avoiding the necessity for frequent and expensive non-biological assays. In addition we suggest that a catchment wide inventory and mapping of land uses and pollution point sources needs to be undertaken as a matter of urgency, to enable the modelling of water quality status, predict future problems, and provide mitigation.

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RINGING REPORT FOR 2003

Renata Medeiros

This was another solid year of ringing activity. I obtained my full ringing license and was then able to share with Marcial Felgueiras responsibility for the operations. Three new trainees joined the ringing team: Filipa Bragança, Paulo Pinto and Sara Roda. As in previous years, ringing took place weekly all year round using the ten established nets around Cruzinha. During the autumn migration period the ringing effort became more intense (almost daily basis); this was only possible due to the help of Heather Coats who came especially to help out. In addition ringing sessions were also conducted in Sargaçal as part of the study on migration strategies in passerines developed by Rob Thomas. For the first time in some years, a ringing session for waders was organised, although only five birds were caught. Storm-petrel ringing continued in 2003, but with a drop in numbers, itself an interesting result. A high number of Little Tern chicks were ringed at Ria Formosa as part of my MSc project on the reproductive success and nest site selection of this species.

The total of 1465 birds ringed during the year represents a good increase on the numbers ringed in 2002, mainly due to the Little Tern and Sargaçal ringing sessions. These have also contributed to a wider variety of birds ringed (59 different species) compared to recent years. Although no additions were made to the ringing list this year, species like Little Bittern, Wryneck, Wren, Redwing, Long-tailed Tit and Short-toed Treecreeper were very special. The ringing list stands now at a total of 54,955 birds of 174 species.

Table 1 below illustrates the monthly and annual totals of new birds for all species ringed during 2003 and Table 2 lists the species and totals of birds ringed in previous years but not 2003. Other people involved in the ringing along the year were Hans Pul, Paul Wallis, Mary Daggen, Victoria and Colin Beale, Bruno Araújo, Dave Bookless (A Rocha UK), Colin Jackson (Kenya), Vera Soukupová (Czech Rep.), Peter Harris and Alain Boisclair-Joly (France).

Table 1 Birds ringed by A Rocha during 2003 and in all years together.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2003	Grand Total
Storm Petrel						108	2						110	2896
Little Bittern									1				1	3
Ringed Plover									3				3	382
Dunlin									2				2	2437
Common Sandpiper									1				1	104
Little Tern					64	195	13						272	293
Collared Dove					1								1	6
Little Owl							2						2	81
Red-necked Nightjar							1						1	23
Swift							1						1	110
Kingfisher									4	1			5	182
Hoopoe				1	1	2		2	1	2			9	394
Wryneck									1				1	17
Swallow				1		2	1		1				5	1507
Yellow Wagtail									4				4	177
Wren							1						1	9
Robin	4		1							13	12	2	32	2283

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2003	GrTotal
Bluethroat									21				21	188
Black Redstart											5		5	134
Whinchat									3				3	58
Stonechat									6	2	2		10	267
Blackbird			3	4	9	25	11	18	10	2	5		87	1195
Song Thrush	1	1									2	1	5	516
Redwing				1									1	3
Cetti's Warbler						1		1	10	1	2		15	130
Zitting Cisticola									3		1		4	351
Grasshopper Warbler								1	4				5	138
Sedge Warbler								1	2				3	248
Reed Warbler					1		1	10	87	4			103	2166
Melodious Warbler					1	1	4	6	4				16	736
Subalpine Warbler										1			1	223
Sardinian Warbler	2			1	1	9	8	3	5	4	4		37	1177
Whitethroat									12				12	421
Garden Warbler				1				7	30	7	1		46	3492
Blackcap	13	1	2	5	2	4			4	29	65	7	132	8405
Bonelli's Warbler								4		1			5	75
Chiffchaff	8	2	10					3	6	8	46	2	85	7837
Willow Warbler								9	43	4			56	2183
Firecrest	1												1	60
Spotted Flycatcher									4				4	167
Pied Flycatcher								2	27	4			33	1170
Long-tailed Tit											1		1	8
Blue Tit					1		1	1		1			4	74
Great Tit	1	2		2	2	8	9	1	2	1	1		29	497
Short-toed Treecreeper								1	1				2	10
Penduline Tit	1												1	165
Golden Oriole								3					3	32
Woodchat Shrike					1		1						2	303
Azure-winged Magpie						2			2				4	45
Tree Sparrow											1		1	185
Waxbill		1	1		2	2	5	4	28	10	20		73	1275
Chaffinch		3		1	12	6	1			6	7	1	37	877
Serin	2	3	4	10	11	1		1		1	2		35	1307
Greenfinch	3			2	9	5	2	18		2	8		49	2228
Goldfinch	1		3	9	22	11	11	6	5	1			69	1747
Siskin	1	1											2	54
Ortolan Bunting									1				1	36
Corn Bunting											1		1	178
Totals	38	14	25	38	140	383	76	105	341	106	186	13	1465	51806

Table 2 Species ringed in 1986-2002 but not in 2003.

Species	Total		
Little Grebe	2	Long-eared Owl	3
Cory's Shearwater	5	Nightjar	1
Swinhoe's Storm Petrel	1	Pallid Swift	68
Madeiran Storm Petrel	2	Bee-eater	95
Cattle Egret	16	Short-toed Lark	58
Little Egret	1	Crested Lark	76
Teal	1	Thekla Lark	2
Black-shouldered Kite	4	Woodlark	1
Short-toed Eagle	7	Skylark	24
Marsh Harrier	1	Sand Martin	55
Montagu's Harrier	1	Crag Martin	7
Sparrowhawk	1	Red-rumped Swallow	1
Kestrel	6	House Martin	68
Osprey	4	Tawny Pipit	8
Red-legged Partridge	1	Tree Pipit	31
Quail	6	Olive-backed Pipit	1
Water Rail	3	Meadow Pipit	216
Spotted Crake	1	Water Pipit	17
Moorhen	12	Grey Wagtail	40
Oystercatcher	1	White Wagtail	53
Black-winged Stilt	15	Dunnock	6
Avocet	3	Rufous Bushchat	4
Stone-curlew	8	Redstart	285
Little Ringed Plover	12	Wheatear	49
Kentish Plover	435	Black-eared Wheatear	4
Golden Plover	1	Rock Thrush	1
Grey Plover	76	Aquatic Warbler	2
Lapwing	1	Paddyfield Warbler	1
Knot	132	Marsh Warbler	16
Sanderling	3	Great Reed Warbler	61
Semipalmated Sandpiper	1	Icterine Warbler	2
Little Stint	37	Dartford Warbler	11
Pectoral Sandpiper	1	Spectacled Warbler	5
Curlew Sandpiper	74	Orphean Warbler	7
Buff-breasted Sandpiper	1	Yellow-browed Warbler	8
Ruff	15	Dusky Warbler	2
Jack Snipe	13	Wood Warbler	1
Snipe	78	Goldcrest	4
Black-tailed Godwit	1	Red-breasted Flycatcher	2
Bar-tailed Godwit	19	Great Grey Shrike	16
Whimbrel	35	Jay	1
Curlew	4	Spotless Starling	13
Redshank	306	Spanish Sparrow	57
Greenshank	17	Rock Sparrow	1
Green Sandpiper	10	Scaly-breasted Munia	17
Wood Sandpiper	3	Brambling	1
Turnstone	33	Linnet	64
Black-headed Gull	19	Common Rosefinch	1
Lesser Black-backed Gull	16	Bullfinch	1
Yellow-legged/Herring Gull	23	Crossbill	36
Sandwich Tern	4	Hawfinch	44
Common Tern	2	Cirl Bunting	1
Turtle Dove	15	Rustic Bunting	1
Great Spotted Cuckoo	1	Reed Bunting	37
Cuckoo	2	Chestnut Mannikin	1
Barn Owl	2	Red-cheeked Cordonbleu	1
Scops Owl	11	Total	3094

RINGING CONTROLS AND RECOVERIES REPORTED DURING 2003

Renata Medeiros

The following list refers to birds which were reported from sites other than the original ringing location. This includes two groups of birds: those ringed during the course of Observatory operations in the Algarve and subsequently reported elsewhere; and those which had been ringed elsewhere and were subsequently controlled at Quinta da Rocha or reported to the Observatory. The recovery circumstances are given.

The following codes are used:

Condition at recovery

X	found dead	R	caught and released by a ringer
XF	found freshly dead or dying	VV	rings or colour marks read in the field

Age when ringed

1	nestling
2	fully grown, year of hatching unknown
3	ringed during calendar year of hatching
4	hatched before calendar year of ringing, but exact year of hatching unknown
5	hatched during calendar year prior to ringing
6	hatched before year prior to ringing, but exact year unknown etc.

Abbreviations used for foreign ringing schemes

BRL	British Museum, London, UK
ESI	Icona, Spain
GEH	Helgoland, Germany

Storm Petrel *Hydrobates pelagicus*

N196	6	06/06/1998	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	14/06/2002	Banneg, Finistère, France	48 21' N 04 46' W
N343	5	15/06/1998	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	25/07/2002	Calf of Man, Isle of Man, England	54 03' N 04 49' W
N711	6	30/06/1998	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	X	11/05/2001	Banneg, Finistère, France	48 21' N 04 46' W
N763	6	08/06/1999	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	19/07/2000	Vatsetter, Yell Shetland, Scotland	60 35' N 01 02' W
N1527	6	11/06/2001	Mexilhoeira-Grande, Faro, Portugal	37 09' N 08 37' W
	R	03/08/2002	Duvillaun More, Monaghan, England	54 04' N 10 10' W
N1684	6	16/06/2002	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	18/07/2002	Sule Skerry, Orkney, Scotland	59 04' N 04 24' W

N1687	6	16/06/2002	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	15/07/2002	Eilean Nan Ron, Highland Region, Scotland	58 33' N 04 26' W
N1770	6	26/06/2002	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	17/07/2002	Eilean Nan Ron, Highland Region, Scotland	58 33' N 04 26' W
N1830	6	03/07/2002	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	19/07/2003	Westman Islands, Iceland	63 28' N 20 10' W
N1833	6	10/07/2002	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
	R	15/08/2002	Skorin, Sandoy, Denmark	37 04' N 08 47' W
BRL	4	01/07/2001	Calf of Man, Isle of Man, England	54 03' N 04 49' W
2488000	R	08/06/2002	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W
BRL	4	14/04/2003	Brough of Birsay, Orkney, Scotland	59 08' N 03 21' W
2506427	R	16/06/2003	Ponta de Almádena, Faro, Portugal	37 04' N 08 47' W

Greater Flamingo *Phoenicopterus ruber*

ESI	1	02/10/1998	Marismas de Odiel, Huelva, Spain	37 07' N 06 29' W
10-00389	VV	15/10/1998	Portimão, Faro, Algarve	37 10' N 08 31' W
ESI	1	21/07/2001	Fuente de Piedra, Málaga, Spain	37 08' N 04 44' W
10-10491	VV	11/08/2001	Ria de Alvor, Faro, Portugal	37 08' N 08 35' W

Avocet *Recurvirostra avosetta*

GEH	1	26/06/1997	Sonke-Nissen-Koog, Schleswig-Holstein, Germany	54 37' N 08 52' E
5303123	X	06/05/2003	Cabo Espichel, Setúbal, Portugal	38 25' N 08 13' W

Redshank *Tringa totanus*

I2737	1	20/09/1994	Ria de Alvor, Faro, Portugal	37 08' N 08 35' W
	X	10/09/2002	Baie de Authie Nord, Pas-de-Calais, France	50 22' N 01 35' E
G4378	6	02/05/1995	Ria de Alvor, Faro, Portugal	37 08' N 08 35' W
	XF	18/05/2003	Hylonda, Sör-Tröndelag, Norway	63 07' N 10 01' W

Little Tern *Sterna albifrons*

E14103	1	06/06/2003	Ria Formosa, Faro, Portugal	37 02' N 08 00' W
	R	29/07/2003	Marismas del Odiel, Huelva, Spain	37 10' N 06 58' W

Blackcap *Sylvia atricapilla*

A129817	3	14/10/1999	Mexilhoeira Grande, Faro, Portugal	37 09' N 08 37' W
	X	29/04/2003	Cambridge, England	52 13' N 00 06' E

SEABIRDS IN THE A ROCHA STUDY AREA

Willem Scheres

Introduction

This article reviews and comments on seabird records from the A Rocha study area over the years. This study area comprises the whole headland of Quinta da Rocha with its eastern and western marshes running north to the EN125, as well as the Alvor Estuary and the sea off the Alvor dunes and its breakwaters. Even though no systematic study has been made on seabirds here, enough records have been collected to warrant description and commentary. The records are extracted from A Rocha Observatory Reports in the period 1985-2003 and from Temme (this report). Over this period, five species of accidental status have been observed. Comparison is made with the presence of seabirds in mainland Portugal and in some cases with their presence in the home country of the author, the Netherlands. Data concerning 17 species are included within three tables below, as is status information from Moore (1997).

Shearwaters, petrels and Gannets (See Table 1)

Cory's Shearwater *Calonectris diomedea*

The Cory's Shearwater is a typical seabird of the Mediterranean and the adjacent part of the Atlantic which breeds on islands. In mainland Portugal the only breeding area of Cory's Shearwaters are the Berlengas Islands 10 km off the Portuguese west coast, with a few hundred pairs. During autumn these Shearwaters are often seen at Cape St. Vincent (Moore, 1997). In the A Rocha study area Cory's Shearwaters have only occasionally been seen. 1997 was a good year with Cory's around the mouth of the estuary in front of the breakwaters in summer and autumn; in July and August up to 20 birds were present. In the first week of October only two were left over. There are no winter and spring records within this area. According to Moore it is a migrant breeder usually only present during the breeding season.

Mediterranean Shearwater *Puffinus yelkouan*

Mediterranean Shearwaters are always present close to the steep continental slopes not far from the Portuguese coast in July and August. Like Cory's, they breed on islands in the Mediterranean, but in contrast they also winter in the Mediterranean Sea. Mediterranean Shearwaters are common passage migrants and winterers close to the Portuguese mainland coastline. In autumn they are guaranteed to be seen in the Sagres/Cape St. Vincent area (Moore, 1997). Off the coast at the Alvor estuary Mediterranean Shearwater records are spread over the year but concentrated in mid-winter. During the first days of January 2001 there was a strong migration to the west, with 332 birds seen in total; the highest number was 263 within four hours on the 2nd. They moved to the west as single individuals and in small groups, the largest group being a flock of 12 on 1 January 2001.

Leach's Petrel *Oceanodroma leucorhoa*

The most important colonies of this petrel in the North Atlantic are situated in Iceland and on the west coast of the British Isles. In the Netherlands it is a scarce passage migrant and is sometimes found inland after gales (Bijlsma, 2001). Leach's Petrels are regular but rare or very localised winter visitors in Portugal. They are usually found dead after storms (Moore, 1997). Temme (2000) describes a wreck of Leach's Petrels on the Algarve coast, comprising 75 corpses found between 21 December 1996 and 1 January 1997. In the A Rocha study area corpses have been found several times in winter and spring. Once a Leach's Petrel was encountered still alive in the most inland part of the study area close to the EN125. On the last day of 2000 and in the first week of 2001 Leach's Petrels were seen flying out to sea off the Alvor Dunes and close to the breakwaters. Up to eight flew around in front of the breakwaters on 3 January and three days later six were recorded at the

same site. The beginning of 2001 was generally good for ‘tubenoses’ like shearwaters and petrels.

Gannet *Morus bassanus*

The Gannet occurs in enormous colonies on islands in the northern Atlantic. In the southern North Sea Gannets are present over the whole year, with large numbers in late summer and autumn (Bijlsma, 2001). Along the Portuguese coastline it is an abundant, regular winter visitor (Moore, 1997). In the A Rocha study area Gannets are regularly seen out to sea off the Alvor Dunes. Being a pelagic bird, it has only once been seen for a long stay within the estuary: in 1990 a juvenile was fishing in the estuary for nearly a fortnight. On some days 100 or more Gannets are seen. The highest number on one day was 406 flying to the west on 3 March 2001. On 27 and 28 February 2001, 174 and 202 respectively flew to the west. Within three days a total of 782 had been seen. On 3 May 1999, during the spring migration, 110 Gannets were recorded to the west. Because seabird observations are not systematically carried out within the study area, frequency and numbers may be underestimated. Temme (2004), however, has carried out a systematic survey at Carvoeiro to the east, and his results are included in this report (p.42). He recorded a total of 1012 Gannets between 3 and 12 March 1998 moving steadily westwards along the coastline with an average movement of 101 per hour. At Cape St. Vincent, numbers of Gannets are sometimes extreme – between 800 and 1400 birds can be counted in one hour.

Table 1 Shearwaters, petrels and gannets recorded in the A Rocha study area.

Species and status (Moore, 1997)	Date	Record
Cory’s Shearwater	20 Aug 1996	1 out to sea
Common migrant breeder	20 Jul 1997	20 at mouth of estuary
Common passage migrant	9–10 Aug 1997	18–20 at mouth of estuary
Sometimes seen in winter	14 Sep 1997	7 at mouth of estuary
	5 Oct 1997	2 at mouth of estuary
Mediterranean Shearwater	31 Mar 1991	4 out to sea
Common winter visitor	10 Aug 1997	1 to the east out to sea
Common passage migrant	5 Oct 1997	2 out to sea
Sometimes seen in summer	31 Dec 2000	5 to the west out to sea
	1 Jan 2001	64 to the west out to sea
	2 Jan 2001	263 to the west out to sea
	3 Jan 2001	5 to the west out to sea
Leach’s Petrel	1 Jan 1990	Several corpses found
Rare winter visitor	12 Jan 1996	1 corpse found
	24 Dec 1996	1 found alive in upper estuary
	25 Mar 1997	1 corpse found
	31 Dec 2000	1 to the west out to sea
	1 Jan 2001	3 to the west out to sea
	2 Jan 2001	1 to the west out to sea
	3 Jan 2001	8 close to the breakwaters
	6 Jan 2001	6 close to the breakwaters
Gannet	18–31 Oct 1990	1 juvenile fishing in the estuary
Abundant winter visitor	19 Oct 1998	62 out to sea
Abundant passage migrant	3 May 1999	110 to the west out to sea
Often seen in summer	1 Jan 2001	40 to the west out to sea
	2 Jan 2001	61 to the west out to sea
	27 Feb 2001	174 to the west out to sea
	28 Feb 2001	202 to the west out to sea
	1 Mar 2001	406 to the west out to sea

Shags and saltwater-bound ducks (See Table 2)

Shag *Phalacrocorax aristoteles*

Even though Shags breed on the cliffs of Cape St. Vincent (Moore, 1997; Rufino, 1989), this species is a vagrant within the A Rocha study area where it has been recorded only twice. Of all the European cormorant species, the Shag is by far the most pelagic. It strongly prefers rocky coastlines with deep water, and steep cliffs without vegetation for resting and breeding. The chance of seeing them in the study area is therefore low.

Eider *Somateria mollissima*

Eiders breed in the coastal areas of Scandinavia, some parts of the British Isles, the Netherlands, Germany and Brittany in France. They winter more or less within their breeding range with some slight extension to the south. During winter they remain out at sea (Ogilvie, 1976). In Portugal the Eider is a vagrant with only four records up to 1998. Two of these records were made in the A Rocha study area. In one case a first winter male dwelled for about half a year in this area, feeding in the estuary during high tide.

Common Scoter *Melanitta nigra*

Although the breeding area of the Common Scoter is as far to the north as that of the very rare Long-tailed Duck (see below), Common Scoters winter as far south as coastal Morocco (Ogilvie, 1976). Of all the seaducks it is by far the most common one seen in the A Rocha study area, and also along the Portuguese coast as a whole. It is often seen in flocks flying low over the sea surface. In only one instance were Common Scoters seen within the estuary: a flock of 12 on 2 December 1998. In 1992, besides the record of one individual on 3 October, there is a casual observation of a group of 12 individuals going west offshore on an ungiven date.

Long-tailed Duck *Clangula hyemalis*

Long-tailed Ducks breed mainly in open tundra in the far north of Europe. In winter they are fully maritime. The duck winters partly within its breeding range and partly to the south, reaching the Baltic and southern North Sea (Ogilvie, 1976). Records in Portugal are exceptional because their wintering area is so far to the north. Only one record in the study area exists, of a female which stayed for somewhat more than a fortnight off the Western Marsh.

Red-breasted Merganser *Mergus serrator*

This fish-eating duck breeds in northern Russia, Scandinavia, around the Baltic, the British Isles and, in its most southern range, in the Netherlands. Wintering occurs along the whole coastal zone of western Europe and along the northern coast of the Mediterranean and also of the Black Sea (Ogilvie, 1976). In Portugal Red-breasted Mergansers are only common in the Sado Estuary (Moore, 1997). In the A Rocha study area they are irregular winter visitors. Sometimes they are seen while feeding within the estuary during high tide. Of the ten records, eight were made during the winter, one in the autumn and one in spring. The maximum number seen is only two. This is much less than the maxima of 20 to 25 individuals seen in the much bigger Tagus estuary, where Red-breasted Mergansers are uncommon winter visitors according to Leitão *et al* (1998).

Skuas, Black-legged Kittiwake and Razorbills (See Table 3)

Great Skua *Catharacta skua*

This large and aggressive Skua breeds on islands in the North Atlantic including the Shetland Islands and Iceland. They winter from the Gulf of Biscay to the Cape Verde Islands off the coast of West Africa and also in the western Mediterranean (Bijlsma *et al*, 2001), coastal Portugal lying within this range. Great Skuas are seen in Portugal both on passage and wintering. Temme (1997) recorded it as a common winter visitor off Carvoeiro, with up to nine birds seen daily. In the A Rocha study

area, the Great Skuas have been seen during the migration season in autumn (October) as well as during winter (December and January). Occasionally they are seen while chasing Yellow-legged Gull, Sandwich Tern or other gulls and terns.

Table 2 Shags and saltwater-bound ducks recorded in the A Rocha study area.

Species and status (Moore, 1997)	Date	Record
Shag	3 Oct 1992	2
Fairly common resident breeder	10 Sep 1996	1 above Western Marsh
Breeding at Cape St Vincent		
Eider	26 Nov – 31 Dec 1993	1 first winter male
Accidental species	1 Jan – 15 May 1994	1 same individual
	9–19 Feb 1998	1 female
Common Scoter	29 Aug 1990	8 seen from Western Marsh
	3 October 1992	1
	2 Dec 1998	12 in the estuary
	3 May 1999	2 on an unusual date
	3 Jan 2001	2 on the sea near breakwaters
	20 Oct 2001	2 on the sea near the Alvor dunes
Long-tailed duck	1–18 Apr 2000	1 female
Accidental species		
Red-breasted Merganser	16 Dec 1989	1
Scarce winter visitor	17 Mar 1992	1
Common in Sado Estuary only	30 Nov 1994	2 on estuary
	1–16 Dec 1994	1
	29–30 Dec 2000	1 female on Odiáxere River
	8 Jan 2001	1 on western part of the estuary
	26, 28 Feb 2001	1 female by the breakwaters

Pomarine Skua *Stercorarius pomarinus*

This medium-sized Skua breeds very far to the north in polar regions of Russia like Nova Zembla, the West Siberian tundras and the Taimyr peninsula. They winter along the coast of West Africa (Bijlsma *et al*, 2001). According to Moore (1997), it is a scarce winter visitor and passage migrant in Portugal. In the A Rocha study area it is an irregular visitor. In 1987 a Pomarine Skua wintered in the estuary during three weeks in December. There are also two autumn records and one in summer. One remarkable observation was made on 20 October 1991. A juvenile flew during lunchtime over Cruzinha, landed in the Odiáxere River, and stayed there for a while before leaving the area. Then it circled upwards like a Buzzard and moved to the east with a circling flight action, and followed an inland course. Its flight-behaviour was remarkable for being like a raptor. In another case a Pomarine Skua was seen chasing a Caspian Tern.

Arctic Skua *Stercorarius parasiticus*

In north-western Europe the Arctic Skua breeds in Scotland, the Faeroe Isles in Scandinavia and also inside the arctic region of Europe. This population mainly winters along the coast of Namibia, thus very far to the south (Bijlsma *et al*, 2001). In the A Rocha study area the Arctic Skua is the most common skua and is mostly seen in September and October. Sometimes wintering birds are recorded. There is only one record in spring. Also in the Netherlands this Skua has its highest presence during September and October, while spring passage is much weaker and wintering birds are rare (Bijlsma *et al*, 2001). It is also the most common of the four Skua species in the Netherlands and Portugal. In Portugal its status is as a fairly common passage migrant and winter visitor (the same as the Great Skua).

Long-tailed Skua *Stercorarius longicaudus*

The long-tailed Skua's circumpolar breeding range is within (sub)arctic regions south to southern Norway. It winters in tropical oceans and, outside of the breeding season, is the most pelagic of the skuas. In the Netherlands and in Portugal the Long-tailed Skua is by far the rarest of the skuas seen. According to Van den Berg (1999) it is fairly rare and according to Moore (1997) has a status as a rare passage migrant. In the A Rocha study area there is only one record, of an adult in a spectacular breeding plumage found injured on the southern rim of the estuary close to the Alvor Dunes. It was brought to the Observatory where it was kept in captivity from 6 to 12 May 1999 (see Plate 1).

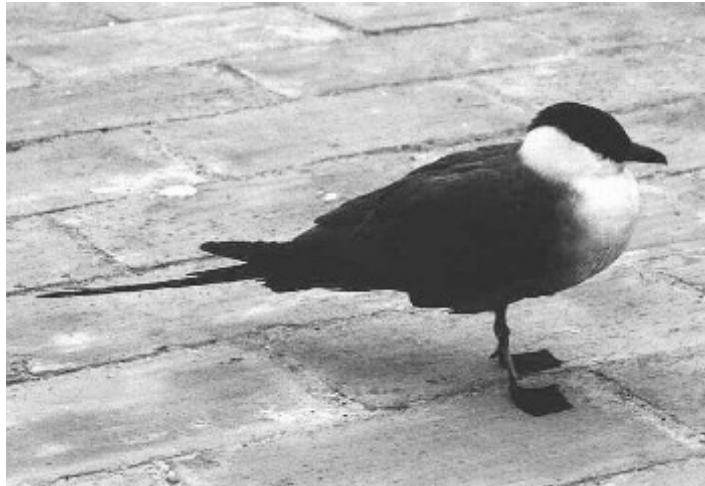


Plate 1 Long-tailed Skua (W. Scheres)

Iceland Gull *Larus glaucooides*

This gull breeds in Greenland and winters in Greenland and Iceland; it is scarce to rare elsewhere along northern Atlantic coasts. In the Netherlands it is a fairly rare winter visitor (Van den Berg, 1999). In mainland Portugal the Iceland Gull is accidental (Moore, 1997). In the A Rocha study area only one has been recorded: on 9 October 1999 an adult flew over the Observatory. The southern location of the Algarve means that the chance of encountering an Iceland Gull here is very small.

Glaucous Gull *Larus hyperboreus*

Glaucous Gulls breed in the far north of the Atlantic, along the coast of Canada, Greenland, Iceland, Spitzbergen and Russia. The Netherlands lie on the most southern edge of their wintering area (Bijlsma *et al*, 2001). In Portugal it is an accidental species (Moore, 1997). As to be expected, therefore, the Glaucus Gull has only once been recorded in the A Rocha study area. A third summer individual was seen sitting amongst a large flock of gulls in the Alvor Estuary on the 20 August 1995, after which it flew eastwards.

Black-legged Kittiwake *Rissa tridactyla*

This species is almost exclusively restricted to the sea and coast. It breeds along the coasts of the north Atlantic in locally great numbers, for example 120,000 pairs along the eastern coast of England. In the Netherlands it is a common passage migrant and winter visitor, and is fairly common in summer. It winters on seas from Nova Zembla to the western Mediterranean and to the Cape Verde Islands (Bijlsma *et al*, 2001). Along the coast of Portugal it a rare bird both on passage and as a winter visitor (Moore, 1997). The Black-legged Kittiwake has only once been seen in the study area: a single bird on 11 November 1994.

Razorbill *Alca torda*

The Razorbill breeds along the coasts of Scandinavia, the British Isles and the Brittany peninsula of France. Wintering occurs on sea and along the coasts of western and northern Europe and North

Africa. It is a fairly common passage migrant and winter visitor in the Netherlands and also in Portugal a common winterer (Bijlsma *et al*, 2001; Moore, 1997). In the A Rocha study area Razorbills are mainly seen out to sea. It has only once been recorded within the estuary. All records of it here have been made during the three winter months. These records are not numerous even though Razorbills are common winterers in Portugal, perhaps because of the relatively little amount of winter seabird observation.

Table 3 Skuas, some gulls and Razorbills recorded in the A Rocha study area.

Species and status (Moore, 1997)	Date	Record
Great Skua	25 Nov 1988	1 in the estuary
Fairly common winter visitor	23 Mar 1997	1 in the estuary
Fairly common passage migrant	31 Dec 2000	1 out to sea
	2 Jan 2001	2 out to sea ¹
	21 Oct 2001	1 in the estuary ²
	27 Feb 2001	1 out to sea
	28 Feb 2001	2 out to sea
	1 Mar 2001	1 out to sea
Pomarine Skua	11–31 Dec 1987	1 light phase, 3 weeks in the estuary ³
Scarce winter visitor	18 Nov 1988	1 dark phase in the estuary
Scarce passage migrant	28 Jul 1989	2 juveniles in the estuary
	21 Oct 1991	1 juvenile on Odiáxere River
Arctic Skua	21 Oct 1988	2 in the estuary
Fairly common winter visitor	6 Jan 1989	1 in the estuary
Fairly common passage migrant	14, 23 Sep 1991	1 in the estuary
	28 Sep, 5 Oct 1994	1 dark phase in the estuary ⁴
	18 Apr 1996	2
	3, 5 Oct 1997	1
	11, 18 Oct 1998	1
	31 Dec 2000	1 out to sea
	2 Jan 2001	2 out to sea ⁵
Long-tailed Skua	6 May 1999	1 adult found injured on the Alvor Dunes
Accidental species		
Regularly off-shore		
Iceland Gull	9 Oct 1999	One adult flying over Cruzinha
Accidental species		
Glaucous Gull	20 Aug 1995	1 third-summer in Alvor Estuary
Accidental species		
Black-legged Kittiwake	11 Nov 1994	1
Fairly common winter visitor		
Bred on Berlengas Islands, 1980		
Razorbill	9, 19 Dec 1994	1 in the estuary
Common winter visitor	28 Dec 1996	1 out to sea
	14 Feb 1998	3 seen from Alvor Dunes
	2 Jan 2001	9 to the west over the sea
	3 Jan 2001	2 close to the breakwaters

¹ Two Great Skuas chasing a Yellowlegged Gull

² Great Skua chasing a Sandwich Tern

³ Pomarine Skua chasing a Caspian Tern

⁴ Arctic Skua chasing a Sandwich Tern

⁵

⁵ Arctic Skua chasing a Sandwich Tern

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A SURVEY OF GANNETS *MORUS BASSANUS* OFF THE ALGARVE COAST AT CARVOEIRO

Manfred Temme⁶

Introduction

The Gannet is well known as a common wintering species and a regular migrant around Cape St Vincent. Walker (1996) carried out systematic observations at this most south westerly point of Europe and has given a detailed report of the occurrence of large numbers in that area.

In comparison, little is known about the presence and numbers of Gannets off the southern coastline of the Algarve. From *ad hoc* sightings near Alvor, this species was considered an occasional passage migrant (Harris *et al*, 1990; Harris & Jackson, 1991, 1992). In recent years more Gannets have been seen off the Alvor dunes, and it is thought that Gannets are often under-recorded (Felgueiras *et al*, 2002). Gannet sightings have numbered up to 200 during pelagic bird-watching trips (Calladine, 1990; Gardiner, 1999; Beale, 2002).

The purpose of the current study was to determine the status of Gannets off the south coast of the Algarve through a more systematic survey.

Method

The so called sea-watching method was used to gain information on numbers and movements of Gannets and other seabirds present in the central cliff region of the Algarve coast. All bird species passing through the view field of a set of 20x80 binoculars were recorded for exactly one hour each day from the cliffs east of Carvoeiro (37°05'N; 08°28'W). In each of the 7-18 day observation periods, the hour between 09:00 and 10:00 was selected, because experience had shown that Gannets are especially active in the morning, whether gathering food or on migration. All birds seen at a distance up to an estimated 4 km were noted. Although the watches were facing south against the sunlight, it was possible to distinguish between adult, immature and juvenile individuals. At such distances, it was not practical to try to separate second- and third-year plumages and sub-adults. The survey was carried out during several intervals between 14 April 1995 and 10 December 2002, encompassing a total of 150 hours of observation. The first results and their analysis are described by Temme (1997).

Results and discussions

Gannets were usually seen in the view field of the binoculars as soon as they were positioned on a sturdy supportive device. Outside of the main migration seasons, Gannets seemed to be mostly on the move to fishing areas, or else were circling and diving for fish, sometimes very near the coast in front of the observer. Below is a detailed account of and commentary on observations by season.

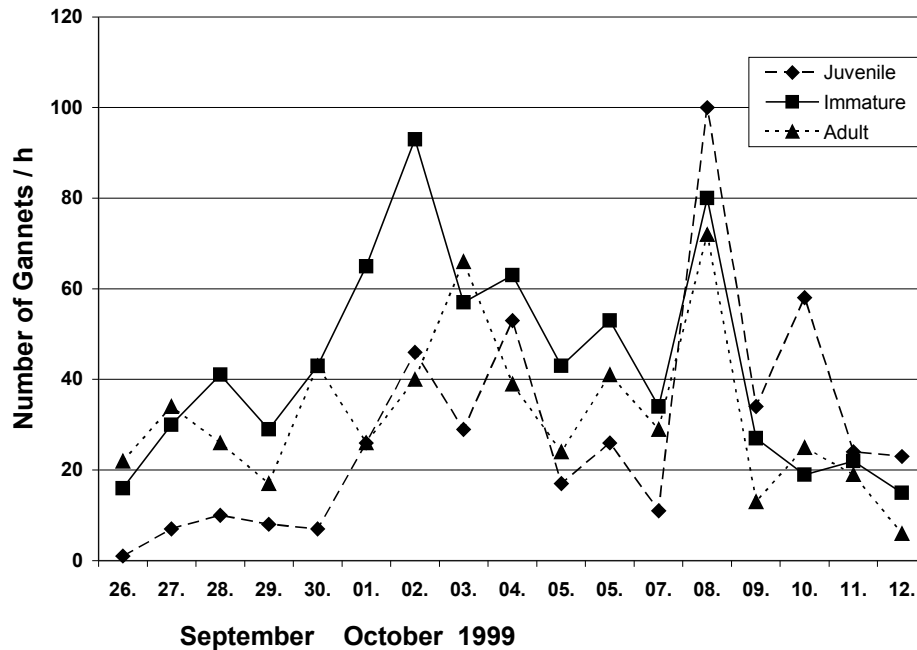
September/October

According to Nelson (1978), young birds leave the breeding areas earlier than the adults, passing in increasing numbers off north-west Spain in September and October. They arrive in late October at Gibraltar and the passage continues into November (Garcia, 1971). This accords with observations off Carvoeiro at the end of September and in the first half of October, with birds of all ages seen,

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but juveniles and immature birds together far outnumbering adults. Figure 1 shows this through the results for 1999.

Figure 1 Gannet numbers off the coast at Carvoeiro, September-October 1999.



November/December

No observations were carried out at Carvoeiro in November. Walker (1996) reports a very high rate of adult birds and fewer younger birds during this month off the Cape. In December the mean number of Gannets seen per hour off Carvoeiro in 1995, 1996 and 2002 was 52 individuals. Similar age class proportions were evident in these three years, with c.86% present being adults, 12% immatures, and only 2% juveniles. Similar figures were recorded at the Cape by Walker (1996). This agrees with the different migration times and wintering strategies of the age classes. Most of the younger birds are apparently already farther south on their way to winter quarters along the north-west coast of Africa, mainly Morocco and Senegal. Meanwhile, large numbers continue to enter the Mediterranean Sea and the wintering population consists of about 86% adult birds (Hasmi, 1999).

January/February

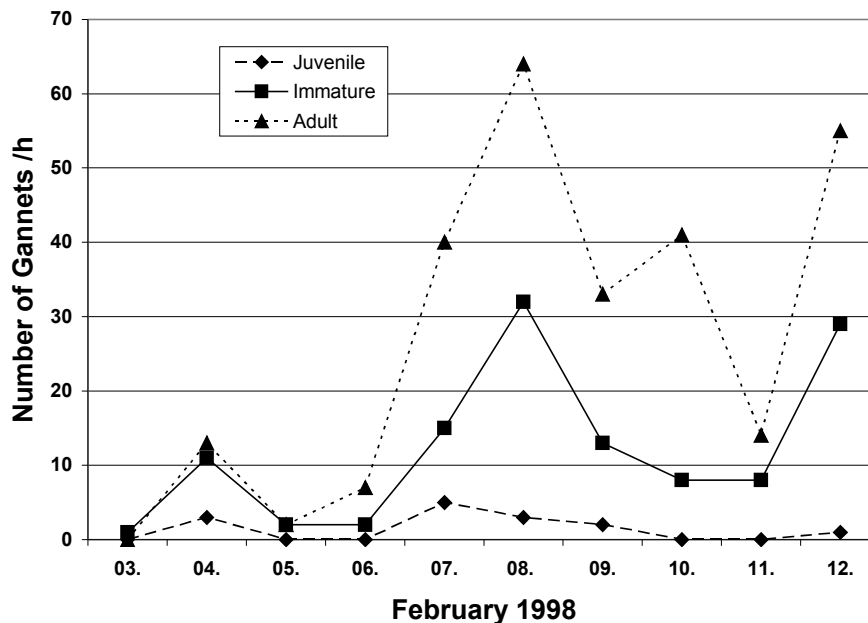
In the first ten days of January 2001 the situation off Carvoeiro is similar to December, with adults making up 83% of the birds observed. This probably again reflects that many adults remain during mid-winter closer to their breeding ranges and some may already move slowly northwards. However, the total number of birds seen is still relatively low. From 3 to 12 February 1998 the total was 361, averaging up to 36 Gannets/hour. Adults composed 67% of the total bird count, with a frequency of up to 64/hour on 8 February. Immature numbers peaked at 32/hour on the same day, while juveniles were never seen at more than 5/hour (Figure 2).

March

In the first half of March 1998 increasing migration movements were obvious. A total of 1012 Gannets (averaging 101 per hour), moved steadily westward along the coastline between 3 and 12 March with adults making up 60%, immatures increasing to 32% and juveniles to 8%. During the second half of this month, west-bound spring migration increased further with most Gannets passing the view field of the binoculars steadily. They often flew in line formations, sometimes up to 19 birds in a flock. In most cases, such groups maintained heights of approximately 20 to 30

metres parallel to the coast. Walker (1996) writes about similar loose ‘skeins’ or mixed-age parties passing the Cape. The migrating flocks at Carvoeiro were mostly led by an adult. However, in the case of juvenile or immature flocks, a bird in its third year led the group. Of the total of 1234 individuals (49 per hour) observed on 25 March, adults represented 65%, immatures 28% and juveniles 7%.

Figure 2 Gannet numbers off the coast at Carvoeiro, February 1998.



April

Apparently the majority of adults have left the Algarve near the end of March to arrive in April in their northern breeding colonies. However, in 1995 and 2000 many adults were still present in the second half of April at Carvoeiro, but reached only 13 and 24% of all birds respectively. In contrast, the numbers of immatures moving westward were up to 52% and juveniles reached proportions of between 26–36%. This would seem to match the overall picture illustrated by Gaston (1970) who, between 13-17 April, describes at Cape Verde, Senegal movement of 400 younger Gannets and only 18 adults. His observations indicate that most adults have already left the wintering area and are further north. Numbers of adults are highest March to mid-May at Cape Clear (Nelson, 1978).

General observations

Generally, the flight activities of Gannets are wind dependent and they are preferentially aflight during periods of stronger winds. Against strong winds they fly very low just above the waves, and with lighter tail winds at elevations of 15 to 35 metres. Stronger migration movements occurred during phases of head winds, following cold fronts and/or in good visibilities. Exceptions to these rules existed, however, and further observation and statistical analysis would be needed to interpret correlations with wind parameters with more certainty.

At Cape St. Vincent, Gannets are at times extremely numerous. Walker (1996) noted feeding frenzies of up to 1700 birds, and occasionally averages of more than 176 birds per hour may be seen. Exceptional large numbers of 800 to 1400 birds in February 1993 and January 1994 were counted by him in less than one hour. Such extreme figures cannot be matched by counts at other areas of the southern Algarvian coastline. However, the c.406 birds, seen in early March 2001 from the Alvor dunes (Felgueiras *et al*, 2002) were noteworthy. Near Carvoeiro, the maximum count so far is of 302 Gannets per hour passing the binoculars view field on 28 March 1996.

Conclusion

This study has revealed that Gannets are a very regular and numerous winter visitor as well as a common passage migrant off the southern coast of the Western Algarve. In spring most birds head westwards along the southern coastline before rounding the cape and continuing north. In autumn they return east along the southern Algarve towards their winter quarters in the Mediterranean Sea or off the north-western coast of Africa. Smaller numbers remain during the winter months in Portuguese waters.

Furthermore, shifts of seasonal abundances of juveniles, immature and adult birds occur. In early spring higher numbers of adults are counted, for they have spent the winter closer to their breeding grounds. In late September/early October, however, it is the younger birds that are more numerous, for they are the earliest to leave their northern breeding grounds and return south for the winter.

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A SHORT SPRING AMPHIBIAN SURVEY ON THE ALVOR ESTUARY

Alan Preece

Introduction

The following is a report on a survey 14-18 March 2003 that used a standard torchlight surveying technique to assess the amphibian fauna of a number of waterbodies in the Alvor Estuary study area.

Methods

The torchlight technique involved using a high-powered torchlight to locate and identify amphibians using potentially suitable habitat. These searches took place shortly after sunset (approximately 7pm). The aquatic surveys involved walking around the margins of the waterbody once and the terrestrial searches were in the form of a walk through potential migration routes and foraging habitat. Listening for calling amphibians made locating suitable aquatic habitat easier. Each waterbody was tested for its salinity and temperature using a hydrometer and a thermometer.

Results

The three species which were found during these surveys were Perezi's Frog *Rana perezi*, Bosca's Newt *Triturus boscai* and Natterjack Toad *Bufo calamita* (Table 1). The locations of sightings are shown in Figure 1.

Table 1 Amphibian sightings and water quality.

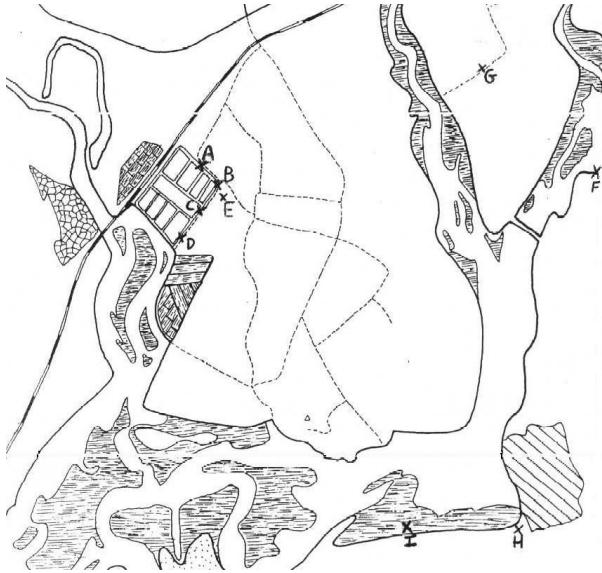
Date	Map reference of water sample	Description of waterbody	Salinity (ppt)	Temp (°C)	Species
14.3.03	A	Fish-farm ditch NW from bend to bridge	2.41	17	<i>Rana perezi</i> , 1 pair in amplexus (<i>Natrix maura</i> also seen)
	B	Fish-farm ditch at bend	2.8	16.5	<i>Rana perezi</i>
15.3.03	C	Fish-farm ditch SW from bend	14.4	16	<i>Rana perezi</i>
	D	Fish-farm ditch SW at inflow pipe	32.6	15.5	-
	E	Western Marsh corner pond	9.15	19	<i>Rana perezi</i>
17.3.03	F	Abicada dam	21.05	14	-
	G	Abicada reed ditch	2.75	13	<i>Triturus boscai</i> (1 seen)
18.3.03	H	Puddles near Alvor football field	0.0	15.5	<i>Bufo calamita</i> (10 calling males, 1 pair in amplexus)
	I	Alvor marsh pond	33.7	15.0	-

Perezi's Frog

This was the only amphibian found in more than one of the waterbodies, and many individuals were usually present. It appears to utilize most types of water body, tolerating salinities of at least 14.4 ppt. This species appears to be common, with calling often heard where no sightings were made. The survey period appeared to be part of, and possibly the start of, the breeding period for this species and Natterjack Toad. Both Perezi's Frog and Natterjack Toad were found with a breeding pair in amplexus indicating imminent spawning.

Perezi's Frog (formerly classified as the Marsh Frog *Rana ridibunda*), occurs across the Iberian peninsula and into the south of France, in Portugal from sea level to 1900 m in the Serra da Estrela (Almeida *et al*, 2001).

Figure 1 Location of amphibian sightings.



Natterjack Toad

This species was found calling in shallow puddles on a night following rainfall. The 0 ppt salinity value of the water in this pond indicated that it could be the result of the previous day's rain. This species relies on these highly ephemeral pools for its specialist reproductive strategy.

Natterjack Toad has a wide distribution across western and central Europe. It occurs from the north to the south of Portugal, with a continuous distribution through the interior of the country.

Bosca's Newt

This is similarly widespread across Portugal, but is otherwise known only from western Spain, being an endemic of the western Iberian peninsula. It was recorded just once, in a ditch at Abicada.

Other species previously recorded

Other amphibian species previously recorded in the study area and reported by Gardiner (1995) are: Sharp-ribbed Salamander *Pleurodeles waltl* (two records at Cruzinha in October 1992 and November 1994); Portuguese Painted Frog *Discoglossus hispanicus* (one frog recorded as *D. pictus* in summer 1994); Common Toad *Bufo bufo* (often observed on damp nights); and Stripeless Tree Frog *Hyla meridionalis* (sporadically seen at Cruzinha). Table 2 lists species whose natural ranges encompass or are near the Alvor Estuary.

Table 2 Amphibian species with confirmed natural ranges near Quinta da Rocha (Godinho *et al*, 1999). * Anuran species

<i>Pleurodeles waltl</i> Sharp-ribbed Salamander	<i>Pelobates cultripes</i> Western spadefoot Toad*
<i>Salamandra salamandra</i> Fire Salamander	<i>Pelodytes punctatus</i> Parsley Frog*
<i>Triturus boscai</i> Bosca's Newt	<i>Bufo bufo</i> Common Toad*
<i>Triturus marmoratus</i> Marbled Newt	<i>Bufo calamita</i> Natterjack Toad*
<i>Alytes cisternasii</i> Iberian midwife Toad *	<i>Hyla meridionalis</i> Stripeless tree Frog*
<i>Discoglossus galganoi(hispanicus)</i> Portugal painted Frog *	<i>Rana perezi</i> Perezi's Frog*

Discussion of method and suggestions for future work

The coastal nature of the study area brings substantial challenges to amphibians as they need both suitable terrestrial and aquatic habitats for adult survival and reproduction. Finding potential breeding sites will make the task of identifying which species are present much easier. Amphibians are more visible and present in much higher concentrations in these waterbodies during the breeding season than at any other time and location throughout the year. Measuring the salinity of suspected waterbodies will help to identify more promising sites, limiting the time spent surveying after dark during the breeding season. This is a necessity to maximize the number of ponds surveyed in a night using the high power torch, which has a charge life of only about one hour.

Following this initial investigation it was found that the more permanent freshwater areas are often very heavily vegetated making torchlight surveying relatively unproductive. However, three species have been successfully located using this method. The success of this method would be aided by the use of amphibian call surveys. As the males of the anuran (frog and toad) species all call at least during the breeding season, further surveys using their unique calls may be valuable. Along with being able to identify individual species it will also help to locate breeding sites in the area and the times of year when they are used. During the present study this call method successfully identified and located the Natterjack Toad population while the surveyors were at least 500 m away from the pond. Sound recordings have been made of the European anuran species to help in the accurate identification of these calls (Roché, 1997).

Unfortunately, call surveys cannot replace night time torchlight surveys. Urodele (newt and salamander) species do not use calls and therefore will not be located by call surveys. However these species may well use the same waterbodies as anurans, therefore it may help to limit torch surveys to the more productive sites.

For both urodeles and anurans refugia searches can be very helpful for surveying outside of the breeding season. Due to the hot, dry Algarvian climate it is probable that only large objects such as rocks and logs will be used. These are more likely to be used in shaded and damp areas and when they are relatively well embedded in the ground. This will help to create a cool, damp microclimate underneath, enabling the amphibians to avoid desiccation and heat stress.

Refugia searches are at best a method which disturbs a valuable microhabitat and at worst it is destructive. Therefore environmental good practice dictates that any such object that is moved should be replaced in exactly the same place as it was found. Any animals found underneath should be removed before the object is replaced and they should be released next to the object so that they can rebury themselves safely.

Care should also be taken during refugia searches as venomous animals may also use these microhabitats, including snakes, scorpions, spiders and centipedes. For safety long, thick leather gloves should be used.

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BIO-PARQUE MONCHIQUE: THE FLORA AND VEGETATION OF FOIA

Will Simonson and Pam Simpson

The following is an abridged version of the project report submitted by A Rocha to the Bio-Parque consortium and available in the Cruzinha library (Simonson, 2003).

Introduction

Bio-Parque Monchique

The Serra de Monchique is a proposed special area of conservation (site code: PTCN0037) within the Natura 2000 network formed under the EC Birds and Habitats Directives. The features for which it has been designated as such are listed in Annex 1 and comprise 15 habitats and 11 species, including two priority species: Iberian Lynx *Lynx pardinus* and the tiger moth *Callimorpha quadripunctaria*. The Natura 2000 area covers 76,008 ha and reaches an altitude of 902 m.

The Bio-Parque initiative seeks to implement Natura 2000 through an integrated package of measures to support nature conservation, access and rural tourism, and local economies. Coordinated by a consortium including landscape architects, biologists and engineers, actions include to: renovate old properties for rural tourism, incorporating ecological functions such as solar energy and natural waste treatment systems; create a network of hiking trails, and interpretation of nature; encourage the restoration of traditional activities associated with the mountain environment; and recreate habitats similar to the original vegetation cover of the mountains.

Aims of the current project

The aims of the current project were to gain a detailed knowledge of the plant communities and vegetation types contained within four council-owned areas of land at and around the summit of Foia. This information is to be used as a baseline for informing future management of the sites, including habitat re-creation and access. Specific outputs intended were:

- an inventory of vascular plant species for each of the study areas and the total land area;
- more detailed distributional information and commentary for notable species;
- a description of the vegetation types present;
- the identification of particularly sensitive and/or priority areas for plant conservation,
- recommendations on habitat recreation and other management.

An additional output became the creation of a photo-library of digital images of plant species recorded.

Previous botanical studies

The flora and vegetation of the Serra de Monchique was documented by Malato Beliz (1982). Simonson (1994) undertook a detailed inventory and vegetation description of a 400 ha area around Picota, comparing species richness of different habitats, and making conservation recommendations. A survey across the Serra of the occurrence of eight species of oak *Quercus* was completed the following year (Simonson, 1995).

Methodology

Study areas

The Serra de Monchique consists of the two syenite massifs of Foia (902 m) in the west and Picota (774 m) in the east, rising above the surrounding lower hills of carboniferous meta-sediments. The town of Monchique is sited between Foia and Picota at an altitude of 460 m. These are the highest mountains of the Algarvian Serras, and this confers on the area a strong Atlantic climatic influence, creating a distinct and biodiverse area that serves as a refuge for a number of species better known in more northern latitudes. Table 1 (from Rivas-Martínez *et al.*, 1990) typifies the bioclimate of Foia as hyperhumid Mesomediterranean, in contrast to the dry to humid Thermomediterranean nature of the Algarve as a whole, including up to Monchique town itself. Rainfall at Foia is up to three times that experienced at the coast.

Table 1 Bioclimates of a line from the Coast (Praia da Rocha) to Foia.

Site	Alt (m)	Median annual temp. (a)	Median max temp in the coldest month (b)	Median minimum temp in the coldest month (c)	Index of thermi city a+b+c *10	Precip (mm)	Bioclimate
Praia da Rocha	4	17.0	8.1	15.3	404	471	Thermomediterranean , dry
Caldas de Monchique	203	17.4	7.2	15.3	399	1093	Thermomediterranean , humid
Monchique	465	15.5	6.9	12.6	350	1346	Thermomediterranean , humid
Foia	877	12.2	4.5	9.1	258	1526	Mesomediterranean Hyper-humid

The geology of igneous syenite rock, with the two local varieties of *foyaite* and *monchiquite*, dates back 70 million years into the Tertiary period. Near Foia the rock is often white and crumbly due to weathering of the minerals into clays (Elsdon, 1988). The syenitic soils (family *Solo Litólico Húmico de Sienitos (Mns)* (Kopp *et al.*, 2000)) derived from the bedrock can reach several metres in depth, and are typically rich in humus and potassium in the A horizon, rendering them fertile for forestry and terrace cultivation of vegetable and fruit crops.

The landscapes and vegetation of the Serra have been substantially altered over the years through deforestation, terraced cultivation, sweet chestnut coppices and modern plantation forestry (eucalyptus and pine). The king Dom João VI gave common rights to the land on the upper slopes of Foia to the people of Monchique town in 1824 and the forest cover was thereafter rapidly removed, such that the modern treeline is now at about 600 m (Mabberley & Placito, 1993). Semi-natural vegetation cover is dominated by shrublands of *Ulex minor*, *Cistus* and *Erica* species, and mixed woodlands of evergreen Cork Oak *Quercus suber*, deciduous Algerian Oak *Quercus canariensis* and Strawberry Tree *Arbutus unedo*. Biogeographically, the mountains are part of the Serrano-Monchiquense superdistrict, belonging to subsector Baixo alentejano-Monchiquense, sector Mariânico-Monchiquense and province Luso-Extremadurens (Costa *et al.*, 1998).

Cork cutting, Arbutus berry picking for *medronho* and the harvesting of other natural products form an important part of the local economy and farming year. Land-use has been undergoing rapid change in recent decades and large areas of terraced land has come out of cultivation. Demographic changes include the replacement of traditional farming communities with expatriate households, and tourism has become an ever-increasing sector.

The four study areas of this project straddle the summit of Foia, on mostly north-facing slopes (figure 1). From west to east they are Vale Largo, Cruz da Foia, Terreno da Foia and Barranco da Garganta. They lie between the altitudes of 670 and 898 m, and together comprise an area of some 400 ha (Table 2).

Figure 1 Map of the study areas.

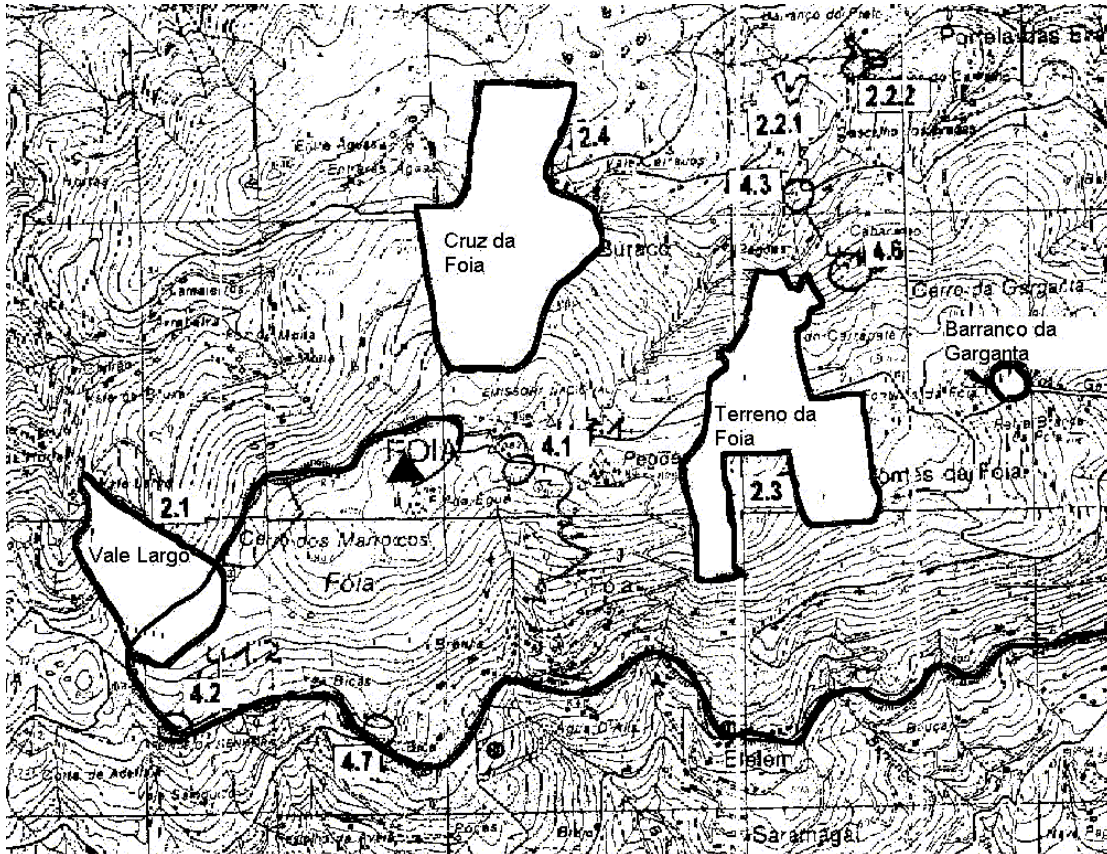


Table 2 Study areas: altitude and aspect.

Study area	Altitude (m)	Main aspect
Vale Largo	670-834	NW
Cruz da Foia	705-898	N
Terreno da Foia	670-880	N (S -)
Barranco da Garganta	734-781	E

Vale Largo includes abandoned terraces and two ruined farm cottages, being otherwise dominated by heathland. The upper part of the site is bisected by the EN263-3 Monchique-Foia road. A zig-zag of unsurfaced tracks provides access to the bottom of the site, where there is a stream culvert.

Cruz da Foia lies to the north of Foia and reaches up to the installations at the summit itself. This largest of the four sites provides vehicular access by a number of surfaced and unsurfaced tracks. A small valley divides the north and south facing slopes of the sites. Much of the area is under old and new forestry. Much also is variously disturbed, including by grazing. There are two reservoirs within the boundaries of the site, and also a ruined cottage.

Terreno da Foia is an irregularly shaped area a part of which crosses the ridge to the east of Foia and descends the south facing slope. It includes both wooded and heathland areas, as well as abandoned terraces and farm buildings.

Barranco da Garganta is a small site on east-facing slopes, dominated by heathland with a single ruined farm property, and a small amount of tree cover.

All of the sites contained water features in the form of seasonal or permanent streams, water mines, stream culverts and pools, which became focii of interest during the course of the botanical survey.

Site surveys

Fieldwork for the project consisted of a total of 16 visits to the study areas between 20 May and 31 July 2003 (Table 3).

Reconnaissance visits were made in May to gain familiarity with the sites, their boundaries and main vegetation types. The sites were traversed on foot with 1:1000 maps supplied by Claudia and Udo Schwarzer being used for navigation. During these visits, species of open habitats (paths, open fields and rocky outcrops), which were less likely to be identifiable later in the season, were recorded. Initial notes on the vegetation were also made.

The main detailed survey was carried out in the two weeks commencing 3 June 2003. Two observers sampled the main vegetation types present at each site, recording the presence of all vascular plant species. Collections were made to confirm identifications back in the laboratory.

A more detailed description of the plant communities present was approached through the taking of relevés in representative areas. These were typically a square of 10 by 10 m, inside of which all species, and their cover-abundance, were recorded. Cover-abundance was estimated following the standard Braun-Blanquet scale (Table 4). Additional data recorded were total vegetation cover (both field/shrub layer and tree layer if present), mean vegetation height, aspect and estimated slope.

Table 3 Site visits

Date (2003)	Sites visited	Purpose
20 May	Terreno da Foia	Reconnaissance
21 May	All sites	Reconnaissance
28 May	Vale Largo	Reconnaissance
29 May	Cruz da Foia	Reconnaissance
4 June	Cruz da Foia	Reconnaissance
17 June	Terreno da Foia	Survey
18 June	Vale Largo	Survey
19 June	Vale Largo	Survey
20 June	Cruz da Foia	Survey
24 June	Cruz da Foia	Survey
25 June	Terreno da Foia	Survey
26 June	V. Largo, C. da Foia, T. da Foia	Survey
27 June	V. Largo, B. da Garganta	Survey
15 July	V. Largo, Cruz da Foia	Follow-up
29 July	V. Largo, C. da Foia, T. da Foia	Follow-up
31 July	C. da Foia, T. da Foia	Follow-up

Table 4 Braun-Blanquet cover-abundance scale.

Rating	Description
R	Individuals rare or isolated
+	Sparsely or very sparsely present, cover very small
1	Plentiful, but of small cover value
2	Very numerous, or cover 5-25%
3	Any number of individuals; cover 25-50%
4	Any number of individuals; cover 50-75%
5	Cover greater than 75%

A series of follow-up visits were made in July to verify some identifications made and fill in other gaps.

Records of notable plant populations, as well as the positions of relevés, were to have been noted at UTM coordinates using a Global Positioning System. After trialling this in the field, it was felt that the accuracy of the method was less than could be achieved by simply plotting positions and areas on the 1:1000 maps. Spatial depiction of the results, therefore, were presented in this form, attached to the main report (Simonson, 2003).

Taxonomic identification

A number of floras were used in the identification of species present, the main ones being the *Flora Ibérica* (Castroviejo *et al*, 2001), *Flora Europaea* (Tutin *et al*, 1968-1980), *Nova Flora de Portugal* (Franco, 1971-1984) and *Flora Vascular de Andalucía Occidental* (Valdés *et al*, 1987). Also of help were *Distribuição de Pteridófitos e Gimnospermicas em Portugal* (Franco & Afonso, 1982) and the *Collins Guide to Grasses, Sedges, Rushes and Ferns of Britain and Northern Europe* (Fitter & Fitter, 1984). Taxonomic nomenclature followed in this project was preferentially that of the *Flora Ibérica*.

Analysis and interpretation

The phytosociology and ecological functioning of the plant communities studied was analysed by commencing with methods of tabular comparison of relevé data (Mueller-Dombois & Ellenberg, 1974) to differentiate unranked communities. These were compared with the communities described in phytosociological literature, in particular the work of Braun-Blanquet *et al* (1956, 1964), Malato Beliz (1982), Rivas-Martínez (1964), Rivas-Martínez *et al* (1990) and Seng & Deil (1999). Other reference sources included the Interpretation Manual of European Union Habitats (European Commission DG Environment, 1999), and Feijão (1963) for the common plant names used in the following text.

Results and interpretation

Floristics

A total of 238 higher plant taxa (236 species) were identified in the four study areas (Annex 2), distributed across 69 families and 174 genera. By comparison, Malato Beliz (1982) recorded 492 taxa across the Serra as a whole, and Simonson (1994) 349 taxa for a similar-sized study area around the summit of Picota, but in a survey that encompassed the months January-September. 21 taxa of the current study are not included in the records of these earlier studies.

The number of taxa within each of the study areas is given in Table 5. An analysis of taxa by broad habitat is also made (Table 6). The species richness of rock outcrops is likely to be under-represented because of the earlier flowering period of species growing in this situation of warmer microclimates.

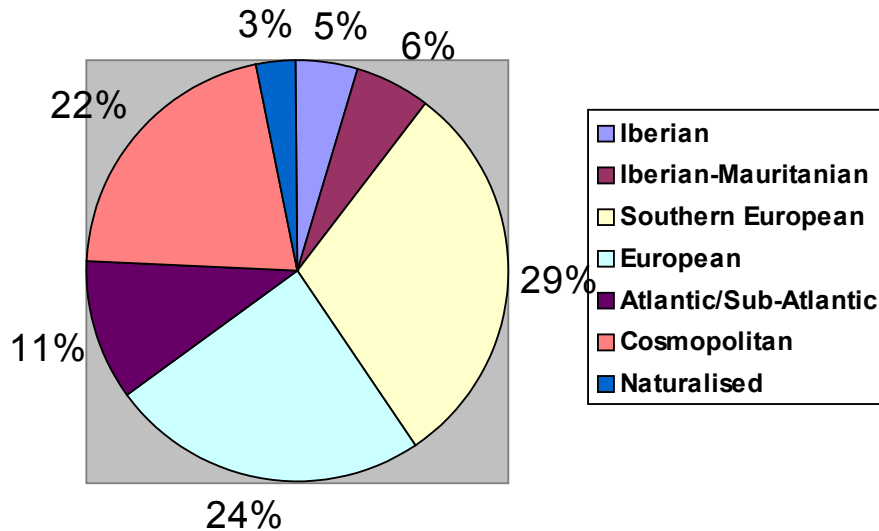
Table 5 Number of vascular plant taxa recorded in the four study areas.

Study area	No. of taxa
Vale Largo	143
Cruz da Foia	162
Terreno da Foia	128
Barranco da Garganta	95

Table 6 Number of vascular plant taxa recorded in the main broad habitats.

Broad habitat	No. of taxa
Open habitats (waysides and cultivated land)	119
Rock outcrops	47
Scrubland	70
Wet areas	77
Woods and forestry	87
Rhododendron copses	45

A phytogeographical analysis of the flora (Figure 2) demonstrates not only the importance of southern European (including Mediterranean) elements, as to be expected within the Algarve, but a strong presence of (Sub)Atlantic and European species due to the montane influence on the climate creating conditions more typical of more northern latitudes (see section 2.1). Examples of Atlantic species include *Ulex minor* and *Avenula marginata* subsp *sulcata*, both common (and the former often dominant) on the highest slopes of the mountains.

Figure 2 Phytogeographical analysis of the recorded flora.

Notable plants

From the results it is possible to highlight as significant the presence of a number of priority and otherwise noteworthy species. A further subset of species can be considered significant for their ecological function and phytosociology, and these are discussed in section 3.3, following.

Armeria beirana Franco ssp *monchiquensis* (Bernis) Franco. Two significant populations of this white-flowered Monchique form were found within the study area of Cruz da Foia. Supposedly one of the rarest plant taxa to be found in the mountains, the species was not found elsewhere although it would be worth checking other rock outcrops around the summit of Foia.

Athyrium filix-femina L. (Roth) Lady Fern (*Feto-fêmea*) This species is representative of a group of six fern species frequently occurring together in damp and shady places, such as cuttings, ravines and stream-banks. Within the Algarve this particular fern is restricted to the highest part of the Serra de Monchique. In this study it was found at Vale Largo and Cruz da Foia.

Campanula primulifolia Brot. This impressive example of its genus was once considered a Portuguese endemic, but recently found in the region of Huelva. In this study it showed a strong affiliation with Rhododendron areas and other more humid situations in Vale Largo and Cruz da Foia.

Centaurea crocata Franco (*Cardalejas*) An ornate Iberian species with a golden-yellow to orange inflorescence, observed in good numbers along one track at the upper end of Vale Largo. Otherwise known from scrubland, heathland and rocky outcrops in the Alentejo and Algarve as well as south-east Spain.

Cupressus lusitanica Mill. Mexican Cypress (*Cedro de goa*) A species of cultivation, but introduced from Mexico to Portugal over 300 years ago and therefore with a long Portuguese association (known as *Ciprés de Portugal* in Spanish). It has not been recorded here previously in known literature. In this study it was found apparently naturalised in shrubland vegetation.

Cytinus hypocistis (L.) L. ssp. *hypocistis* (*Hipocisto*) An unmistakeable parasitic plant of a predominantly tropical family (Rafflesiaceae), which parasitises *Cistus* and *Helianthemum* in Portugal and the Mediterranean region. It has yellow and red inflorescences appearing above-ground. A few examples were found dispersed over Vale Largo and Terreno da Foia.

Dianthus lusitanus Brot. (*Craveiro* sp) This attractive, pink-flowered Iberian/North African species was found in good numbers growing out of the soil-filled crevices and pockets on rocky outcrops at Cruz da Foia.

Dryopteris affinis (Lowe) Frase-Jenk Scaly Male Fern (*Falso Feto Macho/Fentilha*) The sighting of this single individual at the entrance to a water mine at Cruz da Foia, if positively confirmed as the species in question, will probably represent the first record for the Serra de Monchique and indeed south Portugal. Its nearest Portuguese location is the Serra de Sintra.

Ilex aquifolium L. Holly (*Azevinho*) The oldest examples of this tree are a handsome addition to the landscape of the Serra, to which it makes a long 'leap' in its Portuguese distribution from the north-west and Serras de Estrela and Sintra. Within the country it is a species of woodlands on mountain slopes, on non-calcareous soils. It was recorded in three of the four Monchique study areas.

Myrica faya Aiton (*Faia, Faia-das-ilhas*) A rare species within Portugal, where it is questionably native. It is suspected that it was introduced (perhaps by D. João de Castro in 1542) from the Azores where it is common in the laurel forests *laurisilva* (González, 2002). Its native range include

other parts of Macaronesia (Canary Isles and Madeira). In this study it was just found at Vale Largo, near a source of water (its typical situation).

Neotinea maculata (Desf.) Stearn Dense-flowered Orchid The Serra de Monchique is one of several sites for this orchid in the Algarve. It is not demanding of special ecological conditions, except in favouring more or less dry places (Afonso & McMurtrie, 1991). It was seen at Terreno da Foia, being one of the four orchid species recorded in this study.

Ornithogalum pyrenaicum L. One of the less frequent of the *Ornithogalum*s in the Algarve, and in this study only found in and near the *Castanea sativa* woodland of Cruz da Foia. This elegant plant is recognisable by its petals which are green throughout.

Paeonia broteri Boiss. & Reuter Western Iberian Paeony (*Rosa-albardeira*) Whilst not uncommon, this is one of the more ornamental plants of the Serra, and a speciality for botanists visiting the mountains early in the season. In the Algarve it is restricted to the Serra de Monchique and Caldeirão.

Prunus avium (L.) L Wild Cherry (*Cerejeira*) Cultivated throughout Portugal and much of Europe, a single tree was found in the Barranco da Garganta study area, and others apparently growing wild in *Quercus canariensis* woodland at Vale de Peneda Negra. Within the country, it is considered spontaneous only in the north and centre (Franco, 1971).

Rhododendron ponticum ssp *baeticum* L. (Boiss. & Reuter) Hand.-Mazz. *Rhododendron* (*Adelfeira*) This shrub has two centres of distribution: the Black Sea area of South-west Asia (subsp *ponticum*) and SW Iberia (subsp *baeticum*). The Iberian subspecies is to be found on acid soils of southern Spain, and within Portugal in the Serras do Caramulo and Monchique. It is considered as a relic of a species that during the last interglacial period was native over much of Europe (Mabberley & Placito, 1993). It behaves as a sub-atlantic species, distributed mainly along water courses and near springs.

Sedum spp: The co-existing *Sedum* species have somewhat different micro-habitats, *S. brevifolium* being largely found on the southern slopes, *S. forsterianum* only in sheltered areas of vegetation, and *S. album* (*Arroz-dos-telhados*) largely on the exposed shallow soils (Mabberley & Placito, 1993).

Wahlenbergia hederacea (L.) Reichenb. (*Ruínas*) Delicate plant with small bell-shaped blue flowers, inhabiting wet, shady and rocky situations, mostly in the north and centre of the country. It is a species also cultivated in gardens. In the Serra it was only found at Vale Largo.

Review of structural vegetation types and plant communities

Some 22 phytosociological relevés were studied distributed across the four study areas as follows: Vale Largo – 6, Cruz da Foia – 6, Terreno da Foia – 9, and Barranco da Garganta – 1 (Table 7). Broad vegetation types sampled were heathland (10 relevés), rock outcrops (3), modern plantations (eucalyptus and pine) (2), chestnut coppice woodland (1), rhododendron (2), other semi-natural woodland/scrubland formations (2) and wetlands (2).

Whilst the above vegetation types can be easily distinguished in the field, the tabular comparison of relevé data produced a differentiated table of just three groupings: heathland with rock outcrops (12 relevés), woodland and forestry (8), and wetlands (2). The lumping of the relevés is insightful, and will be followed in the following description and discussion. An additional section (3.3.4) describes herb-dominated communities of waysides and cultivated land, not covered by the relevés. Section 4

then draws upon both the floristics (section 3.2) and this discussion on plant communities to put forward specific protection, management and restoration measures for each of the four study areas.

Table 7 Details of relevés taken in the study areas. VL = Vale Largo, CF = Cruz da Foia, TF = Terreno da Foia, BG = Barranco da Garganta

Relevé	Date	Site	Altitude (m)	Aspect	Slope (°)	Vegetation cover (%) Herb/shrub (tree)	Average veg. height (m)	Area (m ²)	Broad veg. type
1	19/6	VL	680	WNW	10	80	1	50	Wetland
2	19/6	VL	740	NW	20	100 (25)	3	100	Rhododendron
3	19/6	VL	765	NW	25	100	3	400	Rhododendron
4	19/6	VL	760	NW	25	50	.5	1	Wetland
5	20/6	CF	755	N	20	80 (90)	.5	100	Chestnut
6	24/6	CF	795	ESE	10	90 (50)	1	100	Pinewood
7	24/6	CF	825	SSW	15	90	.75	100	Rocks
8	24/6	CF	840	N	35	60	.5	100	Rocks
9	25/6	TF	775	NNE	25	30 (50)	1	100	Eucalyptus
10	25/6	TF	740	NNE	20	20 (100)	10	100	Woodland
11	25/6	TF	740	NNE	20	100	5	50	Woodland
12	26/6	TF	820	WSW	10	90	.75	100	Heathland
13	26/6	TF	800	NW	15	100	1	100	Heathland
14	26/6	TF	820	N	15	95	1	100	Heathland
15	26/6	TF	840	NNE	25	100	1	100	Heathland
16	26/6	TF	870	-	0	85	1.5	100	Heathland
17	26/6	TF	845	SSW	20	100	1.5	100	Heathland
18	26/6	CF	875	N	30	30	.5	100	Rocks
19	26/6	CF	860	NE	10	100	1	100	Heathland
20	26/6	VL	805	NW	15	100	1	100	Heathland
21	27/6	BG	760	E	30	95	1	100	Heathland
22	27/6	VL	825	NW	15	100	1.5	100	Heathland

Additional notes on relevés: **1** – a 25 m length of stream near the bottom of the Vale Largo site, cutting into a small ravine at the top end; **2** and **3** – pre-woodland formations with Rhododendron as a dominant shrub component, the latter with a spring and small stream; **4** – a sheltered cutting on the trackside, adjoining a Rhododendron area, with surface water running/seeping into and out of the area; **5** – taken from the core area of old chestnut coppice woodland at Cruz da Foia; **6** – *Pinus radiata* plantation; **7** – a high cover of surface rocks, but also with a developed shrub layer; **8** – rocky outcrop locality, chosen for its exceptional population of *Armeria beirana*; **9** – Eucalyptus plantation; **10** and **11** – two relevés separated by a narrow path, and dominated by *Ilex aquifolium* and *Crataegus monogyna* respectively; **12** to **17** – heathland relevés spread over Terreno da Foia; **18** – rock outcrop, with *Armeria beirana*; **19** to **22** – further heathland relevés from three of the study areas.

Heathland and rock outcrops

The most characteristic landscape of the treeless summit of Foia consists of dense *Ulex minor* heathland with occasional outcrops of syenitic boulders. It is this vegetation mosaic that is described by the bringing together of the 12 relevés shown in Table 8. The differential species used to group these relevés are separated out in table 9.

Table 8 Heathland and rock outcrop (asterisked) plant communities.

Relevé number	7*	17	15	19	14	16	22	12	20	21	18*	13	Constancy in grouping
Orientation	SSW	SSW	NNE	NE	N	-	NW	WSW	NW	E	N	NW	
Slope (degrees)	15	20	25	10	15	0	15	10	15	30	30	15	
Altitude (m)	825	845	840	860	820	870	825	820	805	760	875	800	
Vegetation cover (%)	90	100	100	100	95	85	100	90	100	95	30	100	
Mean vegetation height (m)	.75	1.5	1	1	1	1.5	1.5	.75	1	1	.5	1	
Area (m ²)	100	100	100	100	100	100	100	100	100	100	100	100	
Number of species	16	14	13	17	21	12	13	10	15	16	20	12	

Characteristic species of the class <i>Calluno-Ulicetea</i>													
<i>Ulex minor</i> Roth	2	3	3	4	2	2	2	4	2	2	+	3	12
<i>Avenula marginata</i> (Lowe) <i>J. Houleb ssp. sulcata</i>	+	1	+	+	+	1	+	1				+	9
<i>Erica australis</i> L.	2	+	+		+	5	3	+	2				8
<i>Genista triacanthos</i> Brot.							r						1
Characteristic species of the order and the class <i>Ulicion-cistetalia</i> and <i>Cisto-Lavanduletea</i>													
<i>Thapsia villosa</i> L.	+	+		+	r					r	+	+	7
<i>Lavandula viridis</i> L'Hér	3	+						+		+			4
<i>Xolantha tuberaria</i> (L.) Gallego, Muñoz Garm. & C. Navarro (<i>Tuberaria lignosa</i> (Sweet) Samp.)		+				1	+						3
<i>Erica arborea</i> L.									+				1
Other characteristic species of the class <i>Cisto-Lavanduletea</i>													
<i>Cistus salvifolius</i> L.	+	4		2	5	2	3	3	5	4	+	2	11
<i>Agrostis castellana</i> Boiss. & Reuter		1	1	1	1	1		1	1	+		1	9
<i>Cistus crispus</i> L.	2	+	+	+		+	+				+		7
<i>Andryala integrifolia</i> L.			+		+	+			+		1		5
<i>Teesdalia nudicaulis</i> (L.) R.Br.	r				+								2
<i>Cistus ladanifer</i>			+										1
Characteristic species of the class <i>Quercu-Fagetea</i>													
<i>Pteridium aquilinum</i> (L.) Kuhn subsp. <i>aquilinum</i>	2		2	3	1	1	1	+	1	+	+	3	11
<i>Arenaria montana</i> L. subsp <i>montana</i>	+	+	+	+	+				1	+			7
<i>Rubus ulmifolius</i> Schott			+	+						+		3	4
<i>Lonicera periclymenum</i> L. subsp <i>hispanica</i> (Boiss. & Reuter) Nyman										+			1
Other accompanying species													
<i>Festuca ampla</i> Hack.	+	+	1	+	+	+	+	+	1	+	1		12
<i>Carlina corymbosa</i> L. subsp <i>corymbosa</i>	+	+	1	+	+	+	+				+		8
<i>Holcus lanatus</i> L.			+	1	+			+	1			+	6
<i>Dactylis glomerata</i> L. subsp <i>hispanica</i> (Roth) Nym.	+			+			+		+	+			5
<i>Tolpis barbata</i> (L.) Gaertner		+			+						1		3
<i>Clinopodium vulgare</i> L. subsp <i>arundanum</i> (Boiss.) Nyman				+				+				1	3
<i>Asphodelus ramosus</i> L.		+		+					+				3
<i>Echium rosulatum</i> Lange				+	+				+				3
<i>Daphne gnidium</i> L.							r		+				2
<i>Asplenium onopteris</i> L.										+	+		2
<i>Xolantha guttata</i> (L.) Raf. (<i>Tuberaria guttata</i> (L.) Fourr.)					+						1		2
<i>Digitalis purpurea</i> L. subsp <i>purpurea</i>											+	+	2
<i>Avena barbata</i> Pott									+			+	2
<i>Bromus diandrus</i> Roth				+								+	2
<i>Micropyrum tenellum</i> (L.) Link										+	2		2
<i>Sedum brevifolium</i> DC.										+	1		2
<i>Leontodon taraxacoides</i> (Vill.) Mérat subsp <i>longirostris</i> Finch & X.D.Sell	r				+								2

<i>Reseda media</i> Lag.	r									+			2
<i>Sanguisorba minor</i> Scop. subsp. <i>magnolii</i> (Spach) Coutinho						r	r						2
Other species (observed in one relevé): <i>Poa trivialis</i> L.(7), <i>Campanula lusitanica</i> L. (14), <i>Cardamine hirsuta</i> L. (14), <i>Jasione montana</i> L. (14), <i>Vulpia bromoides</i> (L.) Dumort. (14), <i>Anogramma leptophylla</i> (L.) Link (18), <i>Armeria beirana</i> Franco (18), <i>Briza maxima</i> L. (18), <i>Chamaemelum mixtum</i> (L.) All. (18), <i>Sedum forsterianum</i> Sm. (18), <i>Sedum hirsutum</i> All. subsp. <i>hirsutum</i> (18), <i>Brachypodium phoenicoides</i> (L.) R. & Sch. (21)													

Table 9 Differential species of heathland and rock outcrops.

Species	Constancy
<i>Agrostis castellana</i> Boiss. & Reuter	9
<i>Arenaria montana</i> L. subsp. <i>montana</i>	7
<i>Avenula marginata</i> (Lowe) J. Houlb ssp. <i>sulcata</i>	9
<i>Carlina corymbosa</i> L. subsp. <i>corymbosa</i>	8
<i>Cistus crispus</i> L.	7
<i>Dactylis glomerata</i> L. subsp. <i>hispanica</i> (Roth) Nym.	5
<i>Erica australis</i> L.	8
<i>Festuca ampla</i> Hack.	11
<i>Lavandula viridis</i> L'Hér	4

The heathland vegetation represents the *Cisto-Ulicetum minoris* Br.-Bl., X. Silva & Rozeira, 1964 association, described by Malato Beliz (1982) and others as the most Atlantic (least Mediterranean) of all the plant communities of Monchique. This is indicated by the presence of characteristic species of the classes *Calluno-Ulicetea* and *Querco-Fagetea*. The plant community corresponds to the Ibero-Atlantic *Erica-Ulex-Cistus* heaths sub-type of European Dry Heath (4030) as listed in the Habitats Directive (ECDGE, 1999). *Ulex minor*, whilst constant in all relevés, does not dominate the vegetation in all cases, with *Cistus salvifolius*, *Rubus ulmifolia* and Bracken *Pteridium aquilinum* all competing for that position. The relative abundance of these four species will vary according to microclimate, soil conditions and history of disturbance, but according to the data collected here does not define recognisably different sub-associations. *Rubus ulmifolius* grows strongly where there is an advanced succession to heathland occurring on abandoned terraces (visible on all four sites). *Pteridium aquilinum* is especially abundant on more recently disturbed (burnt or heavily grazed land). The only relevé from which it was absent was that on Terreno da Foia's south-facing slope (17). Other frequent shrubs and tall perennials include *Cistus crispus*, the lavender *Lavandula viridis*, and *Thapsia villosa*, the latter being another species that does well in disturbed areas.

Shrub cover is typically very high (85-100%), dense and impenetrable, and herbaceous species are therefore few in this dense vegetation, with the differential species (Table 9) including the common ones. In relevé 14 there were clearings in the shrub layer containing a number of herbaceous species of the class *Tuberarietea guttata*: *Campanula lusitanica*, *Tolpis barbata*, *Xolantha guttata* (*Tuberaria guttata*), *Vulpia bromoides*, and *Jasione montana*.

The rock outcrops provide a niche for a greater number and cover of often chasmophytic annuals and herbaceous perennials. These include (from relevés 7 and 18) *Asplenium onopteris* and *Anogramma leptophylla* (growing in sheltered crevices), *Micropyrum tenellum*, *Sedum brevifolium*, *S. forsterianum*, *S. hirsutum*, *Teesdalia nudicaulis*, and (at two localities only) *Armeria beirana*. Such species observed elsewhere include *Dianthus lusitanicus* and *Allium massaeselinum*. Whilst

some outcrops are well defined, with cliff faces, others represent the higher end of a continuum of rockiness, reflected also in associated species. These areas serve to increase the diversity of the flora of the otherwise shrubland covered mantle of the the Foia massif.

One should note at this point that the rupicole community of relevé 8 does not fit well into this heathland/rock outcrop grouping, containing just one differential species (*Festuca ampla*) as well as two such from the woodland grouping (*Crataegus monogyna* and *Teucrium scorodonia*). This relevé differed in being in a sheltered north-facing position, backed by a large rock face, and bordering an area of plantation and regenerating pre-woodland. It thus shared characteristics of both community types. The other species present in the relevé were:

<i>Cynosurus echinatus</i> L.	1	<i>Anogramma leptophylla</i> (L.) Link	+
<i>Sedum brevifolium</i> DC.	1	<i>Avena barbata</i> Pott	+
<i>Sedum fosterianum</i> Sm.	1	<i>Dianthus lusitanicus</i> Brot.	+
		<i>Digitalis purpurea</i> L. subsp	
<i>Armeria beirana</i> Franco	2	<i>purpurea</i>	+
		<i>Pteridium aquilinum</i> (L.) Kuhn	
<i>Briza maxima</i> L.	2	subsp. <i>aquilinum</i>	+
<i>Micropyrum tenellum</i> (L.) Link	2	<i>Rumex induratus</i> Boiss. & Reuter	+
		<i>Umbilicus rupestris</i> (Salisb.)	
<i>Allium massaessylum</i> Batt. & Trab.	+	Dandy	+
<i>Andryala integrifolia</i> L.	+		

Such communities represent the ‘Siliceous rocky slopes with chasmophytic vegetation (8220)’ habitat category listed under the Habitats Directive.

As regards the origin of the *Cisto-Ulicetum minoris* plant community, this is contested. The prevalent assumption is that the original climax cover was of semi-evergreen woodland (*Quercus suber* and *Q. canariensis*). Lopes (1841), writing of the land clearance initiated in 1826, described the Foia summit as previously being covered mostly by ‘sovereiros e azinheiras’ (Cork Oak and Holm Oak woodlands) which ‘nowadays have completely disappeared because of the fires’⁷. (In fact, these evergreen oaks are more fire tolerant than deciduous oaks, and will succeed the latter where fire is frequent.) In either case, and whilst the environment for vegetation regeneration post clearance in the early 19th century would have been somewhat altered, it is surprising that vestiges of such oak woodland are not to be found. (Holm Oak *Quercus rotundifolia* shrubs are present at the peak of Picota; the copse of *Quercus suber* trees at 740 m altitude in Vale Largo represent the highest oak trees within the areas of this current study.) Malato Beliz (1982) also takes issue with the theory that the *Cisto-Ulicetum minoris* association can be derived from the destruction of *Cisto-Ericetum australis*, a common adjoining community of more Mediterranean character, and which according to normal rules would give rise to a vegetation typical of dryer (not wetter) areas.

The published flora of Veiga (1869) does not shed light on this matter, given that area descriptions are not included, although his observations on *Castanea* are interesting (see footnote). In the current landscape there are a few Sweet Chestnuts scattered outside of the coppice woods and reaching higher altitudes. Other sparsely distributed small trees and large shrubs in the heathlands of Terreno da Foia are *Ilex aquifolium* and *Rhododendron ponticum* in the wetter areas, and most abundantly the grazing-tolerant Hawthorn *Crataegus monogyna*, (also present in the developing woodland matrix described in 3.3.2) perhaps pointing to their place in at least the understoreys and transitional phases of the original woodland cover at higher altitudes. Otherwise, one can perhaps speculate on whether *Quercus pyrenaica*, as a remnant of *Quercus pyrenaica-Erica australis-Cistus populifolius*

⁷ He also recommends reforestation with oaks, walnuts and pines – from the mid-slopes upwards to avoid impacting on the sweet chestnut woodlands.

shrubland at Picota (Simonson, 1995; Seng & Deil, 1999) had a place as a formerly more widespread canopy species of the Serra.

Woodland and forestry

The second grouping of relevés concerns a varied range of woodland and forestry types (including developing woodlands), ranging from tall Rhododendron shrublands with scattered trees at Vale Largo (relevés 2 and 3), semi-natural developing woodlands dominated by *Ilex aquifolium* and *Crataegus monogyna* at Terreno da Foia (10 and 11), to abandoned sweet chestnut coppice woodland at Cruz da Foia (5) and modern forestry plantations of *Pinus radiata* (6) and *Eucalyptus globulus* (9) at Cruz da Foia and Terreno da Foia respectively (Table 10). To these have been added species recorded on a transect through eucalyptus plantation at Cruz da Foia (ECF) and Terreno da Foia – the same block at relevé 9 (ETF). The differential spp. of these communities are given in Table 11.

Table 10 Woodland and forestry plant communities. ECF and ETF = transect through Eucalyptus at Cruz da Foia and Terreno da Foia respectively.

								Transects		Constancy in grouping
Relevé number	6	9	2	3	11	5	10			
Orientation	ESE	NNE	NW	NW	NNE	N	NNE			
Slope (degrees)	10	25	20	25	20	20	20			
Altitude (m)	795	775	740	765	740	755	740			
Vegetation cover – shrubs/herbs (%)	90	30	100	100	100	80	20			
Vegetation cover – high trees (%)	50	50	25	0	0	90	100			
Mean vegetation height (m) (*understorey)	1.0	1.0	3.0	3.0	5.0	0.5*	10			
Area (m²)	100	100	100	400	50	100	100			
Habitat	Pine	Euc	Rho	Rho	Woo	Cast	Woo			
Number of species	16	16	11	15	18	28	19	ECF	ETF	
Characteristic species of alliance, order and class <i>Quercion occidentale</i> , <i>Quercetea Robori-petraeae</i> and <i>Quercio-Fagetea</i>										
<i>Lonicera periclymenum</i> L. subsp <i>hispanica</i> (Boiss. & Reuter) Nyman	+	+	+	+	+	+	3			7
<i>Castanea sativa</i> Miller		+				5	r	o	C	3
<i>Teucrium scorodonia</i> L. subsp <i>scorodonia</i>						+	r			2
<i>Ilex aquifolium</i> L.				+			5			2
<i>Viola riviniana</i> Reichenb.						+				1
<i>Pteridium aquilinum</i> (L.) Kuhn subsp. <i>aquilinum</i>	5	2	3	3		+	+	c		6
Characteristic species of order and class <i>Prunetalia spinosa</i> and <i>Quercio-Fagetea</i>										
<i>Rubus ulmifolius</i> Schott	2	+	4	3	5	r	3	c		7
<i>Crataegus monogyna</i> Jacq.		r		+	4		2		C	4
Characteristic species of order and class <i>Populetalia albae</i> and <i>Quercio-Fagetea</i>										
<i>Rhododendron ponticum</i> L. subsp <i>baeticum</i> (Boiss. & Reuter) Hand.-Mazz.			2	3			2			3
<i>Campanula primulifolia</i> Brot.				1						2
<i>Arum italicum</i> Miller						+				1
<i>Salix atrocinerea</i> Brot.				+						1
Other characteristic species of class <i>Quercio-Fagetea</i>										
<i>Tamus communis</i> L.	+	+	3	2	+	+	+			7
<i>Brachypodium sylvaticum</i> (Huds.) X. Beauv.	+	1	+		+		+			5

<i>Aristolochia paucinervis</i> Pomel (<i>Aristolochia longa</i> L.)					+	+	+			3
<i>Polystichum setiferum</i> (Forsk.) Woytnar					+		+			2
<i>Frangula alnus</i> Miller				+				o		1
Characteristic species of alliance, order and class <i>Quercion fagineo-suberis</i>, <i>Quercetalia ilicis</i> and <i>Quercetea-ilicis</i>										
<i>Hedera helix</i> L. subsp. <i>canariensis</i> (Willd.) Coutinho			+	+	+					3
<i>Luzula forsteri</i> (Sm.) DC.						+	r			2
<i>Quercus suber</i> L.		r	3						c	2
<i>Ruscus aculeatus</i> L.					+		+			2
<i>Origanum virens</i> Hoffmans. & Link		+								1
<i>Paeonia broteri</i> Boiss. & Reuter						2				1
Other characteristic species of class <i>Quercetea-ilicis</i>										
<i>Rhamnus alaternus</i> L.		()			+		2		o	2
<i>Asplenium onopteris</i> L.		+			+		+			3
<i>Geranium purpureum</i> Vill.	+					+	+			3
Other accompanying species										
<i>Ulex minor</i> Roth		+	+	+	+			o		4
<i>Thapsia villosa</i> L.	r	+				+				3
<i>Digitalis purpurea</i> L. subsp. <i>purpurea</i>	+				+	r		o		3
<i>Cistus salvifolius</i> L.			+	+						2
<i>Holcus lanatus</i> L.	l				+			c	c	2
<i>Clinopodium vulgare</i> L. subsp. <i>arundanum</i> (Boiss.) Nyman	+					+			o	2
<i>Mentha suaveolens</i> Ehrh.					+		+			2
<i>Umbilicus rupestris</i> (Salisb.) Dandy					+	+			o	2
<i>Bryonia cretica</i> Jacq.						+	r	o		2
<i>Erica lusitanica</i> Rudolphi			+	+						2
<i>Eucalyptus globulus</i> Labill.	r	4						c	c	2
<i>Silene latifolia</i> Poir. et, Voy. (<i>Silene alba</i> (Miller) E.H.L.Krause subsp. <i>divaricata</i> (Reichenb.) Walters)					+	+				2
<i>Cirsium vulgare</i> (Savi) Tem	r							o		1
<i>Calamintha sylvatica</i>									o	
Species only observed in one relev�: <i>Cistus populifolius</i> L. subsp. <i>populifolius</i> (3), <i>Asphodelus ramosus</i> L. (5), <i>Bromus diandrus</i> Roth (5), <i>Cynosurus elegans</i> Desf. (5), <i>Galium aparine</i> L. (5), <i>Geranium lucidum</i> L. (5), <i>Heracleum sphondylium</i> L. subsp. <i>sphondylium</i> (5), <i>Hyacinthoides hispanica</i> (Miller) (5), <i>Ornithogalum pyrenaicum</i> L. (5), <i>Poa annua</i> L. (5), <i>Rumex acetosa</i> L. (5), <i>Briza minor</i> L. (6), <i>Campanula lusitanica</i> L. (6), <i>Cynosurus echinatus</i> L. (6), <i>Pinus radiata</i> D.Don (6), <i>Avenula marginata</i> (Lowe) J. Houlb ssp. <i>sulcata</i> (9), <i>Poa nemoralis</i> (9), <i>Mercurialis annua</i> L. (11)										

At lower altitudes in the Serra de Monchique, evergreen (*Quercus suber*) and semi-evergreen (with *Q. canariensis*) woodlands of *Sanguisorbo-Quercetum suberis* (including the *quercetosum canariensis* sub-association) dominate large areas. Characteristic species of this association are present in the wooded habitats of our study areas (*Quercus suber*, *Ruscus aculeatus*, *Luzula forsteri*), but there is a stronger Atlantic character here with a predominance of species of the class *Quercio-Fagetea*, which contain the main deciduous Portuguese woodland types common in the north of the country. Hence the honeysuckle *Lonicera periclymenum* replaces *Lonicera implexa*, and species common in the lower cork oak woodlands such as *Rubia peregrina*, *Arbutus unedo*, *Lavandula stoechas*, and *Cistus salvifolius* are missing. With the exception of the pine plantation at Cruz da Foia, with species such as *Thapsia villosa*, *Campanula lusitanica*, *Cirsium vulgare*, *Cynosurus echinatus*, these wooded habitats are of humid character, with a significant number of ombrophilous shrubs and trees present: *Castanea sativa*, *Crataegus monogyna*, *Paeonia broteroi*, Foxglove *Digitalis purpurea*, and *Ruscus aculeatus*. The presence of *Rhododendron ponticum* in three

relevés and other species of *Populetales albae* (for example *Campanula primulifolia* and *Salix atrocinerea* in relevé 3) suggests high soil moistures. Water features such as streams and springs are contained within or near these woodlands.

Table 11 Differential species of woodland and forest types.

Species	Constancy
<i>Brachypodium sylvaticum</i> (Huds.) X. Beauv.	5
<i>Crataegus monogyna</i> Jacq.	4
<i>Hedera helix</i> L. subsp <i>canariensis</i> (Willd.) Coutinho	3
<i>Lonicera periclymenum</i> L. subsp <i>hispanica</i> (Boiss. & Reuter) Nyman	7
<i>Rhododendron ponticum</i> L. subsp <i>baeticum</i> (Boiss. & Reuter) Hand.-Mazz.	3
<i>Tamus communis</i> L.	7
<i>Teucrium scorodonia</i> L. subsp <i>scorodonia</i>	2

Worth highlighting amongst these quadrats are the sweet chestnut coppice woodland of Cruz da Foia (5) and the semi-natural developing woodlands on the steep north facing slopes of Terreno da Foia (10 and 11). The chestnut woodland had by far the highest plant species diversity, which included healthy populations of a number of species characteristic of woods with undisturbed topsoils (*Aristolochia paucinervis*, *Teucrium scorodonia*, *Luzula forsteri*) and restricted occurrence (*Ornithogalum pyrenaicum* and *Viola riviniana*). Sweet Chestnut *Castanea sativa* is not native to the Algarve, but since 1820 has been grown over large areas of the Monchique mountains, according to Seng & Deil (1999) replacing deciduous woodland. Many areas were lost to blight *Endothria parasitica* at the beginning of the 20th century (Mabberley & Placito, 1993) and the wood at Cruz da Foia must be one of the highest remaining examples. The significant presence of *Castanea* pre-19th century cannot be discounted, as for example in the Carvalhal region where it appears strongly in the palynological record of the first century AD, indicating its spread by the Romans. Interestingly, Veiga (1869) differentiates between *Fagus castanea sativa* and *Fagus castanea sylvestris* in the Monchique Mountains, perhaps suggesting both plantation and naturalised stands at this period.

Castanea sativa is also relatively abundant, as both mature trees and seedlings, in the vicinity of the semi-natural developing woodland at Terreno da Foia. *Crataegus monogyna* reachest its tallest stature in this area, and its presence suggests an advanced stage towards a secondary woodland community. The vegetation at relevé 10 consisted of a 10 metre high canopy of *Ilex aquifolium* and Hawthorn *Crataegus monogyna*, into which reached lianes of *Rhamnus alaternus*. *Rhododendron* and *Rubus ulmifolia* are present in some abundance in the understorey, and *Lonicera periclymenum* is common. Other occasional species included *Polystichum setiferum*, *Aristolochia paucinervis*, *Brachypodium sylvaticum* and *Tamus communis*. There are signs here of persistent litter and good humus formation. The adjoining area in which relevé 11 was taken illustrates the varied woodland/shrubland character of this slope, with a denser thicket of *Rubus* under the *Crataegus* canopy, and the absence here of *Rhododendron* and *Ilex*.

The place of *Rhamnus alaternus* in these semi-natural woodland communities is worthy of note. This character species of the order and class *Pistacio-Rhamnetalia alaterni* and *Quercetea ilicis* reached the height of small trees, with a more luxuriant foliage than the shrubs to be found in the

coastal zone, where it is a common component of the Mediterranean sclerophyllous shrublands. Its occurrence and exceptional height here may suggest a different ecotype with a niche in less arid situations. By comparison, the author observed at Buçaco Forest near Coimbra to the north a woodland community where *Rhamnus alaternus* again reached the low canopy, also composed of *Quercus robur*, with an understorey of *Laurus nobilis*, *Viburnum tinus* and *Ruscus aculeatus*.

The eucalyptus plantation to the west of this area (relevé 9 and transect ETF) showed signs of recolonisation of the woodland's component species, with seedlings and saplings of *Crataegus* and *Rhamnus*, as well as of *Castanea* and *Quercus suber*.

One can perhaps consider the Rhododendron areas of Vale Largo (relevés 2 and 3) as a successional stage behind the Terreno da Foia woodlands, with a similar shrub and tree composition including *Rhododendron*, *Crataegus* and *Ilex*. *Rhamnus alaternus*, *Frangula alnus*, *Myrica faya* and *Salix* spp were also present in this association identified as *Osmundo-Campanuletum primulifoliae* (see 3.3.4 below). There is an abundance here of surface and soil water.

Wetlands

Table 12 contains data for relevés typical of two of the main types of water feature present and common in the study areas: streams and springs. Such features are important for enhancing the biodiversity of the Serra as a whole, with a significant number of hydrophytic species of restricted range in the Algarve. Two of these are the Royal Fern *Osmunda regalis* and bellflower *Campanula primulifolia*, which are characteristic species of the association *Osmundo-campanuletum primulifoliae*, defined at Monchique by Malato-Beliz (1982). This association, of sub-Atlantic character, was used to describe stands of *Rhododendron ponticum*, with *Myrica faya*, in moist soil conditions (eg along water-courses in sheltered valleys) - these are the 'Riparian formations on intermittent Mediterranean water courses with *Rhododendron ponticum*, *Salix* and others' (92B0) listed under the EC Habitats Directive. Such was the context for relevé 4 (a small cutting), with the *Rhododendron* and *Myrica* both present in the vicinity.

Also present in this relevé, and along a ditch leading from it, was *Wahlenbergia hederacea*, a delicate annual associated in other areas of saturated, peaty soils with the insectiferous *Pinguicula lusitanica* L., a species not discovered in this current study. These latter communities are described by Malato-Beliz (1982) from five relevés.

The near vertical sides of cuttings, gulleys and artificial tanks associated with springs, water mines and streams (as well as the crevices of north-facing or shaded cliff faces and terrace walls) are classic habitats for a range of fern species recorded in this study. However, many of the springs and water courses have been canalised and engineered, reducing the habitat available for such species. It is interesting (though not conclusive) to note that of 16 ferns listed by Veiga (1869), only 12 are recorded by Malato-Beliz and Simonson (1994) – could this represent a genuine loss of species associated with a diminishing habitat?

Open and ruderal habitats

Whether by disturbance caused by fire or over-grazing, the clearing of tracks and their subsequent trampling, or simply the stoney nature of soil, the *Ulex minor* matos gives way in places to open habitats dominated by communities of therophytes and some geophytes of the class *Tuberarietea*. These are mostly Mediterranean (rather than (sub)Atlantic) species familiar within the coastal zone of the Algarve, common among them being *Linum bienne*, *Malva hispanica*, *Ornithopus compressus*, *Plantago coronopus*, *Sherardia arvensis*, *Silene gallica*, *Trifolium campestre*, *T. glomeratum*, and *Xolantha guttata*.

Table 12 Wetland plant communities.

Relevé number	1	4
Orientation	WNW	NW
Slope (degrees)	10	25
Altitude (m)	680	760
Vegetation cover (%)	80	50
Mean vegetation height (m)	1	.5
Area (m ²)	50	1
Number of species	29	10
Habitat	Stream	Spring
Characteristic species of the association <i>Osmundo-campanuletum primulifoliae</i>		
<i>Campanula primulifolia</i> Brot.	1	2
<i>Osmunda regalis</i> L.		+
Other species present in both relevés		
<i>Juncus effusus</i> L.	2	+
<i>Oenanthe crocata</i> L.	2	3
<i>Holcus lanatus</i> L.	3	+
<i>Myosotis secunda</i> A. Murray	+	+
Relatively common species		
<i>Apium nodiflorum</i> (L.) Lag.	2	
<i>Cyperus rotundus</i> L.	2	
<i>Mentha suaveolens</i> Ehrh.	2	
<i>Rumex induratus</i> Boiss. & Reuter	2	
<i>Echium rosulatum</i> Lange	2	
<i>Epilobium obscurum</i> Schreber	1	
<i>Lotus uliginosus</i> Schkuhr	1	
<i>Wahlenbergia hederacea</i> (L.) Reichenb.		1
Occasional species		
<i>Andryala integrifolia</i> L.	+	
<i>Briza maxima</i> L.	+	
<i>Pteridium aquilinum</i> (L.) Kuhn subsp. <i>aquilinum</i>	+	
<i>Campanula lusitanica</i> L.	+	
<i>Chamaemelum mixtum</i> (L.) All.	+	
<i>Digitalis purpurea</i> L. subsp. <i>purpurea</i>	+	
<i>Juncus articulatus</i> L.	+	
<i>Malva hispanica</i> L.	+	
<i>Montia fontana</i> L. subsp. <i>amporitana</i> Sennen	+	
<i>Poa annua</i> L.	+	
<i>Poa trivialis</i> L.	+	
<i>Trifolium repens</i> L. var. <i>Repens</i>	+	
<i>Trifolium subterraneum</i> L.	+	
<i>Blechnum spicant</i> (L.) Roth		+
<i>Carex binervis</i> Sm.		+
Species recorded as rare in the relevés: <i>Teucrium scorodonia</i> L. subsp. <i>scorodonia</i> (1), <i>Brachypodium sylvaticum</i> (Huds.) X. Beauv. (1), <i>Prunella vulgaris</i> L. (1), <i>Senecio aquaticus</i> Hill subsp. <i>barbareifolius</i> (Wimmer & Grab.) Walters (1), <i>Eleocharis multicaulis</i> Sm. (4)		

Also frequent within these areas, and sometimes on recently cultivated or grazed terraces with a more closed grassy vegetation are:

<i>Anagallis arvensis</i>	<i>Bromus hordeaceus</i>
<i>Carex divulsa</i>	<i>Chrysanthemum segetum</i>
<i>Crepis capillaris</i>	<i>Crepis vesicaria</i>
<i>Cuscuta epithymum</i>	<i>Echium plantagineum</i>
<i>Galactites tomentosa</i>	<i>Geranium rotundifolium</i>
<i>Hypericum perforatum</i>	<i>Hypochoeris glabra</i>
<i>Hypochoeris radicata</i>	<i>Lapsana communis</i> subsp. <i>communis</i>
<i>Lathyrus angulatus</i>	<i>Linum trigynum</i> subsp. <i>trigynum</i>
<i>Logfia gallica</i>	<i>Lotus parviflorus</i>
<i>Lupinus luteus</i>	<i>Ornithopus compressus</i>
<i>Ornithopus pinnatus</i>	<i>Paronychia argentea</i>
<i>Raphanus raphanistrum</i>	<i>Rhynchosinapsis pseuderucastrum</i> subsp. <i>pseuderucastrum</i>
<i>Sonchus asper</i>	<i>Spergularia purpurea</i>
<i>Taraxacum</i> sp	<i>Trifolium angustifolium</i>
<i>Trifolium ligusticum</i>	<i>Trifolium pratense</i>
<i>Trifolium repens</i> var. <i>repens</i>	<i>Trifolium resupinatum</i>
<i>Trifolium stellatum</i>	<i>Trifolium subterraneum</i>
<i>Vulpia bromoides</i>	<i>Xolantha tuberaria</i>

Where grazing leads to higher nitrogen levels in the soil, the thistle species *Cynara algarbiensis*, *Carduus tenuiflorus* and *Cirsium vulgare* are often to be seen (Malato-Beliz, 1982). A small number of thermophilous species are restricted to where roadside situations confer particularly warm microclimates, these include *Dittrichia viscosa* subsp. *viscosa*, *Psoralea bituminosa*, and *Scabiosa atropurpurea*.

Conclusions and management recommendations

There follows some general remarks and suggested approaches for three categories of land contained within the Bio-Parque study areas. Site-specific recommendations are contained within the full report submitted as part of the Bio-Parque feasibility study (Simonson, 2003).

Particularly sensitive and/or rich plant and wildlife areas and habitats features

These are generally small areas scattered across the landscape. These include sites of species with restricted range (for example of *Armeria beirana*, *Centaurea crocata* and *Wahlenbergia hederacea*) as well as features such as springs, old terrace walls, and larger vegetation areas including Rhododendron copses, Chestnut coppice woodland, and developing semi-natural woodland. Individual trees, for example older specimens of *Ilex aquifolium* and *Quercus suber*, are also to be included here. For these areas and features, a policy of non-intervention is preferred, with protective measures against disturbance (over-grazing, trampling, fire) and succession sometimes necessary. The creation of footpaths, camping areas and other such developments associated with increasing access should be avoided.

Extensive semi-natural vegetation of generally high landscape and nature conservation value

This category covers the majority of the land area, and comprise the *Ulex minor* heathland vegetation with rocky outcrops, as well as old terrace-lands. Less stringent protection measures and controls are generally needed, though there should be a presumption against intervention, unless to manage successional processes or diversify the habitat structure. Grazing levels should be

controlled and their effects monitored. A future fire prevention strategy, employing fire-breaks and possibly limited prescribed burning, should be developed.

Highly modified or degraded vegetation areas

These comprise over-grazed or otherwise disturbed heathland areas, and modern plantations. Restorative techniques should generally be employed in these areas, removing grazing and trampling pressures, stands of eucalyptus, and possibly involving the planting of native tree species.

As a general aim, through Bio-Parque the opportunity exists to create a more diverse landscape with an increased range of habitats for plants and animals. For example, the protection of old trees is important for bryophyte species and late successional epiphytic lichens, the retention and re-creation of water features for amphibians, insects and their specialist flora, open terrace-lands for the nectar sources and food plants of butterflies, and bare ground and stone surfaces for reptiles. When habitat conservation and restoration along these lines can also be linked to revitalising local cottage industries and traditional land use management, the benefits for the local economy and tourism will be plain to see.

Post-script: Management and restoration post-fire

On Friday 19 September a visit to the study areas confirmed that the majority of the land area studied had been burnt in the recent spate of forest fires:

- At Vale Largo, approximately 75% of the area had been affected, including severe burns of the *Rhododendron* patches.
- At Cruz da Foia, the sweet chestnut wood in the valley had escaped, but otherwise the area had been burnt to varying degrees of severity. The rock outcrops with *Armeria beirana* had been affected by supposedly light burns of the herbaceous layer.
- At Terreno da Foia, the burn appeared to be almost 100%, and the developing woodland areas had been completely decimated, except possibly for a couple of trees at the lower edge. The fire did not appear to have reached the canopy of the eucalyptus areas.
- We did not see the Barranco da Garganta site itself, though suppose that it did not escape the fire that had burnt the Eucalyptus plantation above it.
- In addition, the *Quercus canariensis* woodland at Vale de Peneda Negra had been severely affected by shrub if not canopy fires, except for a remnant area that had apparently been helped by a clearing made for a future picnic site. Recovery of some and possibly most of the mature trees is considered possible, though this needs to be carefully monitored.
- The gallery woodland of Joana Mendes, though surrounded by burnt land, was less affected.

This development obviously represents a major regional disaster, including a set-back for the Bio-Parque project. Whilst many common plants of the semi-natural vegetation are fire-adapted and will come back relatively quickly through re-sprouting or seeding, important concerns remain. These are listed briefly here, with an initial commentary on actions recommended.

1. Local extinction of plant and animal species, given the unprecedented scale of the burn. Recolonisation will take longer, when needing to take place across large distances. A monitoring programme (see below) will help detect significant losses and help identify any active reintroduction measures required.
2. Soil erosion on the steep slopes denuded of vegetation is inevitable, though the degree of erosion will depend on the nature of the first autumn rains. Any rapid soil conservation measures (terracing and creation of artificial gulleys) will limit the effects. Where soil is lost, it will be difficult to recover some of the rarer and more valued vegetation types in the short term.

3. Soil conditions (eg organic matter content) and regeneration of the vegetation will be impeded if there is heavy grazing, or inappropriate intervention by heavy vehicles and machinery.
4. Some species may recover slowly, and be deleteriously affected by the rampant regrowth of pyrophytes, of which *Pteridium aquilinum* is an example. Bracken control should be trialled in places.
5. Amongst the species that will recover quickly is *Eucalyptus globulus*. Plantation removal will have to proceed as originally planned.
6. The developing woodland areas, on the other hand, will need considerable time to recover, and active reforestation schemes should be considered now in areas where natural regrowth was previously recommended.
7. Degradation of vegetation is typical if the return rate of fire is too high. Preventative measure against future fires have become all the more important after this year's events.

On a positive note, the current disaster highlights the unsustainability of plantation monocultures, and provides the opportunity to promote the restoration of native vegetation types and associated profitable land uses.

Also, the current study has been timely in documenting the situation pre-fire, providing a baseline of information on plant communities and richness which can be monitored against in the future. It is recommended that a programme of regular monitoring within each of the vegetation types included in this study is instigated over the next years to chart developments in both areas undergoing active restoration, and areas left to natural recovery. One possibility is to relocate and monitor the relevés used in this study. Important lessons can be learned not just for future management and restoration initiatives in the Serra de Monchique but other areas within Portugal that have been affected by the 2003 fires.

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ANNEX 1

Habitats and species listed in the Habitats Directive for the Serra de Monchique

Code Annex 1 habitats

- 3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitriche-Batrachion* vegetation
- 3280 Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*
- 4030 European dry heaths
- 5210 Arborescent matorral with *Juniperus* spp.
- 5330 Thermo-Mediterranean and pre-desert scrub
- 6310 Dehesas with evergreen *Quercus* spp.
- 6420 Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*
- 8220 Siliceous rocky slopes with chasmophytic vegetation
- 9240 *Quercus faginea* and *Quercus canariensis* Iberian woods
- 9260 *Castanea sativa* woods
- 92A0 *Salix alba* and *Populus alba* galleries
- 92B0 Riparian formations on intermittent Mediterranean water courses with *Rhododendron ponticum*, *Salix* and others
- 92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)
- 9330 *Quercus suber* forests
- 9340 *Quercus ilex* and *Quercus rotundifolia* forests

Annex 2 species

- 1065 *Euphydrias aurinia*
- 1078 *Callimorpha quadripunctaria**
- 1128 *Chondrostoma lusitanicum*
- 1220 *Emys orbicularis*
- 1221 *Mauremys leprosa*
- 1259 *Lacerta schreiberi*
- 1338 *Microtus cabrerai*
- 1355 *Lutra lutra*
- 1362 *Lynx pardinus**
- 1434 *Salix salvifolia* ssp. *australis*
- 1785 *Centaurea vicentina*

* Priority species

ANNEX 2

Vascular plant species observed in the study areas

'1982' = Malato Belix (1982), '1994' = Simonson (1994)

SPECIES	Sites			Habitats							Previous studies		
	Va le La rgo 1	Cr uz da Foi a 2	Te rre no da Foi a 3	B. da Ga rga nta 4	Tr ac ksi /cle arings 1	Scr ubl an d 2	Ro cks 3	We t are as 4	W oo d- lan d 5	Rh od od en dr on 6	Eu cal ypt 7	1982 '82	1994 '94
Osmundaceae													
<i>Osmunda regalis</i> L.	X	X						X				X	X
Hemionitidaceae													
<i>Anogramma leptophylla</i> (L.) Link	X	X	X				X	X				X	
Hypolepidaceae													
<i>Pteridium aquilinum</i> (L.) Kuhn subsp <i>aquilinum</i>	X	X	X	X		X	X	X	X	X		X	X
Aspleniaceae													
<i>Asplenium billotii</i> F W Schultz			X				X					X	X
<i>Asplenium onopteris</i> L.	X	X	X	X		X	X	X	X	X		X	X
Athyriaceae													
<i>Athyrium filix-femina</i> (L.) Roth	X	X						X				X	X
<i>Cystopteris fragilis</i> (L.) Bernh.			X						X			X	
Aspidiaceae													
<i>Dryopteris affinis</i> (Lowe) Frase-Jenk			X					X					
<i>Polystichum setiferum</i> (Forsk) Woynar	X	X	X					X	X			X	X
Blechnaceae													
<i>Blechnum spicant</i> (L.) Roth	X							X				X	X
Polypodiaceae													
<i>Polypodium cambricum</i> L.	X		X				X			X		X	
Pinaceae													
<i>Pinus pinaster</i> Aiton				X								X	X
<i>Pinus radiata</i> D.Don		X							X				X
Cupressaceae													
<i>Cupressus lusitanica</i> Mill.		X				X							
Aristolochiaceae													
<i>Aristolochia paucinervis</i> Pomel (<i>Aristolochia longa</i> L.)		X	X	X					X				X
Salicaceae													
<i>Salix atrocinerea</i> Brot.	X	X								X		X	X
<i>Salix</i> x <i>rubens</i> Schrank		X						X					
Myricaceae													
<i>Myrica faya</i> Aiton	X											X	X
Fagaceae													
<i>Castanea sativa</i> Miller		X	X	X					X			X	X
<i>Quercus suber</i> L.	X	X	X	X		X			X	X		X	X
Urticaceae													
<i>Urtica dioica</i> L.		X		X				X	X			X	
<i>Urtica dubia</i> Forskal		X							X			X	X

	Sites				Habitats							Studies	
	1	2	3	4	1	2	3	4	5	6	7	'82	'94
Portulacaceae													
<i>Montia fontana</i> L. subsp. <i>amporitana</i> Sennen	X							X				X	
Caryophyllaceae													
<i>Arenaria montana</i> L. subsp. <i>montana</i>	X	X	X	X	X	X			X	X		X	X
<i>Cerastium glomeratum</i> Thuill.		X			X				X			X	X
<i>Dianthus lusitanus</i> Brot.		X					X					X	X
<i>Paronychia argentea</i> Lam.	X				X								
<i>Petrorhagia nanteuillii</i> (Burnat) P.W.Ball & Heywood	X						X					X	X
<i>Silene gallica</i> L.	X	X	X	X	X							X	X
<i>Silene laeta</i> (Aiton) Godron		X					X					X	
<i>Silene latifolia</i> Poiret, Voy. (<i>Silene alba</i> (Miller))													
E.H.L.Krause subsp. <i>divaricata</i> (Reichenb.) Walters	X	X	X	X	X			X	X			X	X
<i>Silene scabriflora</i> Brot.			X									X	X
<i>Spergularia purpurea</i> (Pers.) G. Don fil.	X	X	X		X							X	X
<i>Stellaria media</i> (L.) Vill. subsp. <i>media</i>		X		X				X	X			X	X
Polygonaceae													
<i>Chenopodium album</i> L.				X					X				
<i>Polygonum aviculare</i> L.		X			X								
<i>Rumex acetosa</i> L.		X							X				X
<i>Rumex angiocarpus</i> Murb.	X	X		X					X	X			X
<i>Rumex induratus</i> Boiss. & Reuter	X	X	X	X	X	X	X	X	X				X
<i>Rumex obtusifolius</i> L. subsp. <i>obtusifolius</i>		X							X				X
<i>Rumex pulcher</i> L. (subsp. <i>divaricatus</i>)	X	X							X				X
Ranunculaceae													
<i>Ranunculus bulbosus</i> L. var. <i>adscendens</i> (Brot.) X. Silva	X	X	X	X	X			X				X	X
Paeoniaceae													
<i>Paeonia broteri</i> Boiss. & Reuter	X	X	X			X	X		X	X		X	X
Papaveraceae													
<i>Fumaria bastardii</i> Boreau			X					X				X	X
Moraceae													
<i>Ficus carica</i> L.				X				X					X
Cruciferae													
<i>Cardamine hirsuta</i> L.		X	X			X			X			X	X
<i>Raphanus raphanistrum</i> L.				X	X							X	X
<i>Rhynchosinapsis pseuderrucastrum</i> (Brot.) Franco subsp. <i>pseuderrucastrum</i>		X	X		X							X	X
<i>Teesdalia nudicaulis</i> (L.) R.Br.	X	X	X		X	X	X						X
Resedaceae													
<i>Resea phyteuma</i> L.			X	X	X								
<i>Reseda media</i> Lag.	X	X	X	X	X	X	X	X	X			X	X
Crassulaceae													
<i>Sedum brevifolium</i> DC.	X	X	X	X	X	X	X			X		X	X
<i>Sedum fosterianum</i> Sm.	X	X	X		X		X			X		X	X

	Sites				Habitats							Studies	
	1	2	3	4	1	2	3	4	5	6	7	'82	'94
<i>Sedum hirsutum</i> All. subsp <i>hirsutum</i>	X	X	X	X			X			X		X	
<i>Umbilicus rupestris</i> (Salisb.) Dandy	X	X	X	X	X		X	X	X	X		X	X
Rosaceae													
<i>Crataegus monogyna</i> Jacq. subsp <i>brevispina</i>	X	X	X	X		X	X		X	X		X	X
<i>Fragaria vesca</i> L.		X	X						X			X	
<i>Prunus avium</i> L.				X	X								
<i>Rubus ulmifolius</i> Schott	X	X	X	X		X			X	X		X	X
<i>Sanguisorba minor</i> Scop. subsp <i>magnolii</i> (Spach) Coutinho	X		X			X						X	X
Leguminosae													
<i>Adenocarpus complicatus</i> (L.) Gay			X					X				X	X
<i>Cytisus striatus</i> (Hill) Rothm.	X											X	
<i>Genista triacanthos</i> Brot.	X					X						X	X
<i>Lathyrus angulatus</i> L.	X				X							X	X
<i>Lotus parviflorus</i> Desf			X	X	X								
<i>Lotus subbiflorus</i> Lag. subsp <i>subbiflorus</i>		X	X						X			X	
<i>Lotus uliginosus</i> Schkuhr	X	X			X			X				X	X
<i>Lupinus luteus</i> L.		X	X		X								
<i>Ornithopus compressus</i> L.	X	X		X	X			X	X			X	X
<i>Ornithopus pinnatus</i> (Miller) Druce	X			X	X							X	X
<i>Psoralea bituminosa</i> L.	X		X		X							X	X
<i>Trifolium angustifolium</i> L.	X	X	X		X			X				X	X
<i>Trifolium campestre</i> Schreber	X	X	X	X	X							X	X
<i>Trifolium glomeratum</i> L.	X	X	X	X	X			X				X	X
<i>Trifolium ligusticum</i> Loisel.	X	X			X							X	
<i>Trifolium pratense</i> L.		X			X							X	X
<i>Trifolium repens</i> L. var. <i>repens</i>	X	X	X	X	X			X				X	X
<i>Trifolium resupinatum</i>		X			X								
<i>Trifolium stellatum</i> L.	X				X								
<i>Trifolium subterraneum</i> L.	X	X		X	X			X				X	X
<i>Ulex minor</i> Roth	X	X	X	X		X	X		X	X		X	X
<i>Vicia disperma</i> DC.	X	X			X					X		X	X
<i>Vicia sativa</i> L.		X			X								
<i>Vicia sativa</i> L. subsp <i>macrocarpa</i> (Moris) Arcang.			X	X	X	X						X	X
<i>Vicia sativa</i> L. subsp <i>sativa</i>	X				X								
Oxalidaceae													
<i>Oxalis pes-caprae</i> L.				X				X				X	X
Geraniaceae													
<i>Geranium lucidum</i> L.		X	X		X		X	X	X			X	X
<i>Geranium molle</i> L.	X	X	X		X			X	X				X
<i>Geranium purpureum</i> Vill.	X	X	X	X		X			X			X	X
<i>Geranium rotundifolium</i> L.				X	X							X	
Linaceae													
<i>Linum bienne</i> Miller	X	X		X	X			X				X	X
<i>Linum trigynum</i> L. subsp <i>trigynum</i>			X		X							X	X

	Sites				Habitats							Studies	
	1	2	3	4	1	2	3	4	5	6	7	'82	'94
Euphorbiaceae													
<i>Mercurialis annua</i> L.	X	X	X	X	X		X	X	X			X	X
Polygalaceae													
<i>Polygala vulgaris</i> L.			X		X	X						X	X
Aquifoliaceae													
<i>Ilex aquifolium</i> L.	X	X	X						X	X		X	X
Rhamnaceae													
<i>Frangula alnus</i> Miller	X	X							X	X		X	X
<i>Rhamnus alaternus</i> L.	X		X						X			X	X
Malvaceae													
<i>Lavatera olbia</i> L.	X									X		X	X
<i>Malva hispanica</i> L.	X	X	X	X	X			X	X	X		X	X
Thymelaeaceae													
<i>Daphne gnidium</i> L.	X	X				X				X		X	X
Guttiferae													
<i>Hypericum perforatum</i> L.			X		X							X	X
<i>Hypericum undulatum</i> Schousb. ex Willd.		X						X				X	
Violaceae													
<i>Viola riviniana</i> Reichenb.		X		X					X			X	X
Cistaceae													
<i>Cistus crispus</i> L.	X	X	X		X	X	X					X	X
<i>Cistus ladanifer</i> L.		X	X			X						X	X
<i>Cistus populifolius</i> L. subsp <i>populifolius</i>	X									X		X	X
<i>Cistus salviifolius</i> L.	X	X	X	X	X	X	X			X		X	X
<i>Xolantha guttata</i> (L.) Raf. (<i>Tuberaria guttata</i> (L.) Fourr.)	X	X	X	X	X	X	X	X				X	X
<i>Xolantha tuberaria</i> (L.) Gallego, Muñoz Garm. & C. Navarro (<i>Tuberaria lignosa</i> (Sweet) Samp.)	X	X	X		X	X						X	X
Curcubitaceae													
<i>Bryonia cretica</i> Jacq.		X	X						X			X	X
Lythraceae													
<i>Lythrum junceum</i> Banks & Solander		X		X				X				X	X
Myrtaceae													
<i>Eucalyptus globulus</i> Labill.		X	X			X			X				X
Onagraceae													
<i>Epilobium obscurum</i> Schreber	X	X						X				X	X
Rafflesiaceae													
<i>Cytinus hypocistis</i> (L.) L. subsp <i>hypocistis</i>	X		X			X							X
Araliaceae													
<i>Hedera helix</i> L. subsp <i>canariensis</i> (Willd.) Coutinho	X		X	X					X	X		X	X
Umbelliferae													
<i>Apium nodiflorum</i> (L.) Lag.	X							X				X	X
<i>Daucus carota</i> L.		X		X	X				X			X	X
<i>Heracleum sphondylium</i> L. subsp <i>sphondylium</i>		X							X			X	X

	Sites				Habitats							Studies	
	1	2	3	4	1	2	3	4	5	6	7	'82	'94
<i>Oenanthe crocata</i> L.	X	X		X				X				X	X
<i>Thapsia villosa</i> L.	X	X	X	X	X	X	X		X	X		X	X
<i>Torilis arvensis</i> (Hudson) Link subsp <i>neglecta</i> (Schultes) Tell.	X	X		X	X			X				X	
<i>Torilis arvensis</i> (Hudson) Link subsp <i>purpurea</i> (Tem.) Hayek	X	X	X		X			X		X		X	X
Ericaceae													
<i>Arbutus unedo</i> L.	X	X				X						X	X
<i>Erica arborea</i> L.	X					X						X	X
<i>Erica australis</i> L.	X	X	X			X						X	X
<i>Erica lusitanica</i> Rudolphi	X		X			X				X			X
<i>Rhododendron ponticum</i> L. subsp <i>baeticum</i> (Boiss. & Reuter) Hand.-Mazz.	X		X						X	X		X	X
Primulaceae													
<i>Anagallis arvensis</i> L.				X	X			X				X	X
Plumbaginaceae													
<i>Armeria beirana</i> Franco subsp <i>monchiquensis</i> (Bernis) Franco		X				X	X						
Gentianaceae													
<i>Centaurium maritimum</i> (L.) Fritsch			X			X						X	
Rubiaceae													
<i>Galium aparine</i> L.		X							X			X	X
<i>Sherardia arvensis</i> L.		X	X	X	X							X	X
Convolvulaceae													
<i>Cuscuta epithymum</i> (L.) L.			X		X							X	X
Boraginaceae													
<i>Anchusa granatensis</i> Boiss.		X										X	X
<i>Echium plantagineum</i> L.	X		X	X	X							X	X
<i>Echium rosulatum</i> Lange	X	X	X	X	X	X		X	X			X	X
<i>Myosotis secunda</i> A. Murray	X	X						X				X	X
Labiatae													
<i>Calamintha sylvatica</i> Bromf. subsp <i>adscendens</i> (Jordan) X.W.Ball			X	X				X	X			X	X
<i>Clinopodium vulgare</i> L. subsp <i>arundanum</i> (Boiss.) Nyman	X	X	X	X	X	X			X			X	X
<i>Lavandula viridis</i> L'Hér		X	X	X		X	X					X	X
<i>Mentha suaveolens</i> Ehrh.				X				X				X	X
<i>Origanum virens</i> Hoffmans. & Link			X	X					X			X	X
<i>Prunella vulgaris</i> L.	X	X	X		X			X				X	X
<i>Teucrium scorodonia</i> L. subsp <i>scorodonia</i>	X	X	X	X			X	X	X	X		X	X
Scrophulariaceae													
<i>Digitalis purpurea</i> L. subsp <i>purpurea</i>	X	X	X	X	X	X	X	X	X	X		X	X
<i>Scrophularia scorodonia</i> L.	X									X		X	X
<i>Veronica anagallis-aquatica</i> L.		X						X				X	
<i>Veronica arvensis</i> L.		X			X							X	
Plantaginaceae													
<i>Plantago bellardii</i> All.		X					X						X

	Sites				Habitats							Studies	
	1	2	3	4	1	2	3	4	5	6	7	'82	'94
<i>Plantago coronopus</i> L. subsp <i>coronopus</i>	X	X	X	X	X							X	X
<i>Plantago lanceolata</i> L.	X	X	X	X	X				X			X	X
<i>Plantago major</i> L.			X		X							X	
Caprifoliaceae													
<i>Lonicera periclymenum</i> L. subsp <i>hispanica</i> (Boiss. & Reuter) Nyman	X	X	X	X		X			X	X		X	X
<i>Sambucus nigra</i> L.		X		X				X	X			X	X
Dipsacaceae													
<i>Scabiosa atropurpurea</i> L.	X				X							X	X
Campanulaceae													
<i>Campanula lusitanica</i> L.	X	X	X	X	X	X		X	X	X		X	X
<i>Campanula primulifolia</i> Brot.	X	X						X		X		X	X
<i>Campanula rapunculus</i> L.	X	X	X		X	X				X		X	X
<i>Jasione montana</i> L.		X	X		X	X						X	X
<i>Wahlenbergia hederacea</i> (L.) Reichenb.	X							X				X	
Compositae													
<i>Andryala integrifolia</i> L.	X	X	X	X	X	X	X	X	X	X		X	X
<i>Carduus tenuiflorus</i> Curtis	X	X	X	X	X		X					X	X
<i>Carlina corymbosa</i> L. subsp <i>corymbosa</i>			X			X						X	
<i>Centaurea crocata</i> Franco	X				X							X	
<i>Chamaemelum mixtum</i> (L.) All.	X	X	X	X	X		X	X	X			X	X
<i>Chrysanthemum segetum</i> L.		X			X								X
<i>Cirsium vulgare</i> (Savi) Tem.		X	X		X	X	X					X	X
<i>Crepis capillaris</i> (L.) Wallr.	X	X	X		X							X	
<i>Crepis vesicaria</i> L.	X				X								X
<i>Cynara algarbiensis</i> Cosson ex Mariz		X			X							X	X
<i>Dittrichia viscosa</i> (L.) W.Greuter subsp <i>viscosa</i>	X				X							X	X
<i>Galactites tomentosa</i> Moench	X	X	X	X	X							X	X
<i>Helichrysum stoechas</i> (L.) Moench subsp <i>stoechas</i>	X	X	X		X	X		X				X	X
<i>Hypochoeris glabra</i> L.	X		X		X							X	X
<i>Hypochoeris radicata</i> L.	X	X	X		X							X	X
<i>Lapsana communis</i> L. subsp <i>communis</i>	X	X			X							X	
<i>Leontodon taraxacoides</i> (Vill.) Mérat subsp <i>longirostris</i> Finch & P.D.Sell	X	X	X	X	X	X	X	X		X		X	X
<i>Logfia gallica</i> (L.) Cosson & Germ.	X	X	X		X		X	X				X	X
<i>Senecio aquaticus</i> Hill subsp <i>barbareifolius</i> (Wimmer & Grab.) Walters	X							X				X	
<i>Senecio sylvaticus</i> L.				X		X							
<i>Sonchus asper</i> (L.) Hill		X			X								
<i>Sonchus oleraceus</i> L.		X			X	X			X			X	X
<i>Taraxacum</i> sp		X			X								
<i>Tolpis barbata</i> (L.) Gaertner	X	X	X	X	X	X	X	X	X			X	X

	Sites				Habitats							Studies	
	1	2	3	4	1	2	3	4	5	6	7	'82	'94
<i>Urospermum picroides</i> (L.) Scop. ex F.W.Schmidt		X			X							X	
Gramineae													
<i>Agrostis castellana</i> Boiss. & Reuter	X	X	X	X		X						X	
<i>Avena barbata</i> Pott	X	X	X	X	X	X	X		X			X	X
<i>Avenula marginata</i> (Lowe) J. Houlb subsp <i>sulcata</i>	X	X	X		X	X	X		X				X
<i>Brachypodium phoenicoides</i> (L.) R. & Sch.			X	X	X							X	
<i>Brachypodium sylvaticum</i> (Huds.) P. Beauv.	X	X	X			X		X	X	X		X	X
<i>Briza maxima</i> L.	X	X	X	X	X	X	X	X	X			X	X
<i>Briza minor</i> L.	X	X			X	X		X	X	X		X	X
<i>Bromus diandrus</i> Roth	X	X	X	X	X	X			X				X
<i>Bromus hordeaceus</i> L.	X	X	X	X	X	X		X	X				X
<i>Cynosurus echinatus</i> L.	X	X	X	X	X	X	X		X			X	X
<i>Cynosurus elegans</i> Desf.		X							X			X	X
<i>Dactylis glomerata</i> L. subsp <i>hispanica</i> (Roth) Nym.	X	X	X	X	X	X			X	X		X	X
<i>Festuca ampla</i> Hack.	X	X	X	X	X	X	X		X	X		X	X
<i>Glyceria declinata</i> Bréb.		X						X				X	
<i>Holcus lanatus</i> L.	X	X	X	X	X	X		X	X	X		X	
<i>Holcus mollis</i> L.			X		X							X	X
<i>Hordeum leporinum</i> Link	X	X	X	X	X			X	X			X	
<i>Lolium rigidum</i> Gaud.		X		X	X				X			X	
<i>Micropyrum patens</i> (Brot.) Rothm.				X					X				
<i>Micropyrum tenellum</i> (L.) Link		X		X	X		X					X	X
<i>Poa annua</i> L.	X	X	X	X	X			X	X			X	X
<i>Poa nemoralis</i> L.			X						X				
<i>Poa trivialis</i> L.	X	X			X	X	X	X				X	
<i>Vulpia alopecuroides</i> L.	X	X			X								
<i>Vulpia bromoides</i> (L.) Dumort.	X	X	X	X	X	X						X	
Cyperaceae													
<i>Carex binervis</i> Sm.	X							X				X	
<i>Carex divulsa</i> Stokes	X	X			X								X
<i>Cyperus eragrostis</i> Lam.			X									X	
<i>Cyperus rotundus</i> L.	X												
<i>Eleocharis multicaulis</i> Sm.	X							X				X	X
<i>Scirpus setaceus</i> L.		X						X				X	
Araceae													
<i>Arum italicum</i> Miller		X	X	X			X		X			X	X
Lemnaceae													
<i>Lemna minor</i> L.		X						X				X	
Juncaceae													
<i>Juncus articulatus</i> L.	X	X						X				X	X
<i>Juncus bufonius</i> L.	X	X	X	X	X			X				X	X
<i>Juncus effusus</i> L.	X	X	X	X	X			X	X			X	
<i>Luzula campestris</i> (L.) DC.			X		X							X	
<i>Luzula forsteri</i> (Sm.) DC.	X	X	X		X				X			X	X

	Sites				Habitats							Studies	
	1	2	3	4	1	2	3	4	5	6	7	'82	'94
Liliaceae													
<i>Asphodelus aestivus</i> Brot.		X		X					X			X	X
<i>Asphodelus ramosus</i> L.	X	X	X	X		X			X				X
<i>Hyacinthoides hispanica</i> (Miller)		X							X				X
<i>Ornithogalum pyrenaicum</i> L.		X			X				X			X	X
<i>Ruscus aculeatus</i> L.	X	X	X						X	X		X	X
<i>Scilla monophyllos</i> Link	X					X						X	X
<i>Urginea maritima</i> (L.) Baker	X			X		X						X	X
Dioscoreaceae													
<i>Tamus communis</i> L.	X	X	X			X			X	X		X	X
Iridaceae													
<i>Gladiolus illyricus</i> Koch	X			X	X	X						X	
<i>Iris foetidissima</i> L.	X							X				X	X
Orchidaceae													
<i>Epipactis helleborine</i> (L.) Crantz	X						X					X	X
<i>Neotinea maculata</i> (Desf.) Stearn			X			X							X
<i>Orchis morio</i> L.	X									X		X	X
<i>Serapias parviflora</i> Parl.		X					X					X	X

ADDITIONS TO THE FLORA OF THE ALVOR ESTUARY

Will Simonson

Six vascular plant species were newly recorded in the Alvor Estuary study area in 2002/03. The family Ruppiaceae is for the first time represented in the flora, and the total flora reaches 533 species. The new records are for:

PRIMULACEAE

Samolus valerandi

LEGUMINOSAE

Trifolium arvense

EUPHORBIACEAE

Euphorbia pubescens

CYPERACEAE

Scirpus lacustris

COMPOSITAE

Aster tripolium

RUPPIACEAE

Ruppia maritima

Most of the species are from wetland habitats and their margins, with three of them (the *Samolus*, *Euphorbia* and *Scirpus*) being recorded in the freshwater marshes of the Abicada peninsula to the east of Quinta da Rocha. The flora of this area was surveyed in some detail this year, the full results of which will be described together with the marshes' bird life in the next Observatory Report.

The emergent Brookweed *Samolus valerandi* is a widespread species of coastal wetlands in Europe. It has tiny white, five-lobed campanulate flowers, and obovate leaves both in a basal rosette and alternate arrangement up the stem. The species was first recorded in a water-filled ditch at Abicada on 10 May 2003.

Emerging from some of the same ditches was the Common club-rush *Scirpus lacustris*. This is a robust member of the genus, with round-sectioned stems of up to 1.5 cm diameter. The inflorescences consisted of lateral umbels over-topped by a stem-like extension.

Euphorbia pubescens is the seventh spurge species to be recorded in our area. It was first sighted at Abicada on 10 March 2003. This is a stout perennial up to a metre in height and has a distinctive covering of hairs. Its typical habitat, as represented here, is damp meadows and river banks (Tutin *et al*, 1968).

Elsewhere, the Beaked Tasselweed *Ruppia marina* was first identified within the evaporation tanks of the Western Marsh salinas. This seagrass formed dense square mats following the regular pattern of deeper scrapes within the tanks. It is a species of saline waters across most of Europe (Tutin *et al*, 1980).

The characteristic Sea Aster *Aster tripolium* was found in late 2002 on the same side of the estuary, on the banks of the Odiáxere River south of the EN-125 road. This is fairly typical habitat for this yellow- (disk florets) and bluish- (ray florets) flowered composite, which has probably been present for a long time, but unrecorded in this little-explored part of the estuary.

Finally, the Hare's-foot Clover *Trifolium arvense* was found within an abandoned field colonised by cistus on 8 May 2003. It brings to 14 the number of clovers identified in the study area.

Reference

Tutin, T.G., Heywood, V.H., Burges, N.A., Moore, D.M., Valentine, D.H., Walters, S.M. & Webb, D.A. (1968, 1980) *Flora Europaea Volumes II & V*. Cambridge University Press, Cambridge, England.

WEATHER REPORT FOR 2003

Ben Carpenter

Recordings from the weather monitoring station at Cruzinha were continued this year, adding to the data recorded from September to December of 2002. The observations were made daily as close as possible to 0900hrs local time and comprised current temperature, maximum and minimum temperature of the previous 24 hours, relative humidity and rainfall over the previous 24 hours.

Records were not made in March and the first week of April, and the data presented here for this period are from the nearest official weather station at Praia da Rocha, which is approximately 8 km away. The year's data are also compared with mean data from this same station between 1941 and 1970, (Faria *et al*, 1981).

Air temperature

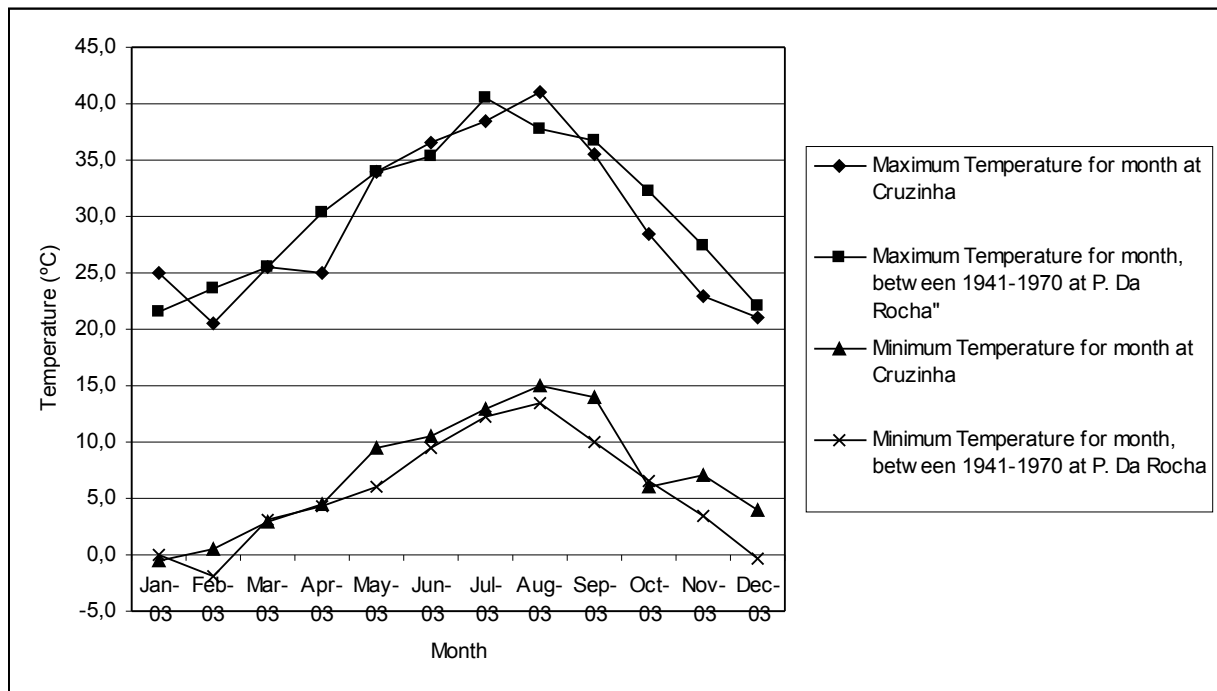
Table 1 and Figure 1 show the maximum and minimum temperatures for each month for the year 2003 at Cruzinha, and at Praia da Rocha for the period of 1941-1970. The highest temperature recorded in 2003 at Cruzinha was 41.0°C on the 1st August. This was on the same date as the highest recorded temperature in history in Portugal (47.3°C), in the Alentejo region north of the Algarve. 2003 was the 17th consecutive year in Portugal with temperatures higher than the average for the period 1961 to 1990 (Ribeiro, 2004). During the summer, the Portuguese government declared a national disaster due to the forest fires that swept through the forests of the Monchique Mountains and other parts of Portugal. After the fires officials estimated that an area the size of Luxembourg had been destroyed, with about 92% of the Monchique mountains devastated (Green, 2003). About 18 people were killed, and the damage was estimated to be around €1 billion (BBC, 2003). The exceptionally hot summer was certainly a contributing factor in all of this.

Table 1 The maximum and minimum temperatures for each month at Cruzinha and the period 1941-1970 for Praia da Rocha.

Month	Temperature °C			
	Maximum for month		Minimum for month	
	Cruzinha	P. da Rocha	Cruzinha	P. da Rocha
January	25.0	21.5	-0.5	0.0
February	20.5	23.6	0.5	-1.9
March	25.5	25.5	3.0	3.1
April	25.0	30.3	4.5	4.3
May	34.0	33.9	9.5	6.1
June	36.5	35.4	10.5	9.4
July	38.5	40.6	13.0	12.2
August	41.0	37.7	15.0	13.4
September	35.5	36.8	14.0	10.0
October	28.5	32.2	6.0	6.5
November	23.0	27.5	7.0	3.4
December	21.0	22.1	4.0	-0.4

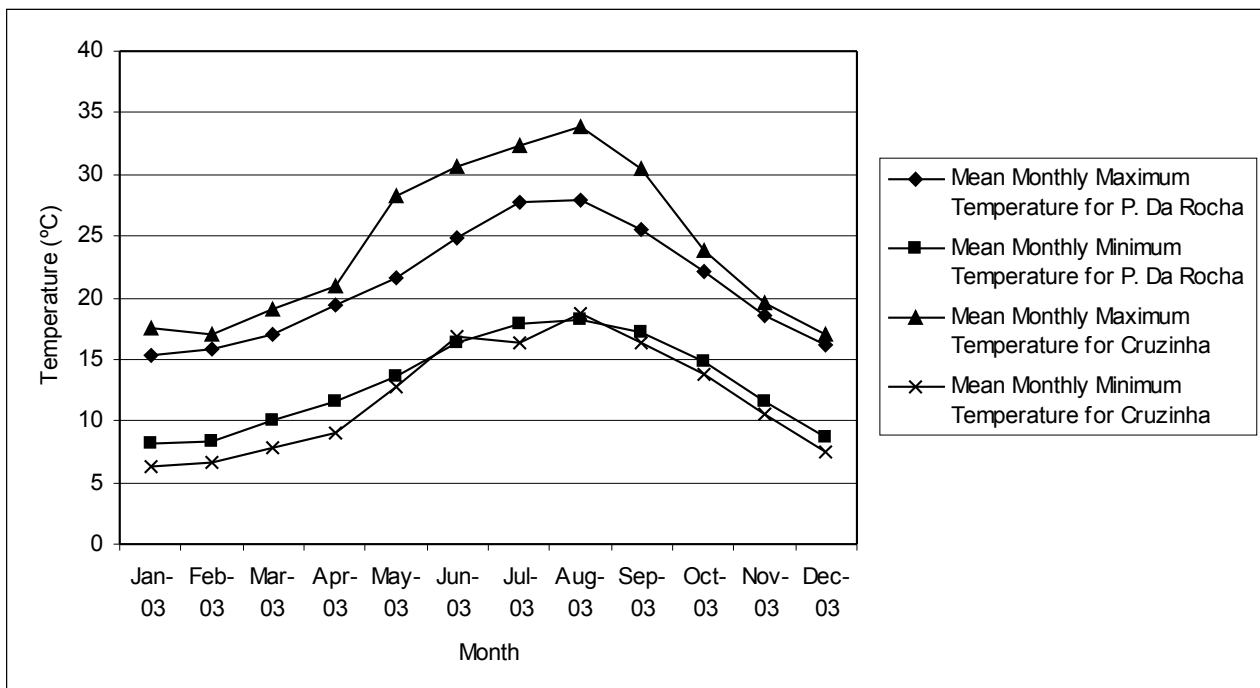
The minimum temperature recorded was of -0.5°C on 12 January. It is noteworthy that the minimum recorded temperatures at Cruzinha for three months (January, March, October) fell below the minimums reached at Praia da Rocha for the same months in the period 1941-1970. The highest recorded temperatures at Cruzinha for three months of 2003 (January, August, June) also managed to exceed the Praia da Rocha records for these months.

Figure 1 The maximum and minimum temperatures for each month at Cruzinha and the period 1941-1970 for Praia da Rocha.



The mean maximum and minimum temperatures for each month at Cruzinha and Praia da Rocha are shown in Figure 2. The mean maximum temperatures at Cruzinha for the summer months (June, July, August, September) are on average 5.6°C higher than the average recorded at Praia da Rocha whereas for the rest of the year the average difference is 1.5°C. The mean minimum temperatures at Cruzinha are on average 1.1°C lower than that of Praia da Rocha, apart from June and August, where they exceed the Praia da Rocha values by 0.4°C and 0.5°C respectively.

Figure 2 Mean maximum and minimum temperatures per month at Cruzinha for 2003, and at Praia da Rocha between 1941-1970.



Rainfall

Measurements from our rain gauge are shown in Table 3. The total rainfall recorded in 2003 was 667.0 mm, which occurred over 82 days of the year.

Comparison with long-term data from Praia da Rocha indicates that 2003 was wetter than average. October and November in particular recorded high rainfalls. The rainiest day was coincidentally on the same day as in the previous year's recording period, which was the 23rd November, with an exceptional 141 mm recorded – almost a third of the annual rainfall to be expected. Considerable flooding was experienced in subsequent days in Portimão, and a dyke at Abicada was breached flooding the marshes.

No rainfall was recorded in the months of June, July and August.

Table 3 Number of days where rainfall occurred and the amount of rainfall per month

Month	Days on which rain fell	Amount of rainfall (mm)	Mean rainfall Praia da Rocha 1941-1970
January	13	53.0	73.4
February	9	65.5	49.5
March	8	56.6	67.5
April	10	61.0	32.0
May	1	4.5	24.8
June	0	0.0	9.7
July	1	0.0	2.1
August	0	0.0	0.8
September	3	27.3	17.2
October	14	121.9	47.8
November	11	195.2	72.2
December	12	82.0	74.2
Total for year	82	667.0	471.2

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