

Artificial disturbance promotes recovery of rare Mediterranean Temporary Pond plant species on the Lizard Peninsula, Cornwall, England

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SUMMARY

Many plant species require habitat disturbance and are therefore tolerant of low-level, anthropogenic disturbance, such as that created by traditional farming practices. Where such practices have declined, conservation management often includes artificial disturbance as a substitute. Nationally important populations of rare plants associated with temporary pools and disturbed trackways had declined at Windmill Farm Nature Reserve on the Lizard Peninsula in Cornwall (England). In light of the historic records for these plants, the presence of a seedbank in the soil was assumed, and was confirmed as likely when the deliberate disturbance of a trackway in 2004 was followed by germination of two rare plant species (Pigmy Rush *Juncus pygmaeus* and Yellow Centaury *Cicendia filiformis*). As a result, the adjacent very overgrown trackway was more fully excavated in 2009. Within eighteen months of management, both these species and two other characteristic plants of temporary pools (Pillwort *Pilularia globulifera*, Three-lobed Crowfoot *Ranunculus tripartitus*) germinated and re-established on the excavated site. The existence of the historic records, together with surveys in both 2002/3 and 2010/11, enabled robust pre- and post-monitoring of the impact of the conservation management. The work shows that excavation has the potential to promote rapidly the recovery of plants associated with disturbance, with the greatest chance of positive results likely to occur when restoration exploits an existing soil seedbank.

BACKGROUND

Many wetland habitats are classified as temporary, characterised by a hydroperiod: water-inundated during the autumn and winter, and drying out in warmer summer months. The environmental heterogeneity of these seasonal wetlands satisfies the habitat requirements of many freshwater species that are otherwise rare or declining (Wood *et al.* 2003, Nicolet *et al.* 2004, Bilton *et al.* 2009). However, ephemeral wetlands are a highly threatened habitat, globally; their unique hydrology makes them particularly vulnerable

to changes in climate and land use (Ruiz 2008). Temporary ponds are generally found within anthropogenically-disturbed landscapes (Stamati *et al.* 2008) and high levels of disturbance can have deleterious effects on pond biota (Wood *et al.* 2003). However, low-intensity disturbance, such as that associated with traditional forms of agriculture, may benefit some species by reducing interspecific competition and aiding seed dispersal (Devictor *et al.* 2007).

The network of temporary ponds found on the Lizard Peninsula in Cornwall is situated

in anthropogenically-influenced landscape comprising mainly heathland, with some farmland and coastal grassland (Wheeler & Byfield 2005, Bilton *et al.* 2009). The ponds in the region are designated as 'Mediterranean temporary ponds', a priority habitat listed on Annex 1 of the Habitats Directive (92/43/EEC). Their presence on the Lizard is due to an unusual set of geological factors, combined with a long history of traditional extensive heathland grazing. The most diverse seasonally-flooded trackway systems occur where thin deposits of wind-blown loess of granitic origin overlie ultramafic serpentine invertebrates, amphibians, and for rare plants. One plant, Pigmy Rush (*Juncus pygmaeus*), is, within the UK, restricted to the Lizard Peninsula, whilst several other species have limited or declining distributions (BSBI 2011, NBN 2011). The tracks were historically used as thoroughfares and for transport associated with the serpentine mining industry until its decline in the second half of the twentieth century. In recent years many tracks have fallen into disuse (Wheeler & Byfield 2005), posing problems for future conservation of the rare plants associated with them. These species (Table 1) are ephemeral macrophytes, sensitive to competition from longer-lived perennials,

and gabbro rocks. The Lizard Peninsula also includes three types of heathland listed by the Habitats Directive (Northern Atlantic wet heaths with *Erica tetralix*; European dry heaths; and Dry Atlantic coastal heaths with *Erica vagans*; European Commission 1992), and is designated a Special Area of Conservation (<http://jncc.defra.gov.uk>).

The Lizard seasonal ponds are generally small and associated with ruts on trackways, though there are some larger pools, many of which are also seasonal (Bilton *et al.* 2009). They are important for various species, including and opportunistically exploiting periodically inundated areas of bare ground (Wheeler & Byfield 2005, Bilton *et al.* 2009). Trackway disturbance creates the necessary areas of bare ground and may increase soil compaction, reducing permeability and therefore increasing the hydroperiod (Maclean *et al.* 2012). Hence, the decline in trackway use has been accompanied by a reduction in the abundance and distribution of the rare plant species of the temporary pools (Wheeler & Byfield 2005).

Studies on temporary pond systems have noted the positive impact on characteristic plant species of replicating the effects of low-level

Table 1: The study species, their characteristics (including seed and spore longevity) and conservation status

Species	Main characteristics	Conservation status*	Source**
<i>Chara fragifera</i> (Strawberry Stonewort)	A green algae. Like all stoneworts, it requires clear water with low nutrient levels, and has long-lived spores. It is present in SW England and parts of Ireland, but absent from Scotland and Wales.	RDB-vulnerable IUCN-vulnerable	Moore, 1986; Stewart, 2004.
<i>Cicendia filiformis</i> (Yellow Centaury)	A very small summer flowering annual. Numbers can vary greatly between years depending on conditions; it is partly dependent on winter inundation to decrease competition.	RDB-nationally scarce UKBAP-priority species IUCN-vulnerable	Rose and O'Reilly, 2006
<i>Juncus pygmaeus</i> (Pigmy Rush)	A small annual rush maturing on exposed mud in summer, flowering May to July. Restricted to the Lizard in the UK. The rate and timing of changes in water level strongly affect numbers each year.	RDB-vulnerable UKBAP-priority species IUCN-endangered	Rich and Jermy, 1998; Rose, 1989
<i>Pilularia globulifera</i> (Pillwort)	A small perennial fern, found on bare mud in slightly acid or neutral soils. Since the 1980s new sites have been found in the west of the UK, so this is an important area for the species. The sporangia have potential for longevity, but this is not proven.	RDB-nationally scarce UKBAP-priority species IUCN-near threatened	Plantlife, 2006b; Lockton, 2011
<i>Ranunculus tripartitus</i> (Three-lobed Crowfoot)	A winter annual (sometimes perennial), growing in shallower water and flowering from March until May. Its seeds are long-lived. The species is localised and diminishing.	RDB-nationally scarce UKBAP-priority species IUCN-endangered	Rich and Jermy, 1997; Plantlife, 2006a

*RDB - Red Data Book; UKBAP - UK Biodiversity Action Plan; IUCN - International Union for Conservation of Nature 2001 Red List Categories

**Other general sources: Biological Records Centre (<http://www.brc.ac.uk>); Botanical Society of the British Isles (<http://bsbi.org.uk/>); Joint Nature Conservation Committee (<http://www.jncc.defra.gov.uk>); National Biodiversity Network (<http://data.nbn.org.uk>); Online Atlas of the British and Irish Flora (<http://brc.ac.uk/plantatlas>)

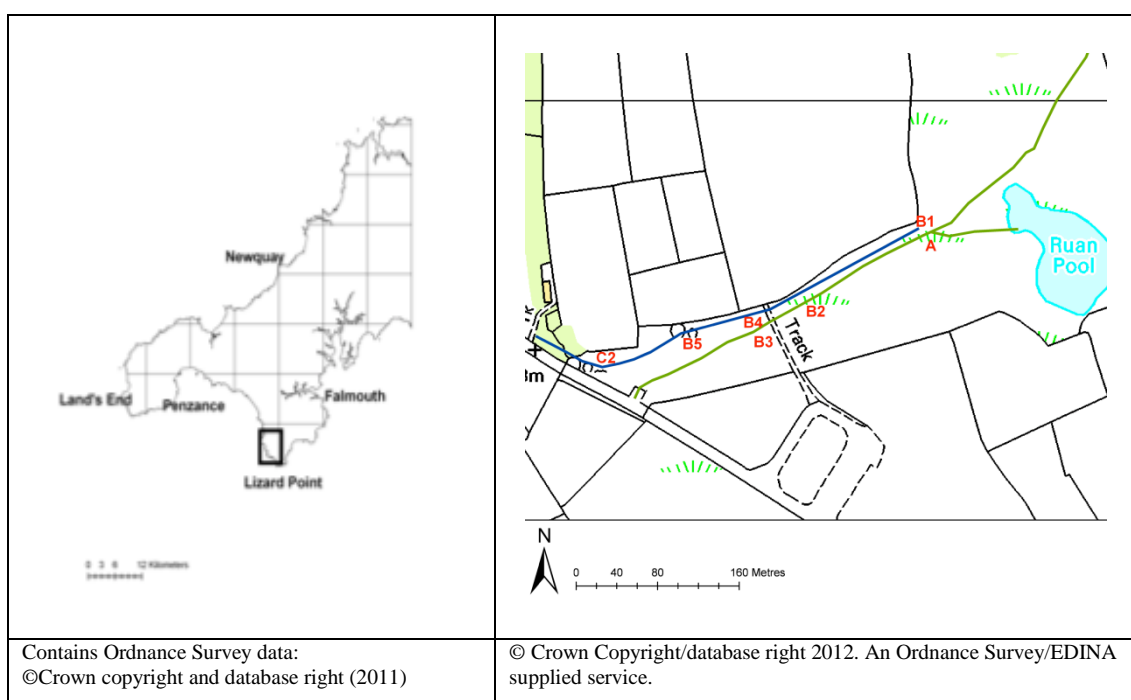


Figure 1: Location of study site. The left-hand map shows the general location (within black box) of Windmill Farm on the western side of the Lizard Peninsula. The right-hand map is of the section of Windmill Farm containing the two tracks. Blue line: north track, green line: south track. A – site where Yellow Centaury was recorded in 2005, and Pigmy Rush in 2009, 2010 and 2011; B1, B2, B3, B4 – main clusters of Pigmy Rush in 2011 on north and south tracks. Yellow Centaury was recorded between A and B3 on the south track in 2010 and 2011, and between B1 and B5 on the north track in 2011. An isolated individual of Yellow Centaury and of Pigmy Rush was found near C2, and a single plant of Three-lobed Crowfoot at B4, on the north track in 2011.

anthropogenic disturbance (Amami *et al.* 2009, Sahib *et al.* 2009), with a particular importance placed on the role of disturbance in accessing the seedbank (Devictor *et al.* 2007, Aponte *et al.* 2010). The plants maintain seedbanks (or spores in the case of ferns and algae) in the ground so that they can quickly exploit favourable conditions such as available bare earth, rainfall and suitable temperatures, when such conditions occur (Moore 1986, Rich & Jermy 1997, Rich & Jermy 1998, Rose 1989, Stewart 2004, Plantlife 2006a, Plantlife 2006b, Rose & O'Reilly 2006, Lockton 2011; Table 1). Pigmy Rush, Yellow Centaury (*Cicendia filiformis*) and Three-lobed Crowfoot (*Ranunculus tripartitus*) are known to be particularly sensitive to environmental conditions and vary in abundance considerably between years, suggesting that seeds lie dormant in years when conditions are less favourable (Devictor *et al.* 2007, Aponte *et al.* 2010). This presence of a viable seedbank may be critical for the positive outcome of conservation interventions that create disturbed, bare earth.

Windmill Farm Nature Reserve (area: 75 ha; grid reference: SW 694 153) is on the Lizard Peninsula in Cornwall (Figure 1) and jointly managed by the Cornwall Wildlife Trust and

the Cornwall Bird Watching and Preservation Society. The site is mainly a mixture of grassland and heathland, together with a larger seasonal pool (Ruan Pool), bog areas and trackways which are water-inundated in the autumn and winter months. The underlying bedrock is serpentine. Ruan Pool and the flooded trackways are typical of temporary pond habitats on the Lizard Peninsula. Windmill Farm Nature Reserve has been actively managed for conservation since 2001. It includes several key ponds – including the large shallow Ruan Pool (perhaps created for watering stock), plus more recent waterbodies created specifically for conservation purposes – as well as the series of old, heathland trackways.

Prior to its purchase, the tracks on Windmill Farm had fallen into disuse, and the rare plants associated with them had declined. One old cart-track about 400 m long had been unused for many years and was completely overgrown. It lay adjacent for part of its length to a less-disused track. For ease of reference, the completely overgrown track is henceforth referred to as the northern track, and the less-disused track as the southern track (Figure 1).

Table 2: Records of Yellow Centaury, Pigmy Rush, Pillwort and Three-lobed Crowfoot at Windmill Farm Nature Reserve on the 'northern' (N) and 'southern' (S) tracks (see main text and Figure 1 for locations of tracks)

Species	Earlier records*	Track	No. plants during surveys	
			2010	2011
Yellow Centaury	1978, 1993, 2003, 2005	S	1371	2440
		N	0	931
Pigmy Rush	1966. 1978, 2009	S	0	64
		N	40	142
Pillwort	2007	S	0	13 fronds
		N	0	0
Three-lobed Crowfoot	c. 1985	S	0	8
		N	0	1

*Records relate to hectares which encompass both southern and northern tracks (Figure 1). Records before 2005 were not generally generated at hectare resolution so provide less certainty on location, though more precise records existing for Yellow Centaury and Pigmy Rush are included. Earlier presence of Pillwort and Three-lobed Crowfoot in the vicinity of the tracks is uncertain because of the resolution of prior records. The only records for Strawberry Stonewort at Windmill Farm are in Ruan Pool (i.e. not on either of the tracks and so not included here).

This paper describes restoration work undertaken along one abandoned track to improve habitat for rare wetland plant species. There are historic records at Windmill Farm for five such species associated with flooded trackways and ponds: Strawberry Stonewort (*Chara fragifera*), a freshwater alga, Pillwort (*Pilularia globulifera*), a rhizomous aquatic fern, Yellow Centaury, Pigmy Rush, and Three-lobed Crowfoot (Tables 1 and 2). Hectare squares in the vicinity of both the northern and southern tracks contain historic records for these species.

ACTION

A botanical survey was conducted in 2002/3 (Wheeler & Byfield 2005) and then, after habitat restoration, monitoring was undertaken in 2010 and 2001 as part of a research project by the University of Exeter. This showed the positive results of an attempt to regenerate the plants by the creation of artificially disturbed bare earth.

Field survey 2002/2003: A survey commissioned by Plantlife, a UK plant conservation charity, to assess the distribution and abundance of these species on the Lizard Peninsula was undertaken in summer 2002 and spring 2003, at times coinciding with their emergence (Wheeler & Byfield 2005). The survey included the southern track at Windmill Farm and Ruan Pool (Figure 1), on 3 July 2002. The northern track was completely overgrown at this point and therefore

contained no suitable habitat for the species. None of the study species were found on the southern track, either, but subsequent active management of Windmill Farm (of Ruan Pool in particular, but with impact on the southern track: see next paragraph) was noted in the report, and a re-survey was recommended.

Habitat restoration:

Southern track – 2004: Ruan Pool was enlarged in 2004: in the course of its restoration the spoil was removed by tractor from the Pool along a short section of the southern track with the aim of deliberate disturbance to access the presumed seedbank (Figure 1). In the following year a colony of Yellow Centaury appeared in the area disturbed by the tractor; and in 2009, a colony of c. 40 Pigmy Rush was recorded on the same site. As a result, and given historic records existed for these species in the vicinity, it was decided to clear and excavate the remainder of the northern track. The work was carried out to specifications provided by Andrew Byfield of Plantlife, one of the two lead surveyors in the original 2002/3 survey. Based on the expectation of an extant seed bank in the soil, it was anticipated that the work would both expose this seedbank, and provide the disturbance that the study species require to reduce competition from other species.

Northern track – 2010: In light of the successes from the re-use of the southern track, and following a programme of scrub clearance to reveal the route of the northern track, contractors undertook excavation work of this



Figure 2: Sections of the northern track: a) overgrown before restoration work; b) after scrub clearance but before excavation; c) immediately after excavation in March 2010; and d) in late winter 2011 (photograph taken in February 2011 when the track was still inundated with water). The section shown in d) contained a single plant of Three-lobed Crowfoot in February 2011, and sizeable colonies of Pigmy Rush and Yellow Centaury when surveyed in late May 2011. (Photograph credits: a), b) and c), Andrew Pay; d) Amanda Scott.

second track, using a mechanical digger, in early March 2010. The specification was to excavate and remove the recently developed organic soils to uncover the original profile of the track ruts and the rudimentary loess-derived soils, and thus expose the buried seedbank. This necessitated a clearance depth of approximately 30cm along the length of the track. The location of the 400 m long restored track is shown in Figure 1. Figure 2 illustrates the track before and after restoration work.

Monitoring surveys 2010/11: Following habitat restoration in spring 2010, surveys were undertaken of the site by researchers from the University of Exeter in 2010 and 2011, at times that coincided with plant emergence. These surveys were undertaken in

the context of a wider survey of the Lizard Downs, replicating the areas surveyed in 2002/3 (Wheeler & Byfield 2005) and it was therefore not only possible to compare records for the site for pre-2002, 2002/3 and 2010/11, but also to set the results within the context of the Lizard Downs as a whole, with the latter acting as a monitoring 'control'. The southern and the restored northern tracks were monitored for the target plant species on 21st July 2010, 24th February 2011, and 24th, 27th, 30th and 31st May 2011. Data were collected by setting out transects of 30 m in length in all locations where the study species were found, and surveying, using 1 m² quadrats to either side of the transect, to at least 3 m on either side (the width depending on the locations of the species). Plant presence or absence, and

numbers in each quadrat, were noted. The high resolution and comprehensive monitoring of the data enabled detailed comparison between 2010 and 2011, and provide a baseline for future monitoring (Table 2).

CONSEQUENCES

The restored northern track saw a reappearance of two of the study species— Yellow Centaury and Pigmy Rush—in particular in 2011, eighteen months after the restoration (Tables 2 and 3). Table 2 gives number of individuals; Table 3 shows the number of occupied hectare squares, allowing better comparisons with historic data, which were less precisely counted and geo-referenced. The southern track, which was not subject to excavation as no ‘overburden’ of recent organic leaf litter and plant debris had built up there, was partly, deliberately disturbed during the 2004 restoration of Ruan Pool> This resulted in the appearance of large numbers of both species in 2010, and even more in 2011. All surveys were timed to coincide with the emergence and continuing presence of the study species.

Results of 2010 survey: The survey on 21st July 2010 found 1371 Yellow Centaury individuals, all along the southern track. Forty Pigmy Rush plants were recorded in a similar location to where recorded in 2009 (Figure 1). No plants were recorded further along the northern track, but the date of survey was only four months since restoration.

Results of 2011 survey: The survey in February 2011 found a single Three-lobed Crowfoot plant on the northern track, and eight on the southern track. The surveys in May 2011 recorded 3373 Yellow Centaury plants, 931 of which were on the northern track, with the remainder mainly found along the southern track, apart from one small colony to the north

of Ruan Pool. The increase in numbers between 2010 and 2011 on the southern track could be due to natural variation between years: Yellow Centaury is sensitive to environmental conditions, in particular winter rainfall. Of most significance was the germination of almost 1000 individuals on the restored northern track within 18 months of the restoration work, where none were present in 2010 (Tables 2 and Figure 1). In the context of a wider survey for these species in 2010 and 2011, undertaken as part of the same project, this number represents a significant proportion of the Lizard population.

Perhaps of even more significance, given its restriction to the Lizard in the UK and overall decline, was the appearance of 142 individuals of Pigmy Rush on the northern track, including 92 which occurred up to 50 m away from the area of spoil from the excavation of Ruan Pool (where the species was recorded in 2010, and where 50 plants were found in 2011). A further 64 were recorded near the southern track, where the species had not been found in 2010 (Table 2 and Figure 1).

A few plants of Three-lobed Crowfoot, a species not recorded on the northern or southern track in 2010, were found in 2011 close to Ruan Pool, and a single plant was found on the northern track. A small amount of Pillwort not recorded in and around Ruan Pool since at least 1961, was also found on the northern track in May 2011 (Table 2).

These results are particularly important because they reveal that Windmill Farm now contains a significant proportion of the Lizard Peninsula populations of some of these species, which have declined elsewhere (Table 3). Based on the 2011 data for the entire Lizard Peninsula, the site hosts about 85% of the population of Pigmy Rush on the Lizard. The wider survey may have missed some

Table 3: Number of hectare squares occupied by pigmy rush and yellow centaury. Counts are calculated by determining the maximum number of plants within hectare squares in either of the survey years within each period and then summing the counts for each square. Maximising counts in either year within each survey period is necessary as the survey period in either year is complete, but some areas were surveyed twice. Determining the counts within each hectare square is necessary as data were only approximately geo-referenced in 2002–03. The control area is the whole of Lizard Downs excluding Windmill Farm.

Variable	Windmill Farm		Control	
	2002–03	2010–11	2002–03	2010–11
Pigmy Rush (occupied 100 m grid cells)	0	5	9	8
Pigmy Rush (count)	0	206	607–2208	119
Yellow Centaury (occupied 100 m grid cells)	0	6	20	24
Yellow Centaury (count)	0	3491	7982–29302	2900

occurrences on the Lizard, given the narrow period within which this species emerges, but the data nonetheless give a reasonable indication. It also hosts 66% of the 5,148 Yellow Centaury individuals recorded over the entire Lizard peninsula in 2011.

Implications: These findings demonstrate that artificial disturbance and habitat restoration for these plants, which rely on disturbance and creation of bare earth to persist, can have a positive impact within a relatively short timeframe, where there is expected to be a viable seedbank. Pigmy Rush, Yellow Centaury, Three-lobed Crowfoot and Pillwort all appeared on the restored northern track within eighteen months, the first two in significant quantities.

Although it is conceivable that the substantial increase in numbers for all species here between 2010 and 2011 could be due to natural variation between years—Yellow Centaury, for example, is sensitive to environmental conditions, in particular winter rainfall—the same general increase was not observed elsewhere on the Lizard Downs. The fact that all four species were found on the southern track suggests that a low level of disturbance maintained by grazing provides suitable habitat for the species at least in the short term. Of most significance was the germination of almost 1000 individuals of Yellow Centaury on the restored northern track, and greater numbers of Pigmy Rush than on the southern track, within 18 months of the excavation work (Table 2 and Figure 1).

The timescale means the appearance of plants on the northern track is likely to be at least partly due to the existence of a viable seedbank in the soil, or even possibly to seeds in the soil deposited there following the enlargement of Ruan Pool, which could then have rapidly dispersed and colonised the new suitable habitat. Germination of Yellow Centaury on this track may also be due to dispersal from the southern track, but the scale of its appearance on the restored northern track in 2011 again suggests a seedbank as a more influential factor. For the other species found, the distances involved similarly suggest germination from a seedbank in the soil is the likely principal source of propagules. The restoration work therefore both created new suitable habitat for the species to exploit, and probably rejuvenated the seedbank. The northern track had been unsuitable for these species for probably 50 years, as there are no records of this track being used over that

timescale until its restoration in 2010, so these results suggest that seeds may have remained viable for almost ten years, and probably longer.

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