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A novel use of the caesium-137 technique to estimate human interference and historical water level in a Mediterranean Temporary Pond

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ABSTRACT

The sustainability of, and the effects of human pressures on, Omalos Mediterranean Temporary Pond (MTP), Chanea, Greece was assessed. The ^{137}Cs technique was used to identify alleged anthropogenic interference (excavation) in the studied area. It was found that about one third of the ponds bed surface material had been removed and disposed of on the northeast edge, confirming unplanned excavations that took place in the MTP area some years ago. Nonetheless, five years after the excavation, the MTP's ecosystem (flora and fauna) had recovered, which indicates that these small ecosystems are resilient to direct human pressures, like excavations. Moreover, with the ^{137}Cs technique it was possible to identify the historical water level of Omalos MTP, when the fallout from the Chernobyl accident reached this area, in May of 1986. Therefore, the ^{137}Cs technique can be useful in the identification of the historical water level of small MTPs and other ephemeral water bodies. Applications include the verification and validation of hydrological models.

1. Introduction

Wetlands are being created and restored with great frequency around the world. The importance of wetland conservation is recognized worldwide, because they represent hot spots of biological richness as well as being a source to humans of freshwater and food. Wetlands are very diverse in their nature, ranging from open water to forested ecosystems or from shallow permanent lakes to temporary ponds. In terms of conservation, some temporary standing freshwater wetlands are considered important habitats for conservation and are recognized by the Ramsar Convention on Wetlands. Furthermore, some are classified as priority habitats by the European Union Habitats Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (European Commission, 2007). Temporary ponds are shallow water bodies that remain flooded for a sufficiently long period of time during winter and spring to allow the development of (semi) aquatic vegetation and animal communities. They often occur in shallow depressions over impermeable ground and have a relatively small catchment area. The depressions present significant variability in size, shape and depth but are relatively small and shallow endorheic water bodies, which are flooded, during the rainy season, for a sufficiently long period to allow the development of aquatic vegetation and hydromorphic soils, but are not in contact with permanently flooded habitats, such as rivers. The hydrological dynamics of these ponds and the consequent temporary availability of resources are crucial for these habitats' species specificity and diversity (Bejaa and Alcazarc, 2003; Dimitriou et al., 2006; Zacharias et al., 2007; Canals et al., 2011; Pinto-Cruz et al., 2011).

There is not yet a widely accepted classification system for temporary ponds. They are globally known under more than 30 different names; vernal pools, daya's, brumal pools, copular pools, ephemeral waters, etc. and in Greece with different names: arolithoi, rousies and kolympes. In the Mediterranean region there are many types of temporary ponds. They vary from small ponds to almost permanent lakes. In particular, Mediterranean temporary ponds (MTPs) are considered one of the most remarkable and threatened freshwater European habitats. MTPs are poorly understood and highly endangered, suffering widespread degradation

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and loss due to increases in the area of land under intensive cultivation and urban use (Bejaa and Alcazarc, 2003; Zacharias et al., 2007).

In Greece there are 18 temporary ponds sites, 73% of which are encountered in the Aegean islands (Fig. 1). The island of Crete has the highest presence of temporary ponds, compared to any other region in the country. The amount of rainfall in these islands rarely exceeds 600 mm a year and the prolonged dry period prevents permanent dominance of aquatic vegetation. Therefore, a primary determinant of species distributions and ecosystem processes is water availability, which is strongly affected by climatic conditions and human landscape use. To add, soil moisture and surface water level are key determinants of plant community composition and ecosystem function (Maclean et al., 2012). For these reasons, a knowledge of the historical water level of a MTP can infer a better understanding of its seasonal function and the phytoplankton assemblage; providing information about its sustainability. Moreover, this knowledge can be used as input for the verification, validation, and confirmation of mathematical and numerical models (Oreskes et al., 1994; Synolakis et al., 2008) that simulate long term water conditions and temporal scales of MTP and other temporary or permanent water ponds.

Caesium-137 (^{137}Cs) is an artificial radionuclide that was injected into the atmosphere mainly through the detonation of nuclear weapons and tests from the 1940s until the late 1970s and later on from the Chernobyl accident in 1986. When dust with the ^{137}Cs isotope settles on the ground, ^{137}Cs strongly bonds with soil particles, limiting its movement by chemical and biological processes (Ritchie and McHenry, 1990). From there on, any redistribution of ^{137}Cs, which can be measured via its strong gamma emission at 661.7 keV, a process known as the ^{137}Cs technique, represents erosion and deposition patterns on the landscape (Kaste et al., 2006).

The ^{137}Cs technique has been successfully used for estimation of soil redistribution (erosion, accretion) by anthropogenic (e.g. tillage, urbanization activities etc) and natural (aeolian forces, precipitations) pressures over the last 30–50 years (Chappell et al., 2011); while, recent papers from various countries continue to investigate the ^{137}Cs specific activity in soil samples (Antovic et al., 2012; Daraoui et al., 2012; Szabó et al., 2012). Moreover, a coordinated research project on assessing the effectiveness of soil conservation measures on erosion control has been organized by the International Atomic Energy Agency and its main conclusions have been recently published in a review paper (Dercon et al., 2012). Using a reference site, information about the evolution of adjacent areas can be extracted, since areas with higher ^{137}Cs yield are assumed to be areas of aggradation, and the areas with lower ^{137}Cs yield are assumed to have undergone topsoil erosion. Moreover, sediment horizons and accumulation rates can be estimated by identifying ^{137}Cs vertical distribution (Ritchie and McHenry, 1990). In the present work the ^{137}Cs technique was used to identify the percentage of human disturbance (excavation) in Omalos MTP and for another novel use, which is the identification of the ponds' historical water level in May 1986, when Chernobyl fallout reached the area.

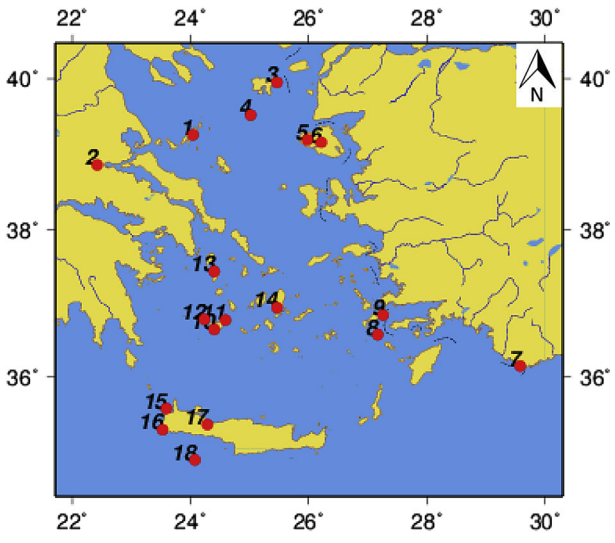

Fig. 1. Spatial distribution of the Greek Temporary Ponds.

2. Methodology

2.1. Study area and background of the problem

The Omalos plateau is located in the Lefka Ori Mountains of Crete, Greece, at a mean altitude of 1.1 km above MSL, and is mainly used for agricultural activities. The mean annual rainfall is 1093.7 mm and the mean annual temperature is 9.3 °C (Ghosn et al., 2010). The geologic formations of the plateau are mainly metamorphic carbonate rocks belonging to either the Trypali Unit or the Plattenkalk Group, which are covered by Quaternary deposits. The Omalos plateau is the largest active polje of Western Crete and covers an area of approximately 6 km^2 (Alevras et al., 2007). It is an ecologically sensitive area, which is protected by a Natura 2000 network and it belongs to the Special Area of Conservation (SAC) named GR4340008 "LEFKA ORI KAI PARAKTIA ZONI". Since 2002, it is part of "Samaria National Park". The plateau accommodates the natural MTP of Omalos (Fig. 2), which is a priority habitat (Natura code: 3170*) in Annex I of the Directive 92/43/EEC. Due to its specific characteristics this pond has suffered significant human pressures and therefore may be prone to extinction.

Omalos MTP has a circular shape, with a maximum area of 8000 m^2 and a maximum depth of 2.6 m, while the catchment of the lake is approximately 10,000 m^2 (Stamati et al., 2008). Its bottom has mild slope and high accessibility and for this reason during summer it is used as a livestock watering reservoir. In winter, it concentrates runoff (rain and snow) and during the summer this water volume is slowly removed by evaporation and livestock watering needs, leading to highly seasonal water level changes (Fig. 2). The main environmental pressure is livestock breeding, since Stamati et al. (2008) estimated that 10,000 sheep and goats graze in the catchment of the pond.

It has to be noted that human interference on MTPs should be avoided, since it can alter seasonal patterns, affect the richness of phytoplankton assemblages and threaten their sustainability (Naselli-Flores, & Barone, 2012). Nonetheless, all MTPs of Greece, except one, are affected by anthropogenic pressures such as, overgrazing, agriculture and hydrological disturbance. The most common threat to the habitat originates from intensive agriculture which either expands over the temporary ponds or pollutes their water with fertilizers. In some cases, there is also artificial recharge of temporary ponds as a restoration practice, which often results in an extended wetting phase and can even make the ponds permanent (Dimitriou et al., 2006; Zacharias et al., 2007).

The anthropogenic pressures on Omalos MTP did not stop at overgrazing and hydrological disturbance. Due to the high watering needs of livestock, an unplanned excavation took place in August 2006. According to eyewitnesses' reports, surface material was removed, by a small excavator, from the ponds center and was disposed of somewhere at the north edge, which at that time had lower topography compared to the other edges. Within hours, the