

## Assessing the environmental status of Mediterranean temporary ponds in Greece

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Mediterranean temporary ponds (MTPs) are highly distinctive habitats with intermittent and unstable environmental conditions, inhabited by several rare and endemic plant and animal species. Temporary pond ecosystems have been classified as endangered all over the world; nevertheless, they are disappearing at a high rate, especially in the Mediterranean region. MTPs are a priority habitat under the European Union Habitats Directive and thus appropriate management and conservation efforts should be applied. Further research is needed in order to better understand the environmental characteristics and ecology of this habitat which is not always the case in many countries. In this study a range of environmental data were collected from the Greek MTP habitat sites including the altitude, the geology, the representativity, the ecological status and other biological data aiming to assess the environmental status of all known Greek MTPs. Statistical analysis were performed and thematic maps were created using a Geographical Information System (GIS). Greek MTP's were classified according to their characteristics and habitat pressures were identified and further analysed. A comparison between the present environmental status of the MTPs in Greece with the MTPs in other Mediterranean countries was undertaken and relevant conservation and management measures were proposed. The outcome of this study was that a significant percentage of the MTP habitat sites in Greece are at risk mainly due to human activities, such as agricultural pollution, expansion of cropland and water resources over-exploitation. It was concluded that immediate restoration and conservation actions should be taken so as to prevent further ecological degradation.

Keywords : Mediterranean Temporary Ponds, ecology, freshwater habitats, phytocommunities, conservation.

### Introduction

Temporary ponds are important habitats that usually occupy depressions, often endorheic, and are particularly well represented in arid, semi-arid and Mediterranean-type regions. These habitats are defined and characterized by their variability in size, hydrological functioning, ephemeral nature of their wet phase (hydroperiod), total dependence on local hydrology and, at the same time, by the absence of any link with permanent aquatic habitats, uniqueness of their vegetation and invertebrate communities (Grillas et al. 2004a, Jakob et al. 2003, Rhazi et al. 2004). Temporary ponds

are isolated habitats, which are also important environments for many migratory birds (Madhyastha et al. 2000, Grillas et al. 2004). On a global scale, temporary ponds are common in northern Europe (Angélibert et al. 2004, Nicolet et al. 2004, Williams 1997), North America (Belk 1998, Graham 2002, Leidy and White 1996, Roshier et al. 2001), Australia (Warwick & Brock 2003) and South Africa (Lahr et al. 2000a, Lahr et al. 2000b, Rhazi et al. 2001b).

The Mediterranean Temporary Pond (MTP) is a priority freshwater habitat type (3170\*, NATURA 2000), that has the aforementioned characteristics and is mainly encountered in Mediterranean countries. MTPs occupy very shallow depressions, which exist only during winter and sometimes spring, while their vegetation mainly comprises Mediterranean therophytic and geophytic species (EC, 2003). Apart from natu-

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ral hydrologic and climatic events, which are the major biological regulatory factors, anthropogenic activities pose serious threats to these habitats. On a global scale, temporary ponds are often neglected due to their ephemeral character. Abandonment of traditional land and water uses, unsustainable management practices, hydrologic alterations (i.e. water abstraction), among others, may lead to the degradation and elimination of these valuable ecosystems (King 1996, Brendonck & Williams 2000, Blaustein & Schwartz 2001, Beja & Alcazar 2003).

In Greece, agricultural intensification during the last 3 decades in combination with public ignorance and lack of environmental education regarding the value of the MTPs, have led to a continuous increase of habitat pressures and to their consequent deterioration. The aim of this study was to assess the current status of MTP habitats in Greece, to examine their dominant characteristics and similarities and to identify potential threats through the use of the Geographical Information System (GIS) and the application of statistical methods. A qualitative comparison of these characteristics and threats with those of the equivalent habitat type in other Mediterranean countries was conducted. Potential management and conservation measures were discussed based on relevant international experience.

## Methods

### Description of the Study Area

The MTP sites are concentrated in the southeastern part of Greece (fig. 1, table 1) due to the dominant climatic conditions of the area (semi-dry) favoring the habitats' typical hydrologic characteristics (alterations between wet and dry periods). In this study MTP sites coincide with the relevant Natura 2000 sites where the priority habitat of Mediterranean Temporary Ponds (Natura code: 3170) has been found. Thus, 'site' is defined as an area comprising either a cluster of ponds or an individual pond as mapped by the Natura 2000 project teams. As illustrated in Figure 1, only 1 out of 18 sites is located in the mainland, whereas the island of Crete has the highest presence of MTP's from any other region of the country (17%). The amount of rainfall in these islands rarely exceeds 600mm a year and the prolonged dry period prevents permanent dominance of aquatic vegetation. The complex of the Cyclades islands, located in the centre of the Aegean sea, hosts five MTP sites (28% of the total number of sites) while another 28% of the MTPs is found in the northern Aegean (fig. 1). Gavdos Island, which is the southern edge of Greece presents several MTPs in the

form of rock pools that develop in small scale calcareous depressions and have mostly species from the Zannichellion class.

### Data analysis

The Natura 2000 database of Greece, as well as data from LIFE-Nature projects (LIFE04NAT/GR/000105 and LIFE99NAT/FR/72049) were used as a basis for this study. Particularly, information regarding the exact location of the MTP sites, their vegetation composition, representativity of typical phytocommunities, eco-status, threats, geological substrate and altitude have been acquired. Ecological status represents the pressures imposed on the habitat by assessing the existing anthropogenic activities and land uses as well as the flora composition at each site. According to the intensity of pressures and threats observed by the Natura 2000 project teams, through field surveys, bibliographic research and existing cartographic data, the MTP sites were classified into 4 quality categories (excellent, good, medium and at risk). Representativity is a dimensionless index that has been used during the development of NATURA 2000 database (EC/266/97) in order to assess the presence of the habitat's typical phytocommunities in the study areas.

All the above data has been initially elaborated in a statistical package (Biodiversity Professional software; McAleece 1997) by applying descriptive statistics, frequency and cluster analysis to derive information about common characteristics at the various sites and potential trends amongst the examined parameters.

The aforementioned data was also imported in ArcView software (GIS) in a tabular form to analyse the spatial component and distribution of the MTP's characteristics. Thematic maps have been produced, presenting the distribution of phytocommunities in the Greek MTP sites, the geological substrate and their eco-status. An analysis of the resulted maps followed to indicate the spatial aspect of the observed trends so as to identify potential relationships between the latitudinal gradient and specific phytocommunities occurrence as well as between island/continental sites and habitats' eco-status and pressures. The latter effort incorporated the socioeconomic component in the assessment since pressures such as tourism is mostly encountered in small and medium sized islands while agriculture can be a significant threat factor in continental areas and in large islands.

All the available information was combined to assess the current status of MTP sites in Greece, with an emphasis on their vegetation and observed pressures. A qualitative comparison was conducted between Greek MTPs and MTPs of other Mediterranean coun-

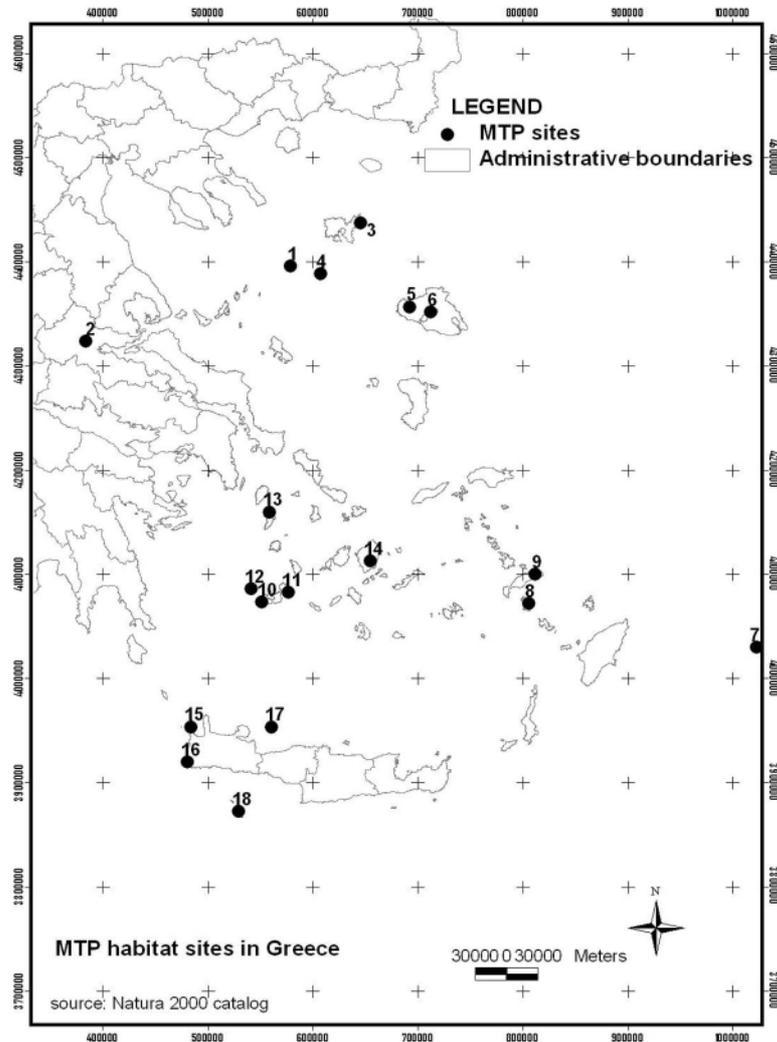


Fig. 1. Location of Greek Mediterranean Temporary Ponds.

tries by the outcomes of the aforementioned analysis (for the Greek sites) and bibliographic data and relevant studies (for the non-Greek sites). Management and conservation issues were also investigated in order to tackle the identified problems and contribute to the restoration of the priority habitat.

## Results

### Phytocommunities of Greek MTPs

A total of 95 plant species were identified in all the Greek MTP sites. Species belonging to the Isoetion phytocommunity (*Callitriche brutia* Petagna, *Tillaea*

*vallantii* Willd., *Elatine macropoda* Guss, *Pilularia minuta* Durieu, *Isoetes hystrix* Bory, etc.), were the most common and dominant phytocommunity of Greek MTPs (fig. 2), followed by species of the Nanocyperion phytocommunity (*Juncus bufonius* L., *Trifolium nigrescens* Viv., *Cyperus fuscus* L., *Juncus hybridus* Brot., etc.). Species of the Isoeto-Nanojuncetea and Zannichellion phytocommunities accounted for 7 % individually. *Carex divisa* Huds., *Bellium minus* L., *Lotus conimbricensis* Brot., and *Spergularia bocconei* Scheele, were the representative species for the former, whereas the latter included *Zannichellia palustris* L., *Ranunculus rionii* L. and *Zannichellia pedunculata* Rchb. Finally, the Thero-Brachypodietalia

Table 1. MTP site codes, names and size (source : Natura 2000 database).

SITE CODE	NATURA CODE	SITE NAME	AREA (ha)
Site 1	GR1430004	ETHNIKO THALASSIO PARKO ALONNISOU - VOREION SPORADON, ANATOLIKI SKOPELOS	249145.62
Site 2	GR2440002	KOILADA KAI EKVOLES SPERCHEIOU - MALIAKOS KOLPOS	47547.07
Site 3	GR4110001	LIMNOS: CHORTAROLIMNI - LIMNI ALYKI KAI THALASSIA PERIOCHI	18231.66
Site 4	GR4110002	AGIOS EFSTRATIOS KAI PARAKTIA THALASSIA ZONI	6283.75
Site 5	GR4110003	LESVOS: DYTIKI CHERSONISOS - APOLITHOMENO DASOS	20974.07
Site 6	GR4110004	LESVOS: KOLPOS KALLONIS KAI CHERSAIA PARAKTIA ZONI	18297.82
Site 7	GR4210004	KASTELLORIZO KAI NISIDES RO KAI STRONGYLI KAI PARAKTIA THALASSIA ZONI	1769.68
Site 8	GR4210007	NOTIA NISYROS KAI STRONGYLI KAI PARAKTIA THALASSIA ZONI	4055.74
Site 9	GR4210008	KOS: AKROTIRIO LOUROS - LIMNI PSALIDI - OROS DIKAIOS - ALYKI-PARAKTIA THALASSIA ZONI	10138.24
Site 10	GR4220005	PARAKTIA ZONI DYTIKIS MILOY	5328.25
Site 11	GR4220006	NISOS POLYAIGOS-KIMOLOS	13855.78
Site 12	GR4220007	NISOS ANTIMILOS-THALASSIA PARAKTIA ZONI	1260.76
Site 13	GR4220010	VOREIODYTIKI KYTHNOS: OROS ATHERAS-AKROTIRIO KEFALOS KAI PARAKTIA ZONI	2855.19
Site 14	GR4220014	KENTRIKI KAI NOTIA NAXOS: ZEFS KAI VIGLA EOS MAVROVOUNI KAI THALASSIA ZONI (ORMOS KARADES-ORMOS MOUTSOYNAS)	8668.41
Site 15	GR4340001	IMERI KAI AGRIA GRAMVOUSA - TIGANI KAI FALASARNA - PONTIKONISI, ORMOS LIVADIA-VIGLIA	5781.30
Site 16	GR4340002	NISOS ELAFONISOS KAI PARAKTIA THALASSIA ZONI	271.79
Site 17	GR4340010	DRAPANO (VOREIOANATOLIKES AKTES) - PARALIA GEORGIOPOLIS - LIMNI KOURNA	4430.51
Site 18	GR4340013	NISOSI GAVDOS KAI GAVDOPOULA	6290.59

phytocommunity (*Plantago weldenii* Reichb. & *Trifolium tomentosum* L.) accounted for 3 % of the total MTP plant communities. At site level, *Juncus bufonius* (Juncaceae) occurred in most MTP sites, thus being the most common species, followed by *Lythrum hyssopifolia* L. (Lythraceae), *Plantago weldenii* (Plantaginaceae) and *Callitriche brutia* (Callitrichaceae).

Regarding the geographic distribution of the dominant MTP phytocommunities in Greece, there is not any obvious pattern (fig. 3). Nevertheless, the Isoetion class is mostly encountered in the islands of central and northern Aegean Sea where more humid conditions occur than in the southernmost located islands of Crete and Gavdos (sites 15,16 and 18), where the phytocommunities of Thero - Brachypodietalia and Zannichellion are encountered. The production of phytocommunity categories of figure 3 covers the site scale and does not represent each pond examined by the responsible scientific team. This explains the existence of categories that incorporate more than one characteristic class of MTP vegetation.

The Cluster analysis performed to investigate ponds with similar plant species composition revealed major differences among sites. As shown in figure 4, the vast

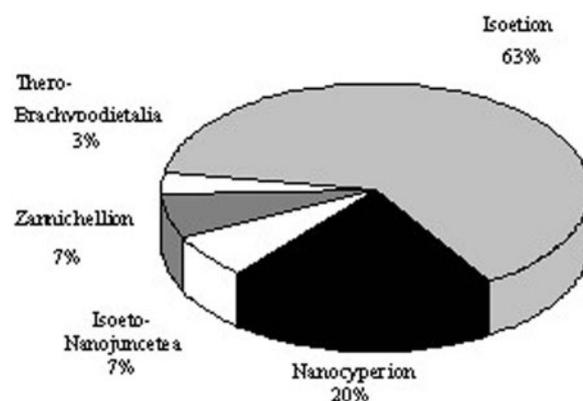


Fig. 2. Dominant phytocommunities of the Greek MTPs.

majority of the sites consisted of different plant species and only 2 groups of the sites had a relatively similar plant community structure (nearly and more than 50% similarity). *Juncus bufonius* was the common species that grouped sites 13 and 8 together, although the geomorphology of these sites was entirely different. Sites 5 and 4 commonly comprised of *Tillaea vaillantii*, *Callitriche brutia* and *Myosurus sessilis* Wats.

Differences in plant composition could be attributed to numerous environmental factors such as altitude, geology, soil type and climate. Mountainous ponds for example, comprise different plant species from ponds that are distributed in sand dunes or coastal plains. Additionally, climatic conditions could play a major role in species distribution. Areas subjected to long droughts (Southeast Aegean islands) are inhabited by species capable of tolerating such conditions.

#### Representativity and environmental characteristics of Greek MTPs

The categorization of representativity of the MTP sites was based on the ecological monitoring and sampling programme conducted for the development of Natura 2000 catalogue. Five representativity classes were used in order to describe the appearance of the typical MTP flora in each habitat. This particular index provides the ability to assess how typical composition of vegetation is at site, while at the same time comprised an indirect measurement of biodiversity.

Of the MTPs examined, 80% presented a “good” and “excellent” representativity of their characteristic phytocommunities, (fig. 5) meaning that there is a significant number of very important habitats that maintain their typical vegetation until today and should be thus managed appropriately to preserve their biodiver-

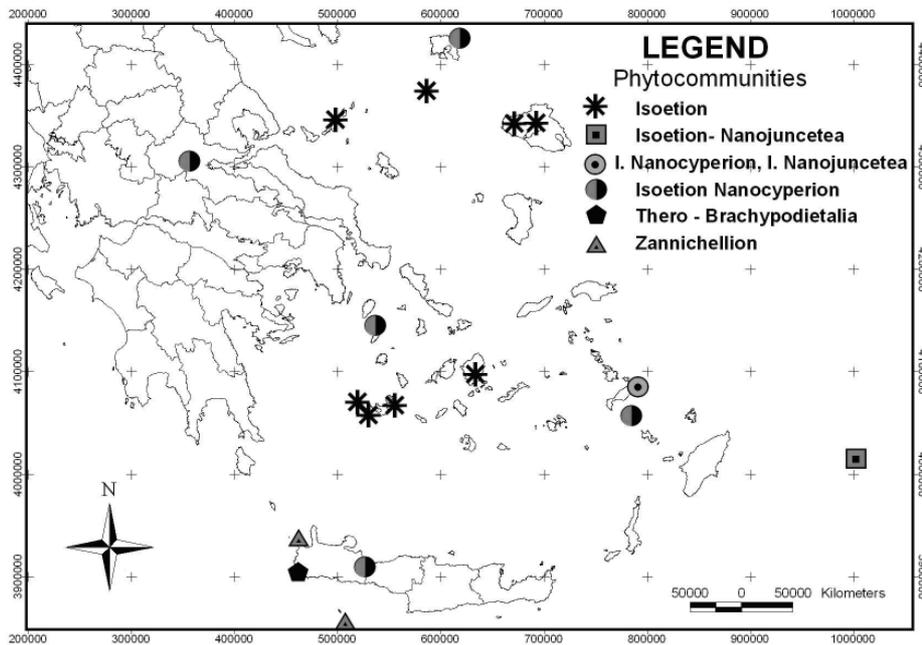


Fig. 3. Map illustrating the representative phytocommunities of each MTP site.

Bray-Curtis Cluster Analysis (Complete Link)

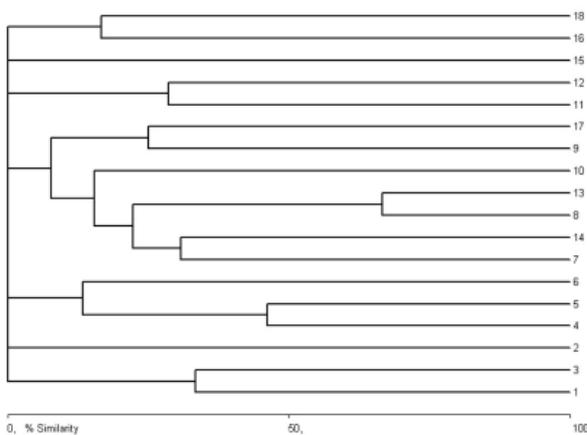


Fig. 4. Dendrogram presenting group of sites with similar plant species.

sity. “Medium” and “bad” representativity was presented by 17% of the sites indicating the existence of significantly degraded sites probably due to human interventions.

Approximately 56% of the MTP sites are located on sedimentary geological substrate (fig. 6) of which 70%

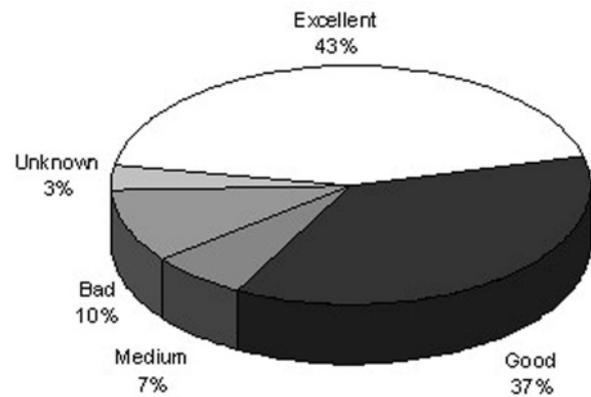


Fig. 5. Representativity of MTPs.

comprises alluvial sediments, silt and sand and 30% consists of limestone. Siliceous formations comprise the substrate of five sites, mainly incorporating volcanic rocks. The geographic distribution of MTP’s with sedimentary formations as substrate is wide, while siliceous substrate is only encountered in three islands of central Aegean Sea (in the Cyclades complex) and in one island of eastern Aegean (Nisiros) that has had volcanic activity in the past. The correlation of phytocom-

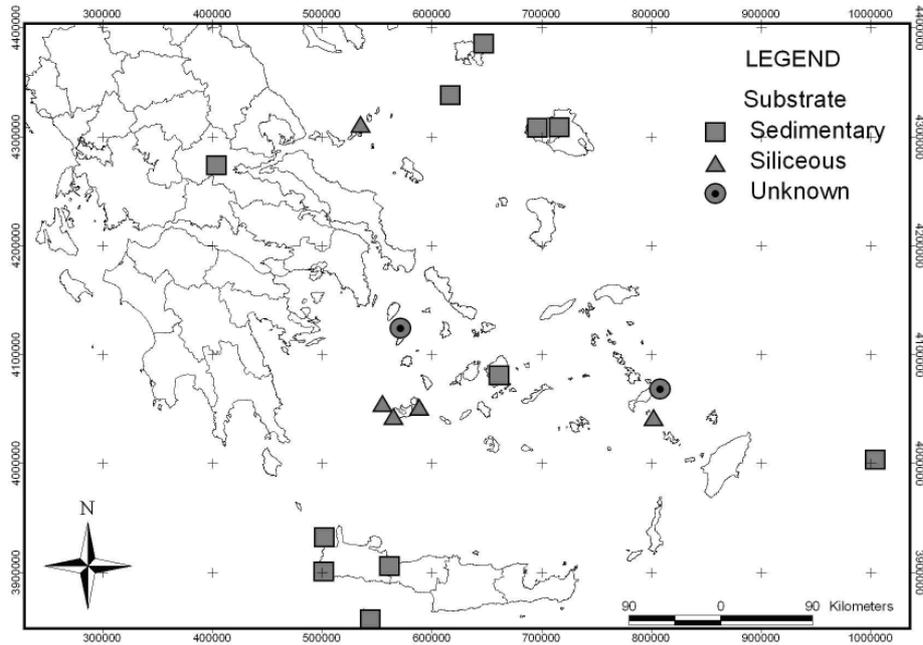


Fig. 6. Map illustrating the geology of each MTP site.

munities with the substrate types indicated that Isoetion is encountered mostly on siliceous formations since approximately 80% of the ponds containing species from the particular class have silica sediments as a geological substratum while for the other classes there is not any significant relationship with the substrate type.

The MTP's in Greece were observed mostly in lowlands since the altitude of all the sites, except the one located on Gavdos island (site 18), was below 300 m above sea level. Moreover, 33% of the sites were encountered in altitudes below 30 m and 44% of the MTP's were located between 30 and 300 m of elevation while some ponds on Gavdos Island were slightly above 300 m (fig. 7).

**Threats and eco-status of Greek MTPs**

The ecological status of the MTP's indicates the pressures that they receive and illustrates significant threats due to human activities. Only 3 sites have "excellent" and "good" eco-status, reflecting minimum levels of pressure and threats, while 33% of the ponds have "medium" eco-status and approximately 40% of the sites are "at risk" (figs. 8 and 9). The sites under immediate risk are mostly located in the northern and central islands of the Aegean Sea while sites in southern and eastern Aegean Sea have mainly medium

ecological status (fig 8). This pattern is probably observed due to the relatively low human pressure existing in the south-eastern part of the country where climatic conditions are not favourable for agriculture and the significant distance from urban areas (Athens) obstructing intense development activities.

All sites, except one (site 1), are affected by anthropogenic pressures such as, overgrazing, agriculture and hydrological disturbance also comprising the most common threats on MTPs throughout Greece. Only site 1 has been unaffected by anthropogenic causes while sites 2, 14 and 16 received more pressures (3 different categories) than the rest of the sites (table 2).

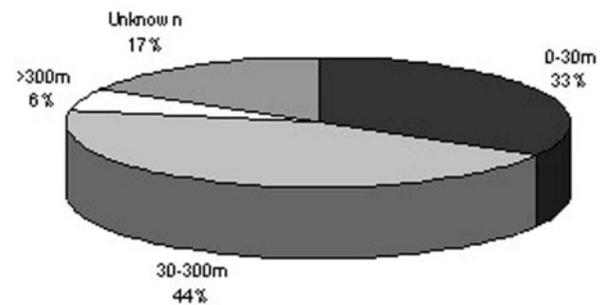


Fig. 7. Altitudinal distribution percentage of Greek MTPs.

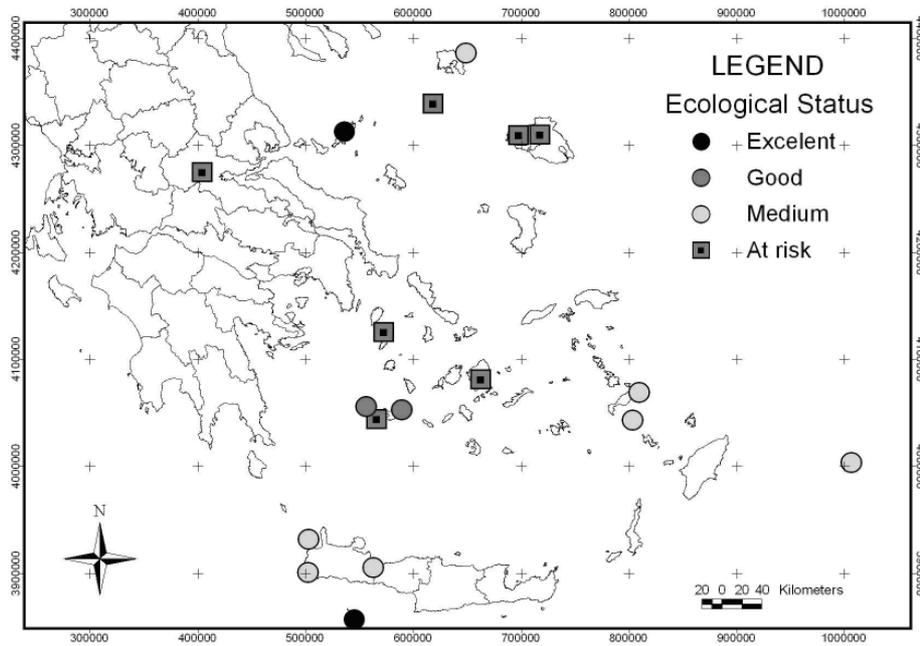


Fig. 8. Ecological status of Greek MTPs.

The pressure category that affects most of the MTP sites is agriculture which has both direct disturbances, loss of habitat through the expansion of cropland, and indirect disturbances such as water pollution. This pressure exists in 29% of all the MTP sites in Greece (figure 9) while hydrologic disturbance problems and overgrazing follow with 19% and 16% of the MTP sites, respectively. Soil excavation from the ponds is the next most common threat which is also related to agriculture and urban development while tourism pressure appears in 11% of the sites mainly due to lack of public awareness on the habitat's ecological/conservation value. The sites that are probably not under threat today represent only 3% of the total MTP sites, which is a significant figure and indicates that immediate actions should commence to protect the MTPs from potential degradation.

Agricultural activities and hydrologic destabilization are today the most significant threats to MTP habitats in Greece (table 2). Agricultural intensification in combination with the use of fertilizers and pesticides can lead to groundwater pollution, significantly affecting the ponds. Hydrologic disturbances mostly originate from human activities including direct water abstraction from the ponds and direct lowering of the

groundwater level (being hydraulically connected to the ponds) as a result of aquifer overexploitation. Overgrazing is also a very important threat for the MTP's since the intensification of stockbreeding in these areas during past decades has affected the vegetation composition and species abundance to a great extent. Furthermore, soil excavation is very often related to horticulture since the dredged material is mainly used as a substrate in greenhouses and in some cases for fertilization. Finally, tourism also imposes some pressure on the habitat since 95% of the MTP sites are located on islands that receive significant number of visitors during the summer months.

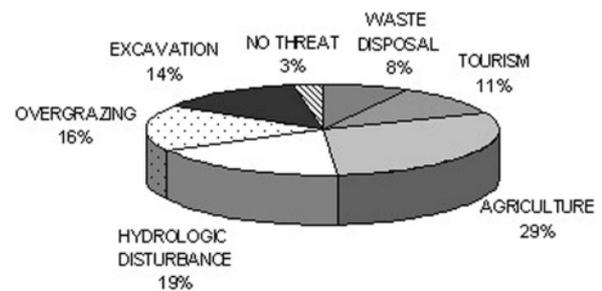


Fig. 9. Types of pressures that degrade MTPs and their percentages.

Table 2. Table demonstrating common threats on Greek MTPs.

SITE CODE	NATURA CODE	WASTE DISPOSAL	TOURISM	AGRICULTURE	HYDROLOGIC DISTURBANCE	OVERGRAZING	EXCAVATION	NO THREAT
Site 1	GR1430004							✓
Site 2	GR2440002	✓		✓	✓			
Site 3	GR4110001			✓				
Site 4	GR4110002						✓	
Site 5	GR4110003						✓	
Site 6	GR4110004				✓		✓	
Site 7	GR4210004				✓			
Site 8	GR4210007		✓					
Site 9	GR4210008				✓	✓		
Site 10	GR4220005			✓				
Site 11	GR4220006		✓	✓				
Site 12	GR4220007			✓		✓		
Site 13	GR4220010				✓			
Site 14	GR4220014	✓		✓	✓			
Site 15	GR4340001			✓			✓	
Site 16	GR4340002		✓	✓			✓	
Site 17	GR4340010		✓				✓	
Site 18	GR4340013			✓		✓		

## Discussion

Temporary ponds are freshwater habitats which favour the establishment of unique and diverse fauna and flora communities. Due to their unstable ecological conditions, living organisms need to be highly adaptable. Comparing the flora characteristics of the Greek MTPs with the respective habitat in other Mediterranean countries several similarities were observed as well as, some differences. *Isoetes* community is encountered in most MTP's throughout the Mediterranean region while several endemic species are also found in different sites such as *Isoetes heldreichii* Wettst. in Greece, *Ranunculus revelieri* Boreau in Corsica, *Eryngium atlanticum* Batt. & Pit., in Morocco, *Artemisia molinieri* Quézel, M.Barbero & R.JLoisel, in Provence and *Marsilea bartardae* Launert in the Iberian Peninsula (Grillas et al. 2004a, Rhazi et al. 2004). The observed differences in flora composition at the various countries and sites are contributed to the diversity of hydrologic conditions and depend on the timing and duration of the inundation phase. The peridophytes *Isoetes*, *Marsilea* and *Pilularia* have variable water requirements, whereas species of *Callitriche*, *Ranunculus*, *Lythrum*, *Eryngium* and *Solenopsis* depend strictly on flooding conditions (Grillas et al. 2004a, Rhazi et al. 2004, Warwick & Brock 2003).

Thus, many local and rare species are expected to be found in these habitat types while *Callitriche* and *Elatine* are considered to be the most threatened plant species in MTPs throughout Europe (Grillas et al. 2004a, Keeley & Zedler 1996). It was observed from the cluster analysis of the Greek MTPs that almost each pond consisted of different plant communities. This is due to the significant variety in environmental conditions observed in the examined habitat sites that present a wide spatial distribution. Particularly, the dominant climatic conditions between the southeast islands in the Aegean sea and the habitat sites in central Greece have significant differences both in seasonal and annual basis. The extended drought periods in these islands causes a very low duration of flooding in the ponds that may be classified as ephemeral or episodic while in the humid areas of the country (rainfall > 600mm annually) MTPs may operate as intermittent or seasonal and therefore respective alterations in the vegetation are observed.

Common pressures were also found in various sites of Mediterranean region. Agricultural activities, water abstraction directly and indirectly from the ponds, as well as, urban development are the most commonly encountered pressures (Beja & Alcazar 2003, Blaustein & Schwartz 2001, Brendonck & Williams 2000, King 1996). Additional impacts are observed in touristic areas where recreational activities often degrade the habitat and therefore measures to inform public and establish conservation schemes should be initiated at European level.

The considerable pressures imposed on the MTP habitat throughout Greece and other Mediterranean countries and the decline of the habitat's ecological status illustrate the necessity for the implementation of management and conservation measures (Boix et al. 2001, Brendonck & Williams 2000). Particularly, increasing public awareness on the values of the MTPs and explaining the benefits that could derive from their conservation is a very important issue when aiming to achieve a long-term protection while a stakeholder participatory approach in designing management schemes is also a prerequisite for achieving a broad consensus.

Management of MTP habitats should also focus on re-establishing the hydroperiod of each pond by applying hydrologic models and other scientific tools so as to estimate the natural duration of flooding, potential human interferences and effects of climate change. Interfering with the morphology of the pond by altering / deepening the bed should be avoided, especially during the dry period, since it may cause loss of plant seeds and macroinvertebrates (Nicolet et al. 2004).

Conservation measures should be undertaken on ponds of different sizes and it would be preferable to include many small ponds rather than one large pond, since in this way a substantial variety of microhabitats can be preserved. Additionally, the creation of MTP(s) in highly degraded habitat sites can be also a beneficial option given the existence of thorough ecological and hydrologic studies (Grillas et al. 2004a).

A simple typology system for temporary ponds should be developed in order to assist in the classification of the ponds according to their characteristics and key components which mostly determine their biotic properties. Additionally, an ecological monitoring program should be initiated for assessing the status of each habitat and for managing the phytocommunities so as to ensure maintenance of the typical MTP species and limited competition from other common species.

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