NATIONAL AND KAPODISTRIAN UNIVERSITY OF ATHENS
SCHOOL OF SCIENCE
FACULTY OF BIOLOGY
DEPARTMENT OF BOTANY

Conservation of priority forests and forest openings in "Ethnikos Drymos Oitis" and "Oros Kallidromo" of Sterea Ellada

LIFE11 NAT/GR/1014 - "ForOpenForests"

ACTION A.3.

Determination of vegetation structure and of flora and fauna composition and phenology in the Mediterranean temporary ponds (3170*)

DELIVERABLE A.3.2

Specifications for the restoration of temporary pond biotic communities in Mt. Oiti and Mt. Kallidromo

Pinelopi Delipetrou, Irini Vallianatou,Kyriacos Georghiou

ATHENS DECEMBER 2015

The project is co-funded by the European Commission financial instrument Life+

ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ΣΧΟΛΗ ΘΕΤΙΚΩΝ ΕΠΙΣΤΗΜΩΝ
ΤΜΗΜΑ ΒΙΟΛΟΓΙΑΣ
ΤΟΜΕΑΣ ΒΟΤΑΝΙΚΗΣ

Διατήρηση δασών και ανοιγμάτων προτεραιότητας στον "Εθνικό Δρυμό Οίτης" και στο "Όρος Καλλίδρομο" της Στερεάς Ελλάδας
LIFE11 NAT/GR/1014 - "ForOpenForests"

ΔΡΑΣΗ Α.3.
Καθορισμός της δομής της βλάστησης και της σύνθεσης και της φαινολογίας της χλωρίδας και της πανίδας στα Μεσογειακά εποχιακά λιμνία (3170*)

ΠΑΡΑΔΟΤΕΟ Α.3.2
Προδιαγραφές για την αποκατάσταση των βιοτικών κοινοτήτων των εποχιακών λιμνίων στα όρη Οίτη και Καλλίδρομο

Πηνελόπη Δεληπέτρου, Ειρήνη Βαλλιανάτου, Κυριάκος Γεωργίου

Proposed reference: Delipetrou P., Valianatou I., Georghiou K. 2015. Specifications for the restorationm of biotic communities in Mt. Oiti and Mt. Kallidromo. Deliverable A.3.2 for the project LIFE11 NAT/GR/2014 - ForOpenForests. National and Kapodistrian University of Athens - HSPN, 17 p.

Table of Contents

SUMMARY

The base studies of the abiotic and biotic factors of the temporary ponds of the project sites on Mt. Oiti and Mt. Kallidromo indicated that restoration of biotic communities should applied in the ponds of Louka, Nevropoli and Mourouzos-Mouriza. Heavy grazing and trampling by animals occurs in all of the above ponds and infrequent grazing occurs at the pond of Alykaina. Trampling by vehicles occurs in all ponds but is is heavy only at the same four ponds. So, two types of fences were prescribed: poles prohibiting the entrance of vehicles and poles plus horizontal planks prohibiting the entrance of animalas as well. The effect of grazing on the communities of the temporary ponds in the project sites has not been explored. Based on the above, the following restoration procedures are specified:

- Ponds of Livadies and Greveno. Fencing with poles.
- Pond of Alykaina. Fencing in part with poles and in part with poles and horizontal planks.
- Pond of Louka. Fencing in part with poles and in part with poles and horizontal planks. Restoration of biotic communities by pot-planting of seedlings and by seeding of the species *Ranunculus lateriflorus*, *Lythrum thymifolia*, *Myosurus minimus*, and *Veronica oetaea*. Removal of the dry grassland species *Convolvulus betonicifolius*.
- Pond of Nevropoli. Fencing in part with poles and in part with poles and horizontal planks. Restoration of biotic communities by pot-planting of seedlings and by seeding of the species *Verbena supina*, *Heliotropium supinum*, and *Mentha pulegium*. Removal of the native or alien invasive species *Xanthium spinosum*, *Cirsium vulgare*, *Cynodon dactylon*, and *Echinochloa crus-galli* mainly by mechanical means.
- Ponds of Mourouzos and Mouriza. Fencing of Mouriza part with poles and of Mourouzos with poles and horizontal planks. Restoration of biotic communities by pot-planting of seedlings and by seeding of the species *Verbena supina*, *Heliotropium supinum*, and *Mentha pulegium*. Removal of the native or alien invasive species *Xanthium spinosum*, and *Cynodon dactylon* mainly by mechanical means.

ΠΕΡΙΛΗΨΗ

Οι μελέτη των αβιοτικών και βιοτικών παραγόντων των εποχιακών λιμνίων στις περιοχές του έργου στα όρη Οίτη και Καλλίδρομο υπέδειξε ότι στα λιμνία Λούκα, Νεβρόπολη και Μουρούζος-Μουρίζα ενδείκνυται αποκατάσταση των βιοτικών κοινοτήτων. Όλα αυτά τα λιμνία υφίστανται έντονη βόσκηση και ποδοπάτημα από ζώα ενώ λιγότερο συχνή βόσκηση παρατηρείται στο λιμνίο Αλύκαινα. Καταπάτηση από οχήματα παρατηρείται σε όλα τα λιμνία, αλλά είναι έντονη μόνο στα τέσσερα παραπάνω. Αποφασίστηκε η τοποθέτηση δύο τύπων φρακτών, μόνο με πασσάλους που εμποδίζουν την είσοδο των οχημάτων και με πασσάλους ενωμένους με οριζόντιες σανίδες που εμποδίζουν την είσοδο και των οχημάτων και των ζώων. Οι επιπτώσεις της βόσκησης στις κοινότητες των εποχιακών λιμνίων των υπό μελέτη περιοχών δεν έχουν διερευνηθεί. Βάσει των παραπάνω, δίνονται οι ακόλουθες προδιαγραφές:

- Λιμνία Λιβαδιές και Γρεβενό. Περίφραξη με πασσάλους.

- Λιμνίο Αλύκαινα. Περίφραξη ενός τμήματος με πασσάλους και του άλλου τμήματος με πασσάλους και οριζόντιες σανίδες.
- Λιμνίο Λούκα. Περίφραξη ενός τμήματος με πασσάλους και του άλλου τμήματος με πασσάλους και οριζόντιες σανίδες. Αποκατάσταση των βιοτικών κοινοτήτων με φύτευση σε γλάστρες και με σπορά των ειδών *Ranunculus lateriflorus*, *Lythrum thymifolia*, *Myosurus minimus*, and *Veronica oetaea*. Απομάκρυνση του είδους ξηρών λιβαδιών *Convolvulus betonicifolius*.
- Λιμνίο Νεβρόπολη. Περίφραξη ενός τμήματος με πασσάλους και του άλλου τμήματος με πασσάλους και οριζόντιες σανίδες. Αποκατάσταση των βιοτικών κοινοτήτων με φύτευση σε γλάστρες και με σπορά των ειδών *Verbena supina*, *Heliotropium supinum*, and *Mentha pulegium*. Απομάκρυνση των εισβολικών ιθαγενών ή επιγενών ειδών *Xanthium spinosum*, *Cirsium vulgare*, *Cynodon dactylon*, and *Echinochloa crus-galli* κυρίως με μηχανικό τρόπο.
- Λιμνία Μουρούζος και Μουρίζα. Περίφραξη της Μουρίζας με πασσάλους και του Μουρούζου με πασσάλους και οριζόντιες σανίδες. Αποκατάσταση των βιοτικών κοινοτήτων με φύτευση σε γλάστρες και με σπορά των ειδών *Verbena supina*, *Heliotropium supinum*, and *Mentha pulegium*. Απομάκρυνση των εισβολικών ιθαγενών ή επιγενών ειδών *Xanthium spinosum* και *Cynodon dactylon*.

1. General outlook

The aim of this deliverable is to present the rationale for the application of restoration interventions for the biotic communities in the temporary ponds of Mt. Oiti and Mt. Kallidromo to be enacted by action C.4 of the project and specify the intervention modes and technical details based on the studies of the abiotic (action A.2) and biotic (action A.3) components of the ponds.

The base study of the abiotic factors proved that the hydrological status of all the ponds is undisturbed with the exception of the flow of additional fresh water in Nevropolis pond. The base study of the biotic communities identified degradation of the typical temporary pond vegetation in the ponds of Louka, Mourouzos, Mouriza, and Nevropoli. This degradation in all the four ponds is apparently due to trampling by animals and vehicles and heavy grazing or overgrazing. On the contrary, the plant communities at the ponds of Livadies, Greveno, and Alykaina on Mt. Oiti are at an excellent status regarding the plant community composition which is influenced only by natural wet and dry phase fluctuations due to meteorological conditions. The ponds of Livadies and Greveno are grazed or trampled by animals or cars infrequently and there were no signs of vegetation degradation due to grazing. The pond of Alykaina is grazed and trampled mainly by animals more frequently, but the impact on the plant communities seems to be very low.

Thus, pilot restoration interventions on the biotic communities were deemed necessary only in the four ponds of Louka, Mourouzos, Mouriza, and Nevropoli but it was decided that all ponds should be fenced in order to prevent the access of vehicles. The central principle in the restoration specifications will be the effort to be in accordance with both the recruitment and the adult (habitat niche) of the species in the communities involved because this will ensure the long term viability of restoration and will not cause artificial range extensions (Young et al. 2005). This means that restoration interventions will focus rather in assisting the establishment of species known to occur and reproduce at the ecological settings of the restoration sites than in creating brand new communities. Moreover, the plant material will originate from local sources, specifically from seed collections performed by action C.7 of the project and there will be a special effort to avoid contamination of the soil used for producing seedlings.

The restoration interventions are pilot and the effects of grazing unexplored in the project ponds, so planning should include plots with grazing-animal trampling and no restoration interventions (no intervention), grazing-animal trampling and restoration interventions (grazing control), no grazing-animal trampling and no restoration inteventions (no grazing control), and no grazing-animal trampling and restoration inteventions (intervention).

Based on the above, specifications for fencing of the ponds were prescribed (Action A.8). Specifically two types of fencing, poles preventing the entrance of vehicles and poles with horizontal planks preventing the entrance of both vehicles and animals, were planned as follows:

- Livadies and Greveno ponds: only poles, no interventions and no reason for preventing animals.

- Alykaina and Louka ponds: only poles for one part of the pond (grazing control) and poles with planks for the other part in order to assess the influence of grazing in both ponds and in order to protect the restoration intervention sites in Louka.
- Mourouzos and Mouriza ponds: only poles for Mouriza (control and grazing control) and poles with planks for Mourouzos (interventions) in order to assess the influence of grazing and in order to protect the restoration intervention sites.
- Nevropoli pond: only poles around the whole perimeter of the pond and poles with planks at two large parts of the lake in order to assess the influence of grazing and in order to protect the restoration intervention sites.

2. Rationale and description of restoration interventions

2.1 Louka pond

The pond of Louka, regarding its geomorphological, hydrological, and geochemical attributes is not identical but similar to the other ponds of Oiti (Action A.2). The plant communities of the pond are also not identical to those of the other ponds of Oiti but belong to the same higher syntaxa differing mainly due to the presence of the species *Mentha pulegium* (Action A.3). The dominance of the latter species may be in part due to its ability to thrive under the pressure of grazing and trampling. Degradation of the pond vegetation is evident in the large participation of dry grassland and pioneer nitrophilous species which are resistant to trampling and not restricted to the transitional zone to grassland. Degradation may be due to trampling and heavy grazing but, on the other hand, grazing may be preventing the growth of elophytes such as *Eleocharis palustris* and *Juncus compressus*.

The restoration of the temporary pond communities will be made by:

- planting the annual species *Ranunculus lateriflorus*, *Myosurus minimus*, and *Lythrum thymifolia* which already grow in the pond and the species *Veronica oetaea* which does not grow in the pond (see deliverable A.4.2),
- removing the geophyte *Convolvulus betonicifolius* (throughout the intervention area).

The restoration regime (Figure 1) will include no grazing-animal trampling and restoration inteventions (intervention), grazing-animal trampling and restoration interventions (grazing control), and grazing-animal trampling and no restoration interventions (no intervention). The treatment no grazing-animal trampling and no restoration inteventions (no grazing control) will not be applied because the pond is very small and the fenced area will be also used for the establishment of *Veronica oeataea*.

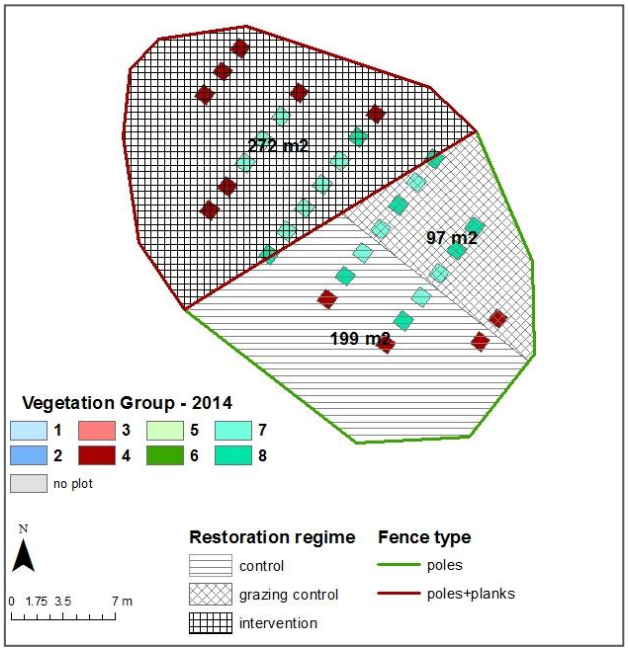

Figure 1. Restoration regime at the pond of Louka.

The plants will be planted in pots in mosaics at openings of the current vegetation or seeded with a seed mixture throughout (see section 3) and the planting scheme, taking into account community composition at various pond depths (Action A.3), will be:

- *Ranunculus lateriflorus* pot-planting at 5% of the intervention area and seeding (10% of seed mixture) at the zone of vegetation groups 7 and 8.
- *Lythrum thymifolia* pot-planting at 5% of the intervention area and seeding (10% of seed mixture) at the zone of vegetation groups 4, 7, and 8.
- *Myosurus minimus* pot-planting at 5% of the intervention area and seeding (10% of seed mixture) at the zone of vegetation group 4.
- *Veronica oetaea* pot-planting at 20% of the intervention area and seeding (see deliverable A.4.2).

Planting will take place while the soil is still innundated but with no open water surface, in early or late May, depending on the status of the pond. Seeding will take place in September or early October, before the autumn rains. Removal of *Convolvulus betonicifolius* will take place immediately before the planting and seeding operations. Plantings and removals will be repeated for at least a second year, as necessary based on monitoring (action D.1).

It must be noted that, except from *Veronica oetaea*, all the other species to be used in the restoration are expected to exist in the soil seed bank of the pond (Aponte et al. 2010 and preliminary results of the soil seed bank of the ponds of Oiti in action C.7). Planting is deemed necessary because *Convolvulus betonicifolius* will be removed, so there needs to be a prompt replacement and also to enhance the chances of typical temporary pond species for establishment at the expense of others.

2.2 Nevropoli pond

The pond of Nevropoli is under heavy grazing and animal trampling and also suffers from trampling by vehicles while the hydrological status is being modified by fresh water flow. The temporary pond vegetation degradation is evident in the invation of thistles or other nitrophilous synanthropic plants including alien species in large parts of the pond, especially at the peripheral parts where the conditions are most suitable for the vegetation of the temporary ponds. The main invading native nitrophilous species are *Cirsium vulgare* and *Cynodon dactylon* and the main invading alien nitrophilous species are *Xanthium spinosum* and *Echinochloa crus-galli*. They are all epizoochorous (adapted to dispersal by animals) except from *Echinochloa crus-galli* which however can be carried by livestock and is easily dispersed by wind or as a soil contaminant (CABI 2016). Also, all the four species can be carried in debris associated with human activities, agricultural machinery, or wheels. Heavy grazing and trampling by animals on the one hand encourage the thistles and other nitrophilous plants, increase the turbidity of the water, and also cause extended disturbance of the soil which prevents the growth of small annuals and even of *Mentha pulegium*. On the other hand, grazing keeps under control the helophyte *Eleocharis palustris* and the alien species *Echinochloa crus-galli*, although it does not affect much the expansion of the grass

Cynodon dactylon which can withstand severe grazing pressure and trampling (Mueller et al. 1995, AGP 2015).

The restoration of the temporary pond communities will be made by:

- removal of thistles, mainly *Cirsium vulgare* and *Xanthium spinosum*,
- removal of other nitrophilous invading species, mainly *Cynodon dactylon* and *Echinochloa crus-galli*,
- planting of the typical temporary pond species *Verbena supina*, *Heliotropium supinum*, and *Mentha pulegium*.

The restoration regime (Figure 2) will include no grazing-animal trampling and restoration inteventions (intervention), grazing-animal trampling and restoration interventions (grazing control), no grazing-animal trampling and no restoration interventions (no grazing control), and grazing-animal trampling and no restoration interventions (no intervention).

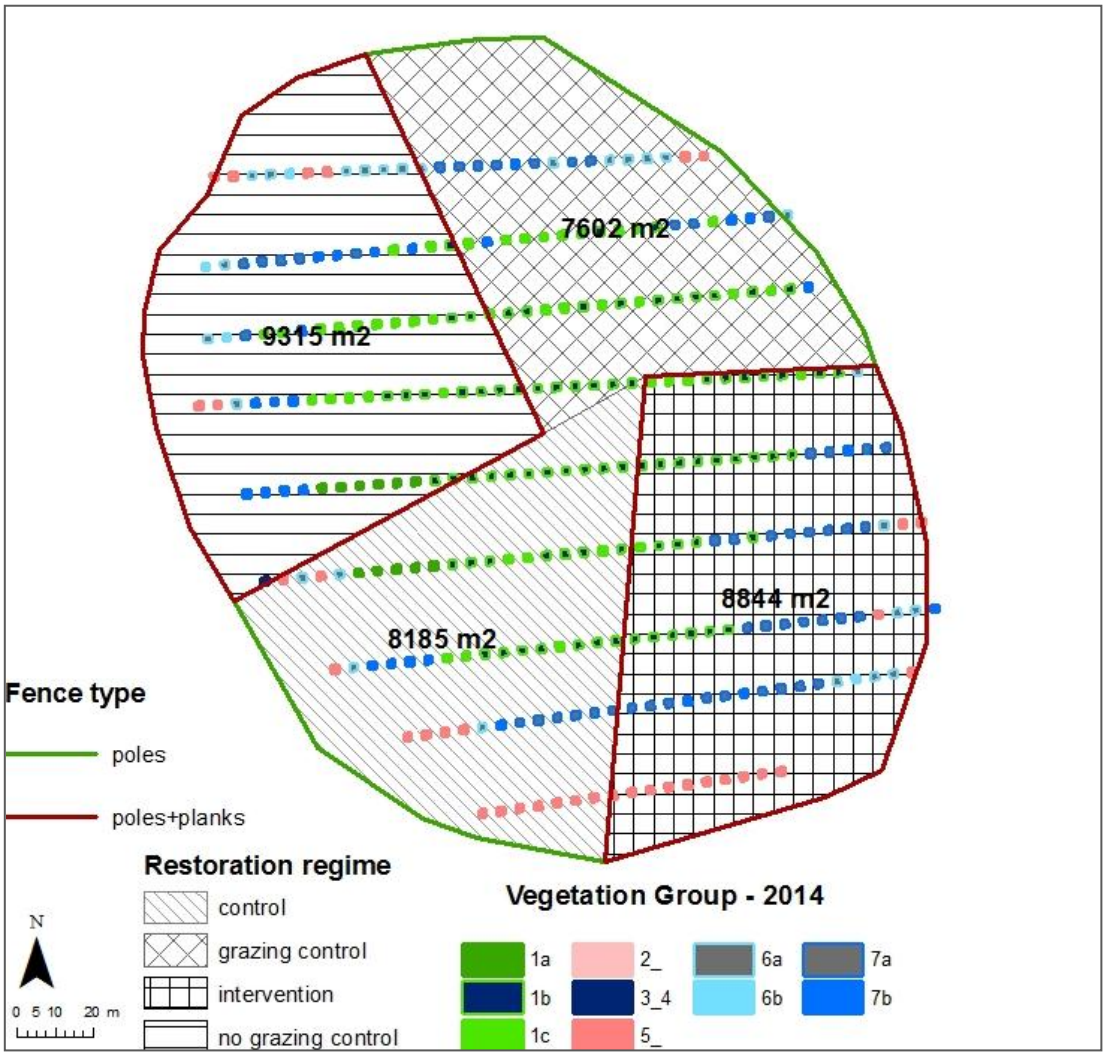

Figure 2. Restoration regime at the pond of Nevropoli.

Removal of invasive species (see section 4) will take place throughout the intervention plots (grazing control and intervention) in late spring and summer of the first year, when the water has withdrawn but the soil is not yet completely dry. Subsequent clearings may be needed as more parts of the pond start to dry. Depending on the results (success of the removal, establishment of typical temporary pond species), the removal at least of the alien annuals *Xanthium spinosum* and *Echinochloa crus-galli* will expand in the whole pond because the maintainance of these plants adjacent to the intervention sites will most probably lead to re-infestation of the cleared plots. The areas to be cleared are mainly the zones of vegetation groups 2, 5, 6a, and 7a but few plants also occur in the zones 6b and 7b.

The planting scheme, taking into account community composition at various pond depths (Action A.3), will be:

- *Verbena supina* and *Heliotropium supinum* pot-planting and seeding (seed mixture 50% each) throughout the intervention area at the zone of vegetation groups 1c, 2, 4, 6, and 7. The plants will be plugged or seeded with a seeded (see section 3) at the cleared plots, immediately after clearing. Seeding will also take place in autumn.
- *Mentha pulegium* planting of transplants (see section 3) throughout the intervention area at the zone of vegetation groups 1a and 1b (at the other vegetation zones there are abundant individuals). These vegetation zones are generally not invaded due to long term flooding and planting will take place as the water withdraws but the soil is still innundated (late summer to autumn).

The soil seed bank is expected to provide new plants at the no grazing control plots where there will be no plantings. *Verbena supina* is known to create at least a temporary soil seed bank in wetlands (Johns & Campbell 2011).

Plantings will be repeated for at least a second year, as necessary based on monitoring (action D.1).

2.3 Mourouzos and Mouriza ponds

The ponds of Mourouzos and Mouriza are very similar and neighbouring. Regarding their geomorphological, hydrological, and geochemical attributes they are not identical but similar to the pond of Nevropoli (Action A.2). The alternation of the wet and dry ecophase however is more erratic and the dry ecophase more extended (deliverable A.3.1). The temporary pond vegetation is fragmented and represented by low cover individuals of the species *Verbena supina*, *Heliotropium supinum*, and *Mentha pulegium*. The degradation of the temporary pond vegetation is also evident in the frequence and dominance of mesophilous eutrophic grassland species, the alien *Xanthium spinosum*, and nitrophilous pioneer species. It is not known whether it is the impact by animal and vehicle trampling and grazing or the wet and dry ecophase alternation pattern, or both that have caused this vegetation status. Nevertheless, an effort will be made for vegetation restoration which will in any case clarify the situation.

The restoration of the temporary pond communities will be made by:

- removal of thistles, that is *Xanthium spinosum*,

- removal of other nitrophilous invading species, mainly *Cynodon dactylon*,
- planting of the typical temporary pond species *Verbena supina*, *Heliotropium supinum*, and *Mentha pulegium*.

Removal of invasive species (see section 4) will take place throughout the intervention plots (grazing control and intervention) when the water has withdrawn but the soil is not yet completely dry. This may need subsequent clearings as more parts of the ponds start to dry. Depending on the results (success of the removal, establishment of typical temporary pond species), the removal at least of the alien annual *Xanthium spinosum* and will expand in the whole area of both the ponds because the maintainance of these plants adjacent to the intervention sites will most probably lead to re-infestation of the cleared plots. The areas to be cleared cover almost the whole ponds.

The restoration regime (Figure 3) will include no grazing-animal trampling and restoration inteventions (intervention), grazing-animal trampling and restoration interventions (grazing control), no grazing-animal trampling and no restoration interventions (no grazing control), and grazing-animal trampling and no restoration interventions (no intervention).

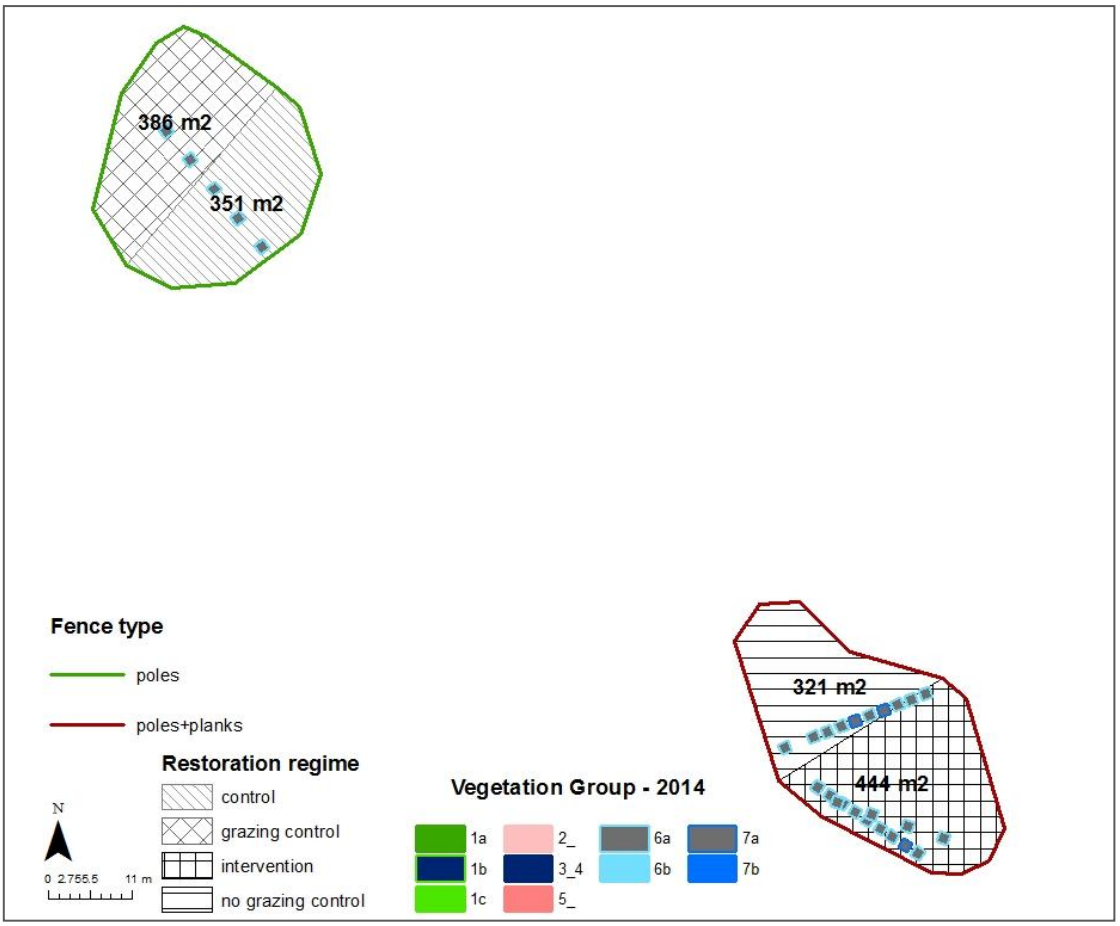

Figure 3. Restoration regime at the ponds of Mourouzos (southeast) and Mouriza (northwest).

The planting scheme, will be:

- *Verbena supina* and *Heliotropium supinum* pot-planting and seeding (seed mixture 50% each) throughout the intervention area. The plants will be planted in mosaics or seeded with a seed mixture (see section 3) at the cleared plots, immediately after clearing. Seeding will also take place in autumn.
- *Mentha pulegium* pot-planting throughout the intervention area. The plants will be planted in mosaics (see section 3) at the cleared plots, immediately after clearing.

It is not known whether there actually is a soil seed bank of typical temporary pond species at the ponds of Mourouzos and Mouriza. The appearance of *Verbena supina* in summer 2015 (while it was not present in 2013) suggests that either there actually is a soil seedbank or that the seeds were transferred by animals or by other means and established due to that year's favourable conditions.

Plantings will be repeated for at least a second year, as necessary based on monitoring (action D.1).

3. Specifications for planting

3.1. Seeding

The annual typical temporary pond species, specifically *Ranunculus lateriflorus*, *Lythrum thymifolia*, *Myosurus minimus*, *Verbena supina*, and *Heliotropium supinum*, reproduce only from seed and cannot be propagated by vegetative means. Thus, seeding directly in the field is an almost obligatory option.

Seeding is expected to be more effective if performed when the ponds are dry before the autumn rains because firstly this is the natural dispersal period of the plants and secondly because even dormant seeds in need of a cold stratification or prolonged low temperatures in order to germinate will exprerience these conditions naturally. Moreover, the plants germinating under these circumstances will produce acclimatised seedlings with more chances to survive.

All seed lots tested up to now (action C.7) have light requiring seeds so seeding should be done on the surface and the seeds should not be covered with soil (even 1 cm of clayey soil will diminish the quantity of light). This attribute is common in many wetland plants (e.g. Salisbury 1970). A light preparation of the soil with a rake or a hoe has been used for seeding at constructed pools (Collinge & Ray 2009). In the pond of Louka, carefull preparation of the dry soil with a small tool and very locally will be applied. In the ponds of Mourouzos, Mouriza and Nevropolis most seeding will be done at invasive species removal plots and raking may not be necessary.

Mixtures of seeds will be prepared (as specified in section 2). The seeds of all the species are very small and light, so it is advisable that they are combined with a small quantity of local soil and then scattered over the soil surface.

3.2. Pot-planting

Direct seeding of wetland plants may be difficult or not effective, so propagation of the plants in a greenhouse and transplanting in the field may be preferable (Hoag 2003). This means that the seeds are planted in a greenhouse, undergo any treatment necessary for germination (as prescribed by action C.7, e.g. gibberellic acid addition or stratification) and produce seedlings. Then, the young plants are transplanted in the field.

The seedlings and young plants of the annual species to be planted are very small and fragile, so it is almost impossible and certainly impractical to transfer them one by one to the field. The use of biodegradable pots (Figure 4), usually made of a mixture of straw, bamboo, wood fibre, or peat moss or even by cow manure, offers a sollution to this problem. These pots can be planted directly in the soil and degrade within 2 – 3 years (Tate et al. 2016, http://www.enviroarc.net/lifecycle.php).

Caution should be taken with the soil used in the pots in case it is contaminated with undesirable seeds. The soil can be de-contaminated by a tretament in a laboratory oven. Also, a soil mixture similar to the natural one (action A.2) or even use of soil from a donor site at the project area is preferable.

Planting in the pots will be attempted by two methods. In both methods, watering is crucial, so the pots can be placed in water tunks for the soil is maintained at an innundated state. Watering from above is not advisable as it may disperse or bury the seeds or minute seedlings.

- The first method is planting seeds directly in the pots. As the seeds are light-requiring, planting should be made by placing them on the soil surface. Treatments necessary for germination should be administered in the potted plants. This method is practical for plants that do not require a specific treatment and for some treatments, like the addition of gibberellic acid. However, the method is impractical for other treatments which require lengthy incubation at specific temperature due to the lack of space in the incubators.
- The second method is administering any treatment necessary for germination in the laboratory in petri dishes lined with agar. As soon as the seeds germinate they are transfered into pots to grow. Transfer of the fragile seedlings to the pots will be done along with the attached agar so that they will not be hurt.

Figure 4. Biodegradable pots made of peat moss, wheat straw and wood fiber and cow manure (from left to right).

The potted plants will be tranfered to the intervention sites and planted (as specified in section 2) at distances of no less than 1 m. Special care should be taken with watering during the transportation. Also, watering of the planted pots at the intervention sites may be necessary for 1 – 2 weeks, depending on the meteorological conditions.

3.3. Transplants

Mentha pulegium is a perennial plant which spreads by rhizomes and it is easy to propagate by soft wood cuttings. Wild transplants can be aquired from a donor site, either in Nevropolis pond from plots with dense cover of the plant or from the neighbouring wetland of Souvala. In order to minimise the effect on the donor site, digging at most 0.1 m^2 from a 0.4 m^2 area is advocated as a rule of thumb (Hoag 2003). Transplants should be planted while the soil is innundated but not flooded, preferably imediatelly after cutting. Alternatively, cuttings could be stored in a cool place and planted later or could be propagated in a green house and transferred to the project site.

4. Specifications for removal of invasive species

4.1. Annual thistles

The main invasive thistles at the intervention sites , *Cirsium vulgare* and *Xanthium spinosum*, are both annuals (*Cirsium vulgare* can also be biennial) and mostly unpalatable, so control by grazing is not applicable. Although the young shoots of *Cirsium vulgare* are actually grazed, spring grazing may cause an outbreak of the population (Silvertown & Smith 1989).

An effective method for the extirpation of both species, especially at small areas, is mechanical removal either immediately prior to flowering or when flowering has just started (CABI 2015). *Xanthium spinosum* can be easily uprooted but for *Cirsium vulgare* excavation of the rosette is necessary. Removal after the onset of flowering and seed setting in summer will not be effective and in any case, the cut plant material should be removed from the sites.

Both species reproduce by seed and are carried by animals, so periodic physical control may be required for the seed bank to be depleted and if animals continue roaming in the site re-infestation may happen. Shearung the animals from *Xanthium spinosum* burrs and *Cirsium vulgare* achenes before they approach the intervention sites seems to be impractical in the setting of Mt. Ak Kallidromo. Planting of the intervention sites soon after the removal of the thistles will promote the growth of the temporary pond species hopefully preventing the regrowth of thistles.

4.2. *Echinochloa crus-galli*

Echinochloa crus-galli is an annual grass reproducing by seed but can also expand when lower nodes of stems develop roots (OLA and MAFF 2002). Simply cutting the plant (mowing) is not effective because it stimulates growth from lateral buds (OLA and MAFF 2002). Hand weeding by uprooting the plant can be effective (CABI 2015) and is the proposed method for the project sites.

Reports regarding the soil seed bank are not consistent. For rice fields, it has been reported that the seed reserves were exhausted in one season and by the third season the field was free of viable seed (Bhatia et al 1990), possibly because seeds lost their germinability due to anaerobic conditions. On the other hand, it is reported that seeds buried over 8 cm remain viable for at least 3 years and some seeds are still viable after 13 years (Maun and Barrett 1986). It is certain that repeated weedings will be necessary if the plant is not controlled by grazing.

4.3. *Cynodon dactylon*

Cynodon dactylon is a perennial grass with underground rhizomes and on the ground runners. It is a species very difficult to extirpate because it easily survives shallow hoeing and thrives on mowing (CABI 2015). Various herbicides, double deep ploughing, and solarization or their combination have proved effective, but these methods are not applicable in a natural setting.

Hand hoeing has proved practical at low concentrations of the plant but should be deep enough to remove not only plants and rhizomes at the upper portion of the soil, but also the deep rhizomes (Lorenzi & Jeffery 1987, Heathman et al. 1986). Frequent clipping of the aerial parts may be effective but should be done repeatedly at the dry period (Lorenzi & Jeffery 1987). Hand hoeing is the method proposed for the removal of the plant from the

project sites. It is hoped that this method followed by the planting of typical temporary pond species will reduce effectively the population of *Cynodon dactylon*.

5. Recording of restoration procedures

All restoration procedures, planting and removal of species, must be recorded in a diary updated on a daily basis.

For plantings the following data must be recorded: number of seeds per pot in the greenhouse and percentage of healthy seedlings, number of pots planted in the field and number of plants in pots per species, number of seeds used for seeding per species, exact sketch of the planting or seeding pattern with the help of GPS, soil innundation status, all equipment and tools used, and problems encountered.

For removal of invasive species the following data must be recorded: number of plants or area cleared per species, sketch of the intervention area with the help of GPS, exact method used for the removal, all equipement and tools used, and problems encountered.

6. Literature

AGP - Plant Production and Protection Home. 2015. Grassland species profiles: Cynodon Dactylon. Food and Agriculture Organization of the United Nations (FAO), http://www.fao.org/agriculture/crops/en/

Aponte C., Kazakis G., Ghosn D., Papanastasis V.P. 2010. Characteristics of the soil seed bank in Mediterranean temporary ponds and its role in ecosystem dynamics. Wetlands Ecol. Manage. 18: 240-253

Bhatia R.K., Sandhu K.S., Singh T. 1990. Germination and longevity of Echinochloa crus-galli L. under natural conditions. Journal of Research, Punjab Agricultural University, 27: 17-21

CABI. 2015. Invading Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

Collinge S.K., Ray C. 2009. Ecology and restoration of vernal pools: A ten year study of plant community dynamics. *In*: Fraga I Arguibau P. (ed) International Conference on Mediterranean Temporary ponds. Proceedings and Acstracts. Consell Insular de Menorca. Recerca, 14. Maó, Menorca. pp. 281-290

Heathman S., Hamilton K., Chernicky J. 1986. Control weeds in urban areas. Cooperative Extension Service 8653. University of Arizona, Tucson, Arizona. 4 p.

Hoag J.C. 2003. I.D.7.a. Restoring herbaceous wetland vegetation by seedlings. *In*: Wetland Science Institute, USDA-NRCS. Wetland Restoration, Enhancement and Management. pp. I.D.7a1-7

Johns C., Campbell C. 2011. Assessing the importance of water born propagule movement for establishment of aquatic vegetation in a long dry wetland. Final Report prepared for the Murray-Darling Basin Authority by The Murray-Darling Freshwater Research Centre, MDFRC Publication 13/2011, May, 58 p.

Lorenzi H., Jeffery L. 1987. Weeds of the U.S. and their control. Van Nostrand Reinhold Co., New York. 355 p.

Maun M.A., Barrett S.C.H. 1986. The biology of Canadian weeds. Canadian Journal of Plant Science 66: 739-759

Mueller J.P., Green J.T., Chamblee D.S., Burns J.C., Bailey J.E., Brandenburg R.L. 1995. Bermudagrass management in North Carolina. North Caroline Cooperative Extension Service - North Carolina State University , College of Agricultural & Life Sciences, 12 p.

Open Learning Agency (OLA) and British Columbia Ministry of Agriculture, Food, and Fisheries (MAFF). 2002. Guide to weeds in British Columbia. Open Learning Agency. Burnaby, British Columbia, Canada. 195 p.

Salisbury E. 1970. The pioneer vegetation of exposed muds and its biological features. Phil. Trans. Royal Soc., London, Ser. B 259: 207-255.

Silvertown J., Smith B. 1989. Germination and population structure of spear thistle Cirsium vulgare in relation to experimentally controlled sheep grazing. Oecologia 81: 369-373

Tate C.L., Sloan R.C., Worthey S.S. 2016. Biodegradable pot trial. Mississippi Agricultural & Forestry Experiment Station.

Young T.P., Petersen D.A., Clay J.J. 2005. The ecology of restoration: historical links, emerging issues and unexplored realms. Ecology letters 8: 662-673