

Ecological Evaluation of Cultivation Practices at Dartmoor Chilli Farm in Devon.

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Many plant and animal species are in danger of extinction largely as a result of human activities^[1]. Overall, land transformation and resultant habitat loss are the primary driving forces for species extinctions and the loss of biological diversity worldwide. Closely linked to human population growth, such transformation is largely as a result of industrialization and the development of intensive arable farming techniques^[2]. In the UK, around 76% of the total land surface area is dedicated to agriculture^[3].

While the lack of wildlife in modern farmland has both aesthetic and cultural implications, it is becoming increasingly evident that intensification and habitat loss are the most frequent causes of pollinator impoverishment reducing crop yield^[4]. Most species of bees and wasps, many ants (Hymenoptera), true flies (Diptera), moths and butterflies (Lepidoptera), and some families of beetles (Coleoptera) visit flowers^[5]. Interactions between plants and these pollinators are essential to the healthy functioning of wild and agricultural communities^[6]. Overall, however, pollinator populations are probably in decline due to habitat destruction and to our increasing dependence on pesticides and herbicides^[7].

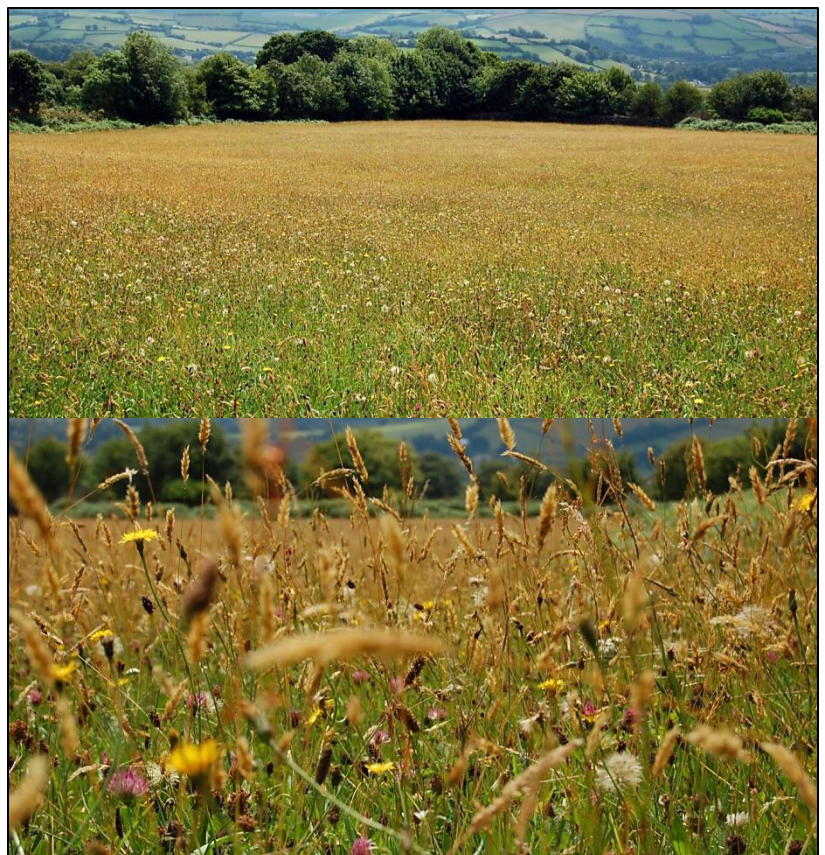
Alternative agricultural techniques can provide non-toxic methods of weed and insect control that incorporate the use of habitat set asides (also referred to as ecological compensation areas) for beneficial insect populations and require the use of fewer toxins^[6]. This is the approach adopted by Dartmoor Chilli Farm in Devon. The farm encompasses an 8 acre smallholding situated 2 miles outside the small town of Ashburton and within the boundaries of Dartmoor National Park which covers an area of 368 square miles in the south-west of England. Dartmoor Chilli Farm specializes in cultivating over 90 varieties of chillies and sweet peppers which they supply from April to October each year. They also have a range of quality hand-made preserves and sauces along with their award winning chilli chocolate.

Both organic and conventional farms in south-west England tend to be small in size, mixed and diverse in terms of semi-natural habitat such as woodlands and hedgerows^[8]. While organic farmers cannot use synthetic pesticides to control weeds and insect pests, however, there are pesticides (e.g. Rotenone) which have been approved for use by organic farmers and may have equally detrimental effects on the environment^[8]. The effects of these chemicals are unlikely to be restricted to agricultural lands themselves as they can drift into the semi-natural habitats where pollinators and other wildlife nest and forage^[9]. Acknowledging this, at Dartmoor Chilli Farm, Kay and Phil Palmer avert from the use of agrochemicals completely and instead create habitats within their agricultural small holding that actively encourage wildlife; therefore increasing biodiversity within the area. In turn, the wildlife present provides services to the farm through pollination and through presenting natural means of biological control.

In accordance with the Agenda 2000 reform of the Common Agricultural Policy of the EU which attempts to coordinate schemes that protect and renew wildlife habitats within farmland ^[4], at Dartmoor Chilli Farm, a 2 acre natural ecological compensation area is set aside where heath, heather, bracken, bramble and gorse are maintained. This habitat is an important focus for ecological restoration efforts as heathlands have a limited distribution internationally and are associated with a number of rare and threatened vertebrate and invertebrate species ^[10]. Additionally, while bracken can be highly invasive, if carefully managed, it can provide good habitat for a number of species of fritillary butterfly (Nymphalidae) ^[11]. Hence, not only does this ensure that suitable habitat remains for wild pollinators to secure pollination services for the farm but is also in keeping with the conservation agenda of Dartmoor National Park.

In addition to this, Kay and Phil Palmer have planted a 2 acre mixed fruit orchard consisting of a number of traditional varieties of apples, plums and pears.

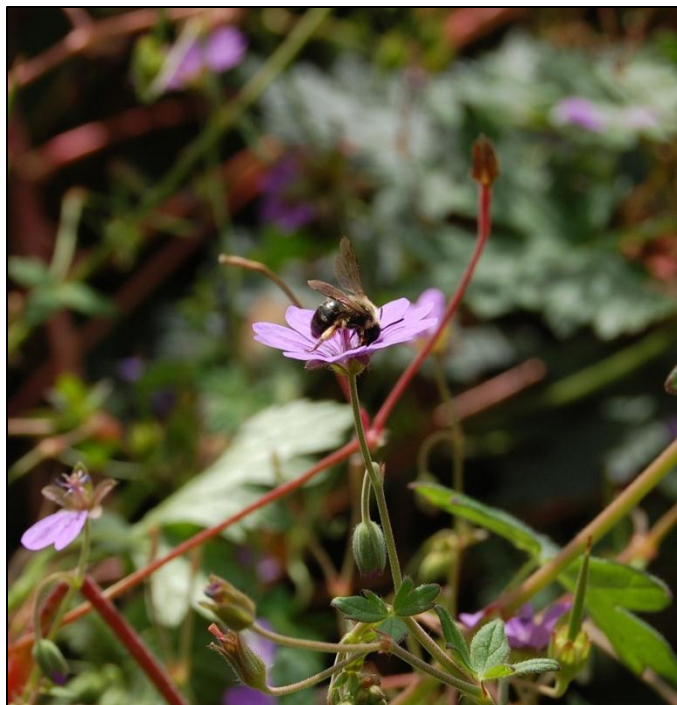
In time they intend to use the fruits from these trees as quality ingredients in the number of chutneys, jams, and sauces that are hand-made on-site by Kay. In order to incorporate the greatest diversity of habitats for invertebrate species, while the grass within the orchard is kept short through year-round grazing by three native ponies, an additional 3 acre meadow is voluntarily set aside by the farm and only grazed in July after the wild flowers have had chance to set seed (see image right) ^[12]. Hay meadows, or unimproved permanent pastures, such as this are important habitats for a number of species including the rare Cirl Bunting (*Emberiza cirlus*). This, a nationally scarce farmland bird, thrives in species rich pastures with a high abundance of grasshoppers; and is a high priority for conservation in the area ^[12].



Above: three acre hay meadow habitat at Dartmoor Chilli Farm.

The main threats to hay meadow habitats, along with the diversity of species occurring in them, are neglect, inappropriate grazing and agricultural improvement including that of cultivation and fertilizer use ^[12]. As such, there are few remaining on Dartmoor with most of the existing ones being protected by management agreements with the Dartmoor National Park Authority or Natural England's ESA and HLS schemes ^[12]. Proper management of unprotected sites similar to the one managed at Dartmoor Chilli Farm; therefore, make an invaluable contribution to conservation efforts within the area.

Pollination is one of several ecosystem services that must be reinstated for ecological restoration to be successful ^[10] and long-term set aside lands are being recognized for their value in the conservation of biodiversity in mostly agricultural settings ^[5]. All such areas support much rural wildlife, mammals, birds, and insects ^[5]. Not unlike Kay and Phil Palmer at Dartmoor Chilli Farm, orchard growers and farmers need to ensure



Above: small solitary bee visiting Geranium species at Dartmoor Chilli Farm.

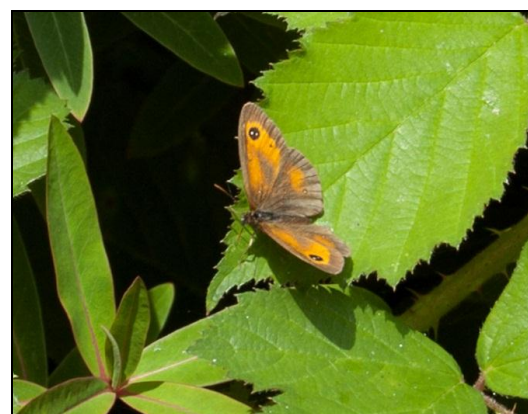
that neighbouring wild habitats remain suitable (i.e. aren't degraded by agrochemical run-off from adjacent land) for wild pollinators if they are to secure pollination services for their crops ^[6]. It is wise, therefore, for farmers to set aside areas for native pollinators and other wildlife within their agroecosystems and to encourage populations by providing forage and nesting sites for their conservation ^[5].

Bees are the most important of insect pollinators ^[7] yet, due to low fecundity, they are also the most susceptible to the use of chemicals and populations are slow to recover from perturbations ^[7]. There has been a 54% decline in managed honey bee populations in England over the last 20 years compared to an average of 20% across Europe ^[13]. Wild insect pollinators such as small solitary bees,

however, are even more vulnerable than honey bees to organophosphate pesticides that have largely replaced organochlorines such as DDT ^[6]. Growing concern about the decline of both domesticated and wild pollinators has resulted in the establishment of special initiatives by the Convention on Biological Diversity (International Pollinator Initiative) and several continental, national and regional programmes ^[9].

Among bees, the best documented group are bumblebees (*Bombus sp.*) ^[9]. Areas of low bumblebee density correspond to areas of intensive agriculture in Britain ^[14] which is likely, at least partly, due to a decline the amount of relatively undisturbed land in hedgerows and other non-cultivated areas as well as the increased use of pesticides and herbicides ^[5]. At Dartmoor Chilli Farm, hedgerows are retained as nesting and foraging sites for birds and as hibernation areas for a number of insect species ^[6]. 64% of British butterfly species can occur in the hedgerow habitat ^[4].

It has been estimated that as much as 84% of the 264 species grown as crops in the European Union are dependent on insect pollination ^[4]. Such crops are usually treated pesticides and fungicides, however, while the surrounding ground is treated by non-selective herbicides ^[4]. Tomatoes, peppers, raspberries and



Above: female Meadow Brown butterfly (*Maniola jurtina*) on bramble at Dartmoor Chilli Farm.

strawberries, all of which are cultivated organically and non-intensively at Dartmoor Chilli Farm, belong to the species group Autogamous-allogamous ^[4]. Members of this group have self-fertile flowers which can set some seed and fruit in the absence of animal visitation ^[4]. Regular pollination by insects, however, increases either the quantity or quality of fruits set thus improving the quality of the final product in many cases ^[4]. In many agricultural systems, crops that would benefit in quality and quantity from more thorough pollination are not sufficiently done so because of heavy pesticide applications ^[6].

In an attempt to mitigate the negative effects that agrochemicals have on native insect populations in farmland, seedsmen often import pollinators in the form of managed European honey bees (*Apis mellifera*) ^[4]. This has often proved unsuccessful however, namely in pollination attempts of intensively farmed carrots, radish and various brassicas ^[4]. Indeed, it is suggested that only 15% of food crops are serviced by domestic honey bees while at least 80% are pollinated by wild bees and other wildlife ^[6]. The superiority of bumblebees in the pollination of raspberry has been documented and these are also used for the pollination of tomatoes and other solanaceous crops including chillies and peppers ^[5]. The use of alternative and more holistic strategies such as those adopted at Dartmoor Chilli Farm, therefore, may help farmers reduce costs involved in crop management.

Services such as pollination and natural pest control provide substantial, if not invaluable, economic benefits to humans particularly in food production ^[8]. Yet it is widely understood that pollination is in such jeopardy from the viewpoints of agricultural productivity and food security that the Convention on Biological Diversity (CBD) and the Food and Agricultural Organization of the United Nations recently (1998-2000) took on leading roles internationally in this area ^[15]. With the annual economic value of insect pollination estimated to be around £130 billion globally in 2005 ^[9,14], it is unsurprising that governments worldwide are investing heavily in schemes that aim to reverse the trend of declining biodiversity in agricultural landscapes ^[8]. Widespread conversion to organic farming has been suggested as one means for achieving this ^[8]. Not unlike Dartmoor Chilli Farm, organic farms will generally have specific crop rotations, greater areas of semi-natural vegetation and will not use synthetic pesticides ^[5].

In addition to pollination, services of natural pest control provide substantial economic benefits to humans; particularly in food production ^[8]. Pest control on organic farms relies largely on cultural practices and naturally occurring predators and parasitoids which are important in controlling populations of otherwise pestiferous insects in all environments ^[5]. Some new and more environmentally sensitive approaches to agriculture recognize and encourage these biological control agents ^[5]. For example, at Dartmoor Chilli Farm, nettles (*Urtica sp.*) are maintained near polytunnels to encourage ladybird beetles and other predacious insects including lacewing while the herb Chervil (*Anthriscus cerefolium*) is planted at entrances to tunnels as a deterrent for slug pests. Indeed, in Europe there is growing awareness of the need to maintain or create flower-



Hoverfly species perched on dandelion at Dartmoor Chilli Farm.

rich field borders to stimulate populations of beneficial insects like aphidophagous hoverflies (Syrphidae), ladybird beetles (Coccinellidae) and parasitoid Hymenoptera ^[5].

Alongside predatory and parasitic invertebrates, amphibians also provide a beneficial means of biological control. At Dartmoor Chilli Farm, a farm pond is managed to provide suitable habitat with which to encourage newts, common frogs and toads. Second to

habitat loss and degradation, the next most common threat to amphibians, as deduced by the International Union for the Conservation of Nature (IUCN) Global Amphibian Assessment 2008, is pollution ^[16]. Chemical pollution encompasses an array of environmental contaminants including pesticides and herbicides which, when in widespread use, have consequences similar to those associated with habitat destruction ^[2].

Cultivated fields are often fertilized in spring, at the same time as amphibian eggs and larvae develop ^[17] and researchers have only recently identified correlations between declining amphibian populations and proximity to agricultural land ^[18]. Nitrate fertilizers have been implicated as a cause for declining amphibian numbers in Europe ^[19]. Amphibians are likely to be especially sensitive to nitrate water pollution due to their semipermeable skin ^[17]. Studies have shown that common toads (*Bufo bufo*) in particular are sensitive to relatively low levels of nitrate in water ^[17] and population densities of common frog (*Rana temporaria*) in the UK are also low in arable areas ^[19]. As no agrochemicals are used at Dartmoor Chilli Farm, however, Phil and Kay are able to ensure that their smallholding contains healthy and functioning terrestrial and aquatic environments to harbour these functionally important organisms.

The preservation of a diversity of exotic and native bee species along with diverse habitat types for other beneficial wildlife within agricultural landscapes will become vital as we increase our agricultural acreages of introduced crops ^[7]. This is likely to occur rapidly in coming years as concerns over global climate change stimulate interest in the amount of greenhouse gases (GHG's) emitted during the production, processing, retailing and use of many consumer goods including food products ^[20]. The carbon footprint is already a result of this ^[20].

Food production and consumption processes are closely associated with substantial GHG emissions ^[21] including that of Nitrous oxide (N₂O) emitted during the fabrication and application of Nitrogen fertilizers and Carbon dioxide (CO₂) from fossil fuels used in agriculture ^[21]. With regards to horticultural products, airfreight has also stimulated a high level of public attention in issues such as "food miles" in recent years ^[20]. One outcome of the carbon footprint, which reports the total amount of GHGs produced for a given activity, is the carbon label ^[20]. This is a certification scheme that communicates a summary of the footprint of a product to

consumer; an initiative which has been implemented in the UK within the last 5 years to enable consumers to make informed purchasing decisions based on the environmental impact of a product ^[20]. Thus, as transport can be one of the major sources of GHG emissions in any supply chain ^[20], consumer response to labelling is likely to increase demand for products that are sourced locally. This means that products such as tomatoes and chillies, for example, which are commercially imported from Israel, may be substituted for those produced locally ^[20] in the UK by companies such as Dartmoor Chilli Farm. This will result in the overall consumption of these products being more sustainable ^[20].



Above: bumblebee (*Bombus* sp) pollinating Aji Limo chilli.

A further impact of the carbon label may be to stimulate research efforts into developing new and innovative farming techniques that make greenhouse production in the UK and surrounding countries more environmentally sound and carbon efficient ^[20]. Bumblebees are now used for the pollination of tomatoes and other solanaceous crops including chillies (see image left) within greenhouses in the UK, for example, and of some leguminous crops ^[10]. At Dartmoor Chilli Farm, attractive flowering plants are placed near polytunnels to encourage bumblebee species.

Even rare species can occur in intensively managed agricultural landscapes if minimal required habitat area is made available and specific ecological requirements (such as the presence of larval host plant) are fulfilled ^[22].

For example, sown weed strips may be used as artificial

compromises for ecological compensation areas such as those set aside at Dartmoor Chilli Farm; these can enhance the species number of several beneficial arthropod groups without enhancing the abundance of pests ^[22]. Semi-natural habitats such as these have been shown to enhance the density and species diversity of ground beetles (e.g. Carabidae) which can be very numerous and predacious insects in arable land ^[22]. Soldier beetles (Cantharidae) are also an important biological control for aphids, caterpillars and other soft bodied pests (see image right) ^[23].

Many proposed approaches aimed at making agriculture more sustainable involve reducing the amount of agrochemicals used and enhancing biodiversity within agricultural systems ^[22]. Thus,



Above: mating common red soldier beetles (*Rhagonycha fulva*) on bramble at Dartmoor Chilli Farm.

adaptive traditional practices adopted at Dartmoor Chilli Farm provide a wealth of knowledge that can be largely transferrable to monotonic and intensive agricultural landscapes which are characteristic of modern farming. These will reduce the necessity for heavy pesticide applications; an important step towards environmentally friendly and sustainable agriculture within the UK and surrounding countries ^[22]. Nonetheless, small scale diversified agro-ecosystems such as Dartmoor Chilli Farm remain globally threatened by agricultural intensification ^[24]. Given the weight of evidence of pollinator loss and associated risks, investment in developing mitigation options through agri-environment schemes ^[9] and through supporting small environmentally sound businesses such as Dartmoor Chilli Farm is essential to ensure sustainable pollination services and the sustainability of future food production.

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