Surface Water Quality in the Gozo Study Area

Vegetation Monitoring to establish Pollution Indices

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1. Introduction

Living organisms integrate and respond to all environmental factors incident upon them. In watercourses, these factors include pollution of many and varied types, including agrochemicals, road run-off and farm effluent. Watercourse organisms have been used to assess pollution for over half a century but the more recent indicator species include plants.

Different plant species have different, though often overlapping, habitat ranges. Changes in habitat which plant species are sensitive to and thus also elicit a response to include: variations in water flow, depth, duration of flooding, disturbance, light reduction, substrate availability for rooting and obviously water quality.

The presence of a species indicates that all environmental factors are, at least, tolerable for that species. Since each species has a preference of environmental factors, the more the species richness, the narrower the possible environmental ranges present in that habitat.

Plant indices work well where the vegetation is both plentiful and predictable. This occurs most frequently in perennial streams in the lowlands with enough water to support aquatic plant species. These conditions do not occur in the Maltese Islands since most streams are no longer perennial, and those that are do not have the requisite volume due to the dry Mediterranean summer.

However, by applying the same principles and taking advantage of the fewer variables, an adequate scheme can be devised. Such a scheme assesses total stresses to a plant community, not just pollution. The extent of dredging, trampling, shading, surfaced beds, surfaced banks, etc. should also be taken into consideration. Provided that these forms of stress can be identified and taken into consideration, the remaining damage may be traced back to pollution.

The chemistry of watercourse water is greatly influenced by the sub-stratum over which it flows, thus, since most of the underlying rock is limestone, Maltese watercourses are lime-influenced. Clay is little and sandstone even less and both don’t afford much influence.

Limestone water is calcium-dominated, with high calcium and low levels of other nutrients. The absence of other nutrients is due to the abundance of the calcium ion itself, which suppresses the presence of other nutrients. Excluding the presence of road run-off and agricultural pollution, there is only one habitat which offers a balance of nutrients – springs.

As in other parts of Southern Europe, the river vegetation does not alter downstream (except if fed directly by springs). This means that any significant change is due to pollution entering the fresh water system at a certain point downstream. In this respect, it is easier to identify and assess the presence or absence of pollution due to the homogeneity of the substratum and therefore of the water medium itself.

However, the extreme, man-made dryness of the watercourses greatly limits aquatic vegetation. Perennial (spring-fed) streams are small and few. Most wet watercourses flow for a part or all of the time between October and May and is heavily dependent on the extent of rainfall.

Rock pools with a clay bottom or on seepages, are the only habitat-type that may support water all year round, even when flow drops considerably.

2. Pollution Evaluation

Pollution is usually chemical in nature and anthropogenic in source. Its effect is an alteration of the chemistry of a habitat, which varies according to the intensity and type of the pollution. Such a variation in habitat will result in a variation in the structure of the plant and animal community found in that habitat.

No macrophyte species has evolved to tolerate anthropogenic pollution yet, although this feature can already be found in some species of bacteria which can either resist or even benefit from such pollutant levels.

Evaluation of aquatic species must be carried out when there is enough water supply in the habitat. This may be possible around December or by early February when all species have already emerged, or the last year’s shoots of the harder emergents are still visible.

Table 1 gives the pollution ranges of the main water plants and a list of some other habitat factors that can be used. Pollution ranges are given over an 8-point scale, from *a* (good) to *h* (very stressed). Since no watercourse in the Gozo Study Area is totally clean and undamaged, the highest Pollution Index (*a*) denotes a watercourse that is in the best condition when compared to the others at present.

Table 2 shows the habitat type, while table 3 provides additional notes about the habitats.

3. The Cleaning Power of Vegetation

Microbes break down chemical substances, both natural and anthropogenic, to obtain their energy. Most purification is by microorganisms. Different species have different chemical reactions and it is on these processes that sewage treatment depends on.

Microbes occur in watercourses, in the water, though they greatly increase in number in the presence of larger plants. These plants provide surface area, and shelter in the water, and chemical exudates which benefit the microorganisms. Plant species therefore differ in their purifying ability, both in degree and in kind: some pollutants break down faster in the presence of exudates from one plant, others with exudates from another plant. Similar, but lesser purification occurs by the aerial parts of the plant. The best cleaning is of pollutants touching the soil surface and passing underground through the root zone.

However, stagnant water in pools may be deficient in oxygen. This anoxic environment may cause strong anaerobiosis and slow down the breakdown of complex substances. The most favourable environment for decomposition is where both aerobic and anaerobic conditions exist; the next best is highly oxygenated and well-lit water.

Self-purification of water bodies is very important. Tall monocotyledons are those most commercially used, being easy to grow and providing much surface area, particularly below ground level. Table 1 shows the tall monocotyledons occurring in severe pollution, thus highlighting their ability to purify the water. If new channels are created for polluted run-off, they should be planted with monocotyledons if predominantly wet and with other perennial species if dry, as these grow for much of the year.

Although vegetation cleans and purifies water in watercourses, native vegetation should not be altered for this purification process, this means that tall monocotyledons should not be planted where submerged and short aquatics should grow instead. This would definitely modify the community of biota occupying that particular habitat and lead to an unbalance in the ecosystem.

Similarly, buffer strips of vegetation should be encouraged and preserved beside a watercourse. Even a 2m buffer strip on each side of a water course is enough to cleanse the incoming run-off water, although there may be a need of 50m or more to remove all the nitrate from polluted soils.

4. Method adopted

The vegetation in every 15m length of watercourse found in the Gozo Study Area, was listed and plant cover assessed. The length assessed was shorter if the water habitat was smaller in size and shorter in length.

The relevant habitat is where at least roots are flooded with water during the main wet season, and where the species listed in Table 1 are to be found. The different species were identified and checked against Table 1 and a single, or a range of possible grades was then determined – the more the species, the more accurate was the grading given. Confirming a grade or narrowing a range was then carried out using Table 5. Tables 1 to 4 as well as Table 6 were used for reference in conjunction with Table 5.

5. How to Interpret the Results

In natural or traditionally managed watercourses, the plant community is diverse, the cover is high (subject to scour and grazing) and many of the species are pollution-sensitive. As noted before, all species occur in a chemical range within their natural habitats, so the presence of a small proportion of pollution-tolerant species is not relevant. Conversely, if most or all plant species present are pollution tolerant or favoured then the site can be classified as being polluted. In the case of the Gozo Study Area, the Blanket weed, the Sewage Fungus and *Rumex conglomeratus* are three of the most popular pollution indicator species and may be found when a site is polluted.

Where watercourse vegetation is abundant, that indicating the most pollution is the Blanket weed covering the water and *Rumex conglomeratus* on the edge. Therefore, if cover of pollution-sensitive species is high, the presence of pollution is low, while a high cover of pollution-tolerant or favoured species indicates the presence of pollution.

Although some species are considered to be pollutant tolerant or favoured by these conditions, no species can tolerate extreme pollution. This means that even if at first pollution-tolerant or favoured species may be seen to flourish in relatively polluted water, if the extent of pollution increases, even they will eventually become sparser and often discoloured until they disappear completely.

This does not mean that sparse vegetation cover is only due to the negative effect of pollution. Vegetation can be reduced for many reasons as can be seen in Table 5, which lists non-pollution sources affecting vegetation cover. If a site is found to possess any one of the conditions mentioned in Table 5, then the Pollution Index of the site should be increased (bettered).

A general rule to follow is that if a site has three or more pollution-tolerant or favoured species and no pollution-sensitive species, then it is definitely a polluted site. A site with no species at all may be grossly polluted, but may also be just too dry, too recently dredged etc. for any aquatic plants to grow. In this case a close look at and smell of the water, will be sufficient to determine whether the absence of vegetation is due to pollution or not.

There are of course many different kinds of pollution, including agrochemicals, sewage, farm effluent, road run-off and industrial chemicals. The detailed patterns of plant behaviour of course vary with the presence and concentration of these pollutants in the habitat, since the proportions of nutrients and the nature of the toxins differ with each source and type of pollution.

6. Results obtained

After the summer drought, a period of water is needed before water-supported plants, and some of the small emergents have grown enough for a survey to be conducted.

The rainfall year 1999-2000 was mostly dry but with a very wet month November to December, raising the annual average. By March 2000 this resulted in streams with few springs (and in particular with easy infiltration down through the watercourse bed) which were late in being wetted, but early in drying. Xlendi watercourse in the Lunzjata valley has the most springs of the surveyed streams, followed by the upper Ramla tributary.

Tables 8.1, 8.2 and 8.3 list the
- sites surveyed
- vegetation present
- vegetation index
- presence or absence of pollution
- other habitat factors important in determining the vegetation cover.

Only one area, the Xlendi watercourse by the road bridge from Fontana and Victoria, was surveyed in spring 1999 and was then re-surveyed in spring 2000 (Ref Table 8.1).

A sub-adequate vegetation of grades b, c, or d, with ample well-grown *Apium nodiflorum* and *Nasturtium officinale* had turned into a badly polluted area with only the Blanket weed (pollution favoured) monodominant plant found in the water. The latter plant is indicative of pollution in the area.

The dry land beside the watercourse which becomes flooded in wetter weather was found to be without *A. nodiflorum* and *N. officinale*. *Rumex conglomeratus* (pollution favoured) and *Arundo donax*, both able to tolerate considerable pollution, were found in that area.

One tiny, discoloured and flaccid plant of *N. officinale* was found on a waterfall where oxygenation is greatest. These results clearly indicate that new pollution had entered between the bridge and the public access part of Wied il-Lunzjata, some 400m upstream. This is most probably due to run-off down the valley from the recent housing. There is also the possibility of new effluent-producing farms or the dumping of carcasses in the main stream (though none were noticed).

The upstream part of the Spring 2000 survey included the tributaries upstream of Kercem. The wet area found was on the downstream part of the easterly tributary. It was apparent that both carried pollution in wetter periods, presumably from settlements and roads.

At the time of survey, neither tributary flowed where the streams fall down the steep rocky slope to the Wied il-Lunzjata. Remnants of pollution showed that, earlier in the winter the streams had flowed down, so polluting the upper part of the Xlendi in the Lunzjata Valley.

The Lunzjata valley has slopes with many springs especially around the head. The influx of cleaner water upstream, improves the water quality. Although potential contamination with agrochemicals cannot be ignored, it is very much cleaner than that from upstream run-off tributaries, but is grossly polluted less than 0.5km downstream, as already outlined before.

One of the four major tributaries of the Ramla watercourse was surveyed for the first time. The survey was downstream from near the top of the it-Tafla tributary. This tributary is small upstream and carries little swift storm run-off. Tall monocotyledons can therefore grow well, preventing the growth of shorter plants and thus reducing species diversity. The vegetation is satisfactory for the habitat. Springs emerge from the watercourse bed. Construction has led to pollution by silt. Refer to Table 8.2. This type of pollution is presumed to be only temporary.

This relatively clean tributary meets a badly polluted tributary flowing from Nadur road and the new housing area. Pollution here is severe, but improves downstream, then drops again. This pollution also improves downstream especially since it is helped by impoundments which act as settling ponds for pollution.

At the time of the survey, the watercourse dried before reaching the mouth due to infiltration, thus, pollution was not carried down at that time. This is not to say that pollution could not have been present in the pool at the mouth from earlier rains. The pool is also brackish since it receives seawater in storms. The extent of disturbance is high, since it is a very popular beach in summer. The vegetation present is thus indicative of the influence of salt (and humans) in the area. The effects of other factors could not be estimated.

The tributary of the Ilma valley (below the hotel, refer to Table 8.3), which carries extreme storm flow (D. De Ketelaere, personal communication), dries very quickly. There were a few, small fresh water pools in both autumn 1999 and March 2000, the latter being unexpected. The probable explanation is rapid infiltration through faults, etc. (D. De Ketelaere, personal communication). The beds are obviously storm-swept and the scarcity of land vegetation is consistent with this. The algal remains indicate the presence of pollution, presumable from run-off, but no Pollution Index can be calculated.

6.1 Tables of Results

The results from the field are initially collected together with additional data, in the form of comments, on the site itself. Comments include:

- the extent of wetness,
- species richness,
- presence or absence of pollution or
- of other sources of damage.

This is carried out to assess all the stress-factors present in the habitat and an initial Pollution Index is given to the site. The Pollution Index is most often presented as a range and only when all the stress parameters have been taken into consideration, is this range narrowed down to one value.

Tables 8.1, 8.2 and 8.3, give a clear illustration of which parameters affecting the sites are noted and also, the Pollution Index (as a range) that is given to each section of the site. All the data is then summed up into one, Pollution Index value, using Table 5.

<u>Key to tables 8.1 to 8.3:</u>

Damage Pollution Index from a (good) to h (very stressed)
P = pollution is the main source of damage.
X = other source/s of damage
N/A = not calculable - too dry, too salty, but site was entered into table because pollution was evident, or site was otherwise interesting.

Tables 1-4 and 6 have then be used in conjunction with Table 5 to narrow down the range of values to one value for each sampled site.

6.2 Finalized Tables of Results with 'corrected' Pollution Indices.

Tables 9.1 and 9.2 and 9.3, give a Pollution Index which includes all the stress factors noted in Tables 8.1, 8.2 and 8.3.

Table 9.4 gives Pollution indices for another site sampled, namely Marsalforn Valley.

7. Making Reference to Vegetation Quality in the Past

The present vegetation can be classified as being very damaged and stressed. Table 7 gives species assemblages of the frequent species for comparable rivers in the south of Italy which are now damaged. It also lists some of the Maltese watercourse species of pre-drying days, without indication of frequency.

From this comparison, it would be reasonable to conclude that the traditional site diversity in the Gozo Study Area is 10+ species and 60+% cover, with only a few of the species being pollution-tolerant or favoured.

The typical watercourse shape would be wide with gentle banks bearing emergents, which come up as the water level falls in early spring. The emergent species would be more numerous than the submergents as the variation in watercourse water in the Mediterranean climate makes a harsher habitat for the latter.

8. Conclusions

Plants are very sensitive in their response to the conditions in which they live, primarily because they cannot leave a hostile habitat to another one which is more suitable for their needs. Consequently, their occurrence, abundance, and habitat can be used to draw conclusions on these conditions. Since each species differs in its behaviour, the more species present in one site, the more accurate the diagnosis made is.

The general principles of vegetation interpretation were worked out in temperate climate, where vegetation is more abundant. With these principles, however, a reasonable interpretation can be made even in the most polluted watercourses found in the Gozo Study Area.

The use of such a tool is limited however, to those watercourses where there is enough water for aquatic vegetation to develop. This represents much less than 10% of the whole length of watercourse. Such a study is also limited to those months when the vegetation is present, in turn this is heavily dependent on pattern and extent of rainfall. The latter factor was a limiting factor throughout this exercise.

The great advantage of vegetation monitoring, though, is that it is quick, needs no expensive equipment and is therefore cheap. It was possible to carry out the analysis of at least forty sites. Once recorded, these sites can then be analyzed.

<u>Table 1 Pollution indicator ranges</u>

Species[1]	a	b	c	d	e	f	g	h
Alisma plantago-aquatica	x	x	x	x	x	x		
Apium nodiflorum	x	x	x	x	x			
Arundo donax	x	x	x	x	x	x	x	x
Callitriche stagnalix	x	x						
Chara vulgaris	x	x	x	x				
Cyperus longus	x	x	x	x	x	x		
Eleocharis palustris	x	x	x	x	x	x		
Lemna minor		x	x	x	x	x		
Mentha aquatica/pulegium	x	x						
Nasturtium officinale	x	x	x					
Ranunculus trichophyllus	x	x	x					
Rumex conglomeratus	x	x	x	x	x	x	x	x
Scirpoides holoschoenus	(Usually irrelevant as too high above water. Tolerant.)							
Typha domingensis	x	x	x	x	x	x	x	x
Veronica anagallis-aquatica	x	x	x					
Veronica beccabunga	x	x						
Small grasses	x	x	x	x	x	x	x	x
Blanket weed [2]			x	x	x	x	x	x
Sewage fungus [3]					x	x	x	x

Characters	a	b	c	d	e	f	g	h
Clear water [4]	x	x	x	x				
Foaming water [5]			x	x	x	x	x	x
Turbid water 6			x	x	x	x	x	x
Opaque Run-off water								x
Toxic line [7]							x	x
Darkened silt [8]				x	x	x	x	x
Deep silt [9]		x	x	x	x	x	x	x
Smell (not just anaerobic)			x	x	x	x	x	x

[1] *typical ranges*. It is always possible for these to be exceeded by exceptional habitat factors and they are often reduced by e.g. Drying or disturbance, the species being restricted to only part of their usual range.

[2] *filamentous alga*, attached to the substrate, are present in all wet watercourse habitats. It is only when nutrients are raised that these grow out to form long trailing filaments, which form a blanket.

[3] *sewage fungus* (a mixture of bacteria and fungi) grows with high organic pollution e.g. carcasses, raw sewage.

[4] *clear water* is not necessarily clean water. The main clear pollutants in the Maltese Islands are agrochemicals. Other pollutants in the same concentrations are worse pollutants causing turbidity.

[5] *foaming water*. This is usually from detergents. If there is a washplace in current use or upstream it could be solely due to the detergents used. Usually though, detergents are accompanied by sewage, road run-off or factory effluent.

[6] *turbidity* – 40m deep watercourse bed not visible. This is due to several causes namely:

- Recent storms, flowing storm water-carrying silt. This should be disregarded and the site re-surveyed a few days later.
- Recent disturbance, whether road construction upstream or livestock at the site.
- Phytoplankton, like blanket weed requires a raised nutrient level to survive.
- Road and other settlement run-off
- Factory effluent or run-off
- Farm and house effluent

[7] *toxic band*. A band above normal water level which is flooded by storm flows (or the highest longer-term water of the season). When water is sufficiently poisonous, the plants here are absent, small or discoloured.

[8] *silt* may be darkened by run-off or effluent pollution, or by very anaerobic conditions caused by pollution rich in organic compounds.

[9] *deep silt*. Run-off from rain brings silt into the watercourse and this is then washed down to the sea. Human impact (intensive farming, construction, road use) has much increased silt deposition and has decreased loss, not just by abstraction and drainage, but by the insertion of weirs and other obstructions, which slow the flow and cause deposition upstream.
Silt contains more nutrients and pollutants than sand or stones. Extra silt thus causes the smothering of short plants, a change in rooting habitat (texture and stability) and a possible increase in pollution of the substrate.

Table 2 Main habitats of the aquatic species

1. EMERGENTS	
a. Tall Monocotyledons	
Arundo donax *Cyperus spp.*	*Phragmites australis* *Scirpoides holoschoenus* *Typha domingenesis*
b. Rather shorter, but also narrow tall monocotyledons	
Eleocharis spp.	*Juncus spp.*
c. Short, bushy dicotyledons, 'fringing herbs'	
Apium nodiflorum *Mentha aquatica* *Nasturtium officinale*	*Veronica anagallis-aquatica* *Veronica beccabunga*
d. Wide-leafed edge species	
Alisma plantago-aquatica	*Rumex conglomeratus*
2. WATER-SUPPORTED SPECIES	
a. Floating	
Lemna minor	Blanket weed
b. Thread-leafed submergents	
Myriophyllum spp. *Ranunculus trichophyllus*	*Zannichellia palustris* Blanket weed Sewage fungus
c. Wide-leafed, rooted	
Alisma plantago-aquatica	*Nymphaea spp.*

Table 3   Habitat notes for the principle species

Alisma plantago-aquatica
Silted places. Silt always contains more nutrients and pollutants than sand or stones in the same habitat and forms a different rooting habitat. Springs are unlikely to have the silt or nutrients permitting this plant to do well. It is therefore more likely to be found away from headwater areas and away from scour. It is dormant in autumn and winter, emerging early in spring and so can grow in deep-flooded places that are shallowing in March.
Apium nodiflorum
Mostly in or by winter-flowing water. In reasonably clean habitats, though tolerates pollution to some extent. See table 4 for changes in form.
Arundo donax
In places damp at least in winter, long-term flooded only by shallow, lime-dominated and non-scouring water. Typical of seepages and springs, banks of wetter watercourses and beds of dryer ones.
Callitriche stagnalis
Mostly driven from watercourses by water loss and high pollution levels.
Chara vulgaris
Grows from the bottom, requiring clear or shallow water above. Its anchorage is not strong so it will not be found growing in watercourses with fast flows. It is also sensitive to high pollution levels.
Cyperus longus
Prefers wetter habitats than *Arundo donax*, but drier than those of *Typha domingensis* and also without any form of pollution. Typically where there is low scour and long-term dampness or wetness, on edges of wetter watercourses and beds of drier ones.
Eleocharis palustris
In long-term dampness or wetness – not in quick-draining substrates. When found short in mixed species, this indicates high-quality conditions. When taller and monodominant, (refer to table 4), this indicates moderate pollution with both organic and inorganic pollutants.
Lemna minor
On the water surface and not deep rooted, so it may easily be washed away by a strong flow. A sheltered and flooded source is needed for it to occur in long-term. When spreading and dominant, it requires higher nutrients than those of upstream, unpolluted reaches. Blanket weed, though, has a higher nutrient range.

Mentha aquatica, Veronica anagallis-aquatica, Veronica beccabunga
At the edges of clean, winter-flowing stable water where tall monocotyledons are prevented from growing due to scour, dredging etc.
Nasturtuim officinale
Found in conditions favoured by *Mentha aquatica, Veronica anagallis-aquatica* and *Veronica beccabunga*, and *Apium nodiflorum*.
Ranunculus trichophyllus
A suitable gravel rooting habitat and flow at least early in the season is necessary. It avoids both severe scour and a high degree of pollution. With continuous flow, the streams stay strong, in still water they become weak, enabling plants to break off and grow near the surface of deep water.
Rumex conglomeratus
Tolerant to pollution and spreading. Like *Eleocharis palustris*, indicating high-quality wet-land when small, sparse in a mixed stand, but occurring larger in moderated pollution, often extending as the only species in very polluted areas.
Typha domingensis
Tolerant to pollution and spreading. Grows in substrates made up of fine-particles and in water up to 1+ m deep. Avoids scour.
Blanket weed
Spreading fast since the middle 1990s. Growing originally from the substrate, but often found floating when abundant. Pollution-tolerant and may be found in a higher nutrient range than the other floating species, *Lemna minor*.
Sewage fungus
In various shades of white, yellow, red or brown, from short to 1+ m long.

<u>Table 4 Species altering with fluctuating pollution levels (see table 1 for ranges)</u>

1. Growing larger	
Apium nodiflorum *Nastridium officinale* (in mild pollution only) *Rumex conglomeratus*	*Eleocharis palustris* *Lemna minor* (high cover) Blanket weed
2. Growing more flaccid, or yellower	
Apium nodiflorum *Rumex conglomeratus*	*Nastridium officinale*
3. Monodominance where Multidominance is possible	
Limestone streams tend to be short of nutrients, so restricting plant growth. Consequently many species can grow together, none overshadowing another. When pollution raises nutrients and introduces toxins, those species tolerating the new regime may grow tall, shade out others and become monodominant.	
N.B. Growth in the Gozo Study Area is impossible to predict by dates, because the rainfall is so variable and growth depends on the amount of water available in the habitat. A clean (or near-clean) water site should be found and used for reference. The same site can be used to verify flaccidity.	

Table 5 Cover and Diversity rating

1. Cover	
Improve the index if cover is:	60%+ of submergents and short emergents (excluding Blanket weed)
Leave index as is if cover is:	Composed of tall monocotyledons or 20-60% is covered and clause below does not apply.
Lower the index if cover is:	Composed of over 15% Blanket weed, by more if over 30%, if *Lemna minor* cover is over 40% (except in a downstream site on a larger water course), or if total vegetation cover is less than 20%.
2. Diversity (In a site of about 15m long, or a whole site if shorter in length.)	
Improve index if there are:	6+ species (not including large *Rumex conglomeratus, Typha domingensis*, Blanket weed and Sewage fungus.
Leave index as is if there are:	6+ species including those mentioned above. 4+ species excluding those mentioned above.
Lower index if there are:	1-3 species excluding those mentioned above. 3-5 species including those mentioned above and if only those mentioned above are present.
N.B. Typha domingensis on its own is not necessarily a pollutant indicator.	

Table 6 Principal non-pollution causes of reduction in vegetation

1. Inadequate supply of water. a. Only present for a short time b. Inadequate in volume c. Too deep
2. Substrate unsuitable for rooting, e.g. rock, concrete
3. Recent scouring flow
4. Shading by taller plants or constructions
5. Grazing by livestock and harvesting of e.g. *Arundo donax*
6. Dredging and digging
7. Trampling, off-roading and similar disturbance
8. Dumping of rubble and rubbish
9. Constructions, walls, roads etc.

Table 7 Species assemblages for comparison

1. Partial list, rivers 1850s Maltese Islands (Grech Delicata, 1853)	
Alisma plantago-aquatica *Apium graveolens* *Apium inuendatum* *Apium nodiflorum* *Callitriche stagnalis* *Cyperus badius* *Cyperus longus* *Eleocharis palustris* *Glyceria maxima* *Glyceria plicata*	*Lemna minor* *Mentha aquatica* *Nasturtium officinale* *Ranunculus fluitans* *Ranunculus trichophyllus* *Scirpoides holoschoenus* *Scirpus maritimus* *Veronica anagallis-aquatica* *Veronica beccabunga* *Zannichellia palustris*
Only 12 of these 21 species appear in Table 1.	

2. Principal river species, Sicily, 1980s (Haslam, 1987)	
Alisma plantago-aquatica *Apium nodiflorum* *Arundo donax* *Cupularia viscosa* *Cyperus spp.* *Equisetum telmatiae* *Juncus inflexus* *Juncus spp.*	*Nasturtium officinale* *Phragmites australis* *Potamogeton crispus* *Typha spp.* *Zannichellia palustris* Small grasses Enteromorpha sp. Blanket weed
Of these 16 species or groups of species, 12 species are, or could be in the Gozo Study Area list. (Cupularia viscosa is more of a dry edge species and Phragmites australis is found more in coastal areas and rare in the vicinity of springs). The reference vegetation is 8+ species, 50+% cover.	

Table 7 Species assemblages for comparison - continued

3. Principal river species in lime-influenced areas in the far south of Italy, 1980s (Haslam, 1987)	
Apium nodiflorum *Arundo donax* *Cyperus spp* *Lemna minor* *Mentha spp.* *Myriophyllum alterniflorum* *Nasturtium officinale*	*Petasites hybridus* *Phragmites australis* *Ranunculus spp.* *Scirpus lacustris* *Sparganium erectum* *Typha spp.* Small grasses
Of these 14 species or groups of species, only 11 species are or could be found in the Gozo Study Area list. The reference vegetation is 10+ species, 50+% cover.	

4. Principal river species in the limestone garigue area of Apuilo, Italy, partial list, 1980s (Haslam, 1987)	
Apium nodiflorum *Lemna minor* *Phragmites australis* *Polygonum hyropiper* agg. *Potamogeton pectinatus* Scirpus lacustris	Scirpus maritimus *Sparganium erectum* *Typha spp.* Small grasses Blanket weed
Of these 11 species or groups of species, 8 species are or could be in the Gozo Study Area list. The reference vegetation is 5+ species, 60+% cover.	

Table 8.1 Annotated Results of Survey - Xlendi

							Source of damage other than pollution (main)
Xlendi	1	Tributary (east) upstream of Kercem. Water in long puddles, not flowing. Around grid ref. 307892. Aquatic:	puddle with Blanket weed dry band	N/A	P		
			including *Rumex conglomeratus* 40%.	N/A	P		
	2	Aquatic:	Blanket weed 15%, *R. conglomeratus* <10% edges	d-g	P	X	Not wet for long enough (but if completely clean, will not take long for species to grow)
	3	As last		d-g	P	X	
	4	Downstream of main road, same tributary. Aquatic:	Blanket weed 20% *R. conglomeratus*, land spp. side.	e-g	P	X	
	5	Aquatic:	Blanket weed 15% *R. conglomeratus* 50%	d-g	P	X	
	6	Near dry:	*R. conglomeratus* 10% and land species 60%	N/A	P		
	7	Just above the water fall, near dry:	*R. conglomeratus* 20% in land species, Blanket weed 10% in small puddle.	N/A	P		

	8	Head of Wied Lunzjata, many springs, received polluted water from two tributaries during wet weather. Around grid ref. 309889. Aquatic:	algae	b-f	P	X	Not wet for long enough (but if completely clean, will not take long for species to grow)
	9	Aquatic	*R. conglomeratus* 30%	d-g	P	X	Also much rock in bed
	10	Below confluence, much spring water received. Aquatic:	Nil	h	P	X	Maintained clear of 'weed'. Water appears to be clean.
	11	Tributary. Aquatic:	*Apium nodiflorum* 50%	b-e		X	Stream to narrow, space available is too small.
	12	Main. Aquatic:	*Apium nodiflorum* edges, *Arundo donax* edges, benthic algae, some.	c-e	P	X	Maintained clear of 'weed'. Water appears to be clean.
	13	Main road bridge from Fontana (and Victoria). Aquatic:	Blanket weed 80%, not clear.	g	P		Duplicate of 1999.
		Dry, narrow edge band:	*A. donax, R. conglomeratus*	N/A	P		
	14	Aquatic:	Blanket weed 100%, *R. conglomeratus* edge but out of water.	g	P		Duplicate of 1999.
		Dry wide edge band	*R. conglomeratus* 30%, *A. donax* 30%	N/A	P		

Table 8.2 Annotated Results of Survey - Ramla

Ramla		From the tributary with it-Tafla on it on the map (between Nuffara and Ggantija) to Ramla bay. Around grid reference 347894 to 356912.					
	1	Aquatic and edge (for sites 1-7): water brown-turbid.	*Cyperus longus* 70%, *Eleocharis palustris* 10%, *Rumex conglomeratus* 10%, land spp.,	c-f	P	X	Narrow steam without severe storm flow tall monocotyledons shading, so short species cannot grow: vegetation skewed.
	2		*C. longus* 50%, land species 50%	N/A		X?	
	3	deep silt	Blanket weed 15%, *C. longus* 70%, *E. palustris* <10%, *R. conglomeratus* <10%,	c-f	P?	X	
	4		*C. longus* 80%, *R. conglomeratus* <10%, land spp.	b-f	P?	X	
	5		*C. longus* 100%	b-f	P?	X	
	6		*R. conglomeratus* <10%, land species 50%	N/A	P?	X	
	7	At confluence: deep silt	*C. longus* 80%, *E. palustris* 20%, *R. conglomeratus* <10%,	b-f	P?	X	
	8	Downstream confluence with tributary from Nadur. Stream now wider and only aquatic habitat recorded.	Blanket weed 60%	g	P	X	
	9	Much rock in bed	Blanket weed 50%	f-g	P	X	Rock outcrops over which plants cannot grow.
	10	Rock in bed	Blanket weed 15%, (bottom algae 60%)	f	P	X	
	11	Considerable silt	Blanket weed 15%	f	P	X	

	12	Some rock in bed	Blanket weed 90%	g	P		Rock outcrops over which plants cannot grow.
	13		Blanket weed 80%, *R. conglomeratus* side <10%	g	P		
	14		*Chara* 20%, Blanket weed 10%	C/d	P	X	Most of site deep, liable to sudden changes in level.
	15		Blanket weed 10%, *Enteromorpha sp*. 30%, *Phragmites australis* side 10%	N/A	P	X	Brackish (influence of salt)

<u>Key:</u>

Damage Pollution Index from a (good) to h (very stressed)
P = pollution is the main source of damage.
X = other source/s of damage
N/A = not calculable - too dry, too salty, but site was entered into table because pollution was evident, or site was otherwise interesting.

<u>Table 8.3 Annotated Results of Survey - Ilma</u>

Ilma		North tributary (rising north of Ghajn Abdul), the eastern tributary of this (rising near Ghar Ilma), near and at the confluence of the tributary rising in Gharb. Around grid reference 257900 (below the new hotel).					
	1	Ilma tributary, downstream for a short way. Dry: ground level high.	*Arundo donax* 100%	N/A	?		
	2	Puddles:	Benthic algae	N/A	P		In wet weather, this stream carries a lot of water. Making these beds storm swept.
	3	Confluence with Gharb tributary, dry		N/A	P?		
	4	Downstream. Small puddles,	a few small land species	N/A	P?		
	5	Downstream. Dry:	long benthic algae 25%	N/A	P		
	6	Downstream. Dry:	Land species including *Arundo donax* 100%	N/A	P		As above, but some land species have managed to re-grow.

Silt and soil was being washed down from a construction site just upstream of the top site recorded. This form of pollution will probably be temporary with no long-term effects, unless the soil was already polluted with biocides. None the less, the low growing species may be smothered with an increase in the silting parameter.
The second source of pollution was from Nadur, and entered at site 8 on Table 8.2. This pollution is toxic in nature and contaminates the area whenever the stream flows. It is noticeable that the pollution lessens between sites 8 and 11, and then worsens.
It seems likely that this pattern is due to the entry of another tributary from Nadur.

<u>Key:</u>

Damage Pollution Index from a (good) to h (very stressed)
P = pollution is the main source of damage.
X = other source/s of damage
N/A = not calculable - too dry, too salty, but site was entered into table because pollution was evident, or site was otherwise interesting.

Tables 9.1-9.4 Gozo Study Area Pollution Indices - Final Results

Table 9.1 Xlendi

Site No.	Pollution Index
1	N/A
2	e
3	e
4	f
5	e
6	N/A
7	N/A
8	d
9	e
10	h
11	c
12	d
13	g
14	g

Table 9.2 Ramla

Site No.	Pollution Index
1	d+
2	N/A
3	d+
4	d
5	d
6	N/A
7	d
8	g
9	f+
10	f
11	f
12	g
13	g
14	c+
15	N/A

Table 9.3 Ilma

Site No.	Pollution Index
1	N/A
2	N/A
3	N/A
4	N/A
5	N/A
6	N/A

a = good
h = very stressed
+ = index for pollution presumed better than that given i.e. a pessimistic assessment

The site numbers in the tables above, correspond to actual names of the surveyed sites. The grid reference of each site can also be given. These have been added in table 9.4, showing the final results for Marsalforn valley.

Table 9.4 Marsalforn

Site No.	Site Name	Grid Reference	Pollution Index
1	Pool in northern tributary upstream of Tar Valley	313906	g+
2	Upstream ‘Kukjat’ site	314903	h
3	‘Kukjat’ site	304903	g+
4	Tar valley	31589~9	f
5	Downstream Victoria tributary	313897	a
6	Tributary to Victoria tributary from hill	312903	f
7	‘Ghattuq’ site on main road	322899	e
8	‘Srug’ site on main road	325896	d
9	Downstream on main road	328911	e
10	Downstream on main road	328912	e
11	Downstream on main road	328912	h+
12	Downstream on main road	331913	g
13	Downstream on main road	331913	f
14	Upstream Marsalforn	336920	(too dry)
15	Marsalforn	336922	(too salty)

a = good
h = very stressed
+ = index for pollution presumed better than that given i.e. a pessimistic assessment