

*An assessment of the success of agri-
environment schemes at increasing
breeding success of lapwing in the Avon
Valley, Hampshire.*



A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science and the Diploma of Imperial College London

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List of acronyms

ATN – Avon Tyrell North

ATS – Avon Tyrell South

BTO- British Trust for Ornithology

BM – Burgate Manor Farm

CAP - Common Agricultural Policy

CBC- Common Bird census

CM – Cowards Marsh

CSS – Countryside Stewardship Scheme

E - Ellingham

ELS – Entry Level Stewardship

ES – Environmental Stewardship

ESA – Environmentally Sensitive Areas

FF – Folds Farm

H - Hucklesbrook

HK11 – Higher Level Stewardship prescription aimed at breeding waders

HLS – Higher Level Stewardship

I - Ibsley

JNCC – Joint Nature Conservation Committee

KM – Knapp Mill

KNC – Kingston North Common

MF – Moortown Farm

O - Ogber

OELS – Organic Entry Level Stewardship

RSPB – Royal Society for the Protection of Birds

SR – Somerley Reclamation

W - Winkton

Week – Week Farm

West – Westover Farm

WF – Wattons Ford

Abstract

Agricultural intensification has been detrimental for species associated with agricultural landscapes. Breeding waders, in particular, have experienced huge declines. Agri-environment schemes have tried to reduce impact of agricultural intensification on biodiversity by focusing on the habitat requirements of species and offering farmers payments to manage their fields to produce suitable habitat for species such as waders. Currently, the emphasis is on certifying as much land as possible. As such, there is a risk that quantity is favoured over quality and the success of schemes is being overlooked. In addition, there are certain notable omissions in recent agri-environment scheme prescriptions. Agri-environment schemes do not recommend providing suitable habitat for each life history stage of the breeding season and completely ignore the issue of predation. This study investigates the shortcomings of agri-environment schemes to assess the potential for improvement, through new and novel approaches.

Aknowledgements

I would like to thank Dr. Andrew Hoodless, Dr. Simon Leather and Dr. Tilly Collins for all their help and guidance with this project. I would also like to thank the Natural England Office in Hampshire for providing information on land management and the farmers who granted us access to their farms and made this project possible. Finally, I would like to thank Phillip Churchill and Amy Williams for assisting in the data collection.

Word Count: 14,987

1. Introduction

1.1 Introduction to the problem

In the UK agricultural landscapes cover approximately 75% of land area (Devereux et al 2004); 67% of this is grassland (McCracken and Tallowin 2004). Any changes in agricultural practices and policy can, therefore have dramatic impacts upon the biodiversity and ecosystems within the UK, particularly grassland associated species and systems. Over the past 70 years British agriculture has changed dramatically. The full impacts on the flora and fauna of the UK are still being realised and policy is continuously striving to minimise negative consequences.

The central driver of change in agricultural practice has been the introduction of economic and technological incentives to increase productivity following the Second World War (Benton et al 2003). This is not a phenomenon unique to the UK; unprecedented levels of agricultural intensification have also been experienced throughout Western Europe and North America over the past 70 years (Benton et al 2003). Intensification has expanded the amount of land under agricultural production; and increased the production within it.

Lister (1964) notes all land capable of producing a crop or pasturage for stock, even poor and marginal land, was reclaimed and put to use following the Second World War. In addition to poor and marginal land, wetlands were drained and grasslands became clear pasture (Lister 1964; Devereux et al 2004; Elington et al 2008). It has been estimated that approximately 30,000 kilometers of wet grassland remains in the UK, as around 20,000 kilometers were drained between 1940 and 1980 for agricultural conversion (Wilson et al 2005). Lowland wet grassland is now subject to a UK Government's Biodiversity Action Plan (BAP 2010). As part of the EU, UK agricultural intensity increased as a result of price support policies such as the Common Agricultural Policy CAP (Donald et al 2000). This includes the use of inorganic fertilizers, early and repeated mowing, intense grazing and higher stocking densities and increased silage production, all with the ultimate aim of optimising yields (Vickery et al 2001; Vickery et al 2004).

The increase in the area of land used for agriculture and the increased intensity with which this land is now managed has transformed UK landscapes to include great areas of homogenous, fast growing, and competitive grass species (Benton et al 2003; Vickery et al 2004). Generally, the

impact on UK biodiversity has been negative with many species experiencing population and range contractions. Donald et al (2000) note that former communist countries, that have experienced far slower rates of intensification, have had significantly lower declines in farmland biodiversity. This adds further weight to the theory that agricultural intensification is largely responsible for the biodiversity declines countries, such as the UK, are now witnessing.

The impacts have been particularly negative for bird species. This is not surprising considering approximately 60% of Europe's threatened bird species are associated with agricultural landscapes (Ausden and Hirons 2002). Gregory et al (2004) found in their study of lowland farmland birds in the UK that 58% had shown long-term declines and 32% short-term declines, although their list was not definitive. As a result of these dramatic declines, DEFRA (The UK Department for Environment, Food and Rural Affairs) has agreed a public service agreement to reverse the long-term declines in farmland bird populations, as measured by the Farmland Bird Index, by 2020 (Bradbury and Kirby 2006).

The loss of wet grassland has been particularly devastating for UK wader populations. This study will focus on the lapwing, which has declined 49% in England and Wales between 1987 and 1998, and is now Amber Listed as a Bird of Conservation Concern (Ausden and Hirons 2002; Wilson et al 2005). Since 1999 the RSPB has established 11 regional Lapwing Recovery Projects throughout the UK (Sheldon et al 2003). This is a start, but the increasing concentration of waders into fewer areas makes the management of these sites crucial to ensure population recovery (Wilson et al 2005). Detailed understanding of distributions and factors affecting the productivity of the species is required to increase the chances of population stabilization and recovery. This study will address factors influencing the distribution and productivity of the species so that spatially explicit and relevant management recommendations can be made.

1.2 Study site

The study is based in the Avon Valley on around 993 square hectares of farmland. The study site runs from Fordingbridge, Hampshire, to Christchurch, Dorset. The area is of particular interest as the southwest of England has been noted as a region to have experienced some of the greatest declines in lapwing number in the UK (Wilson et al 2005). There are 208 fields in the study site, most of which consist of pastoral farms predominated by wet grassland. Fig 1.3 shows the site.

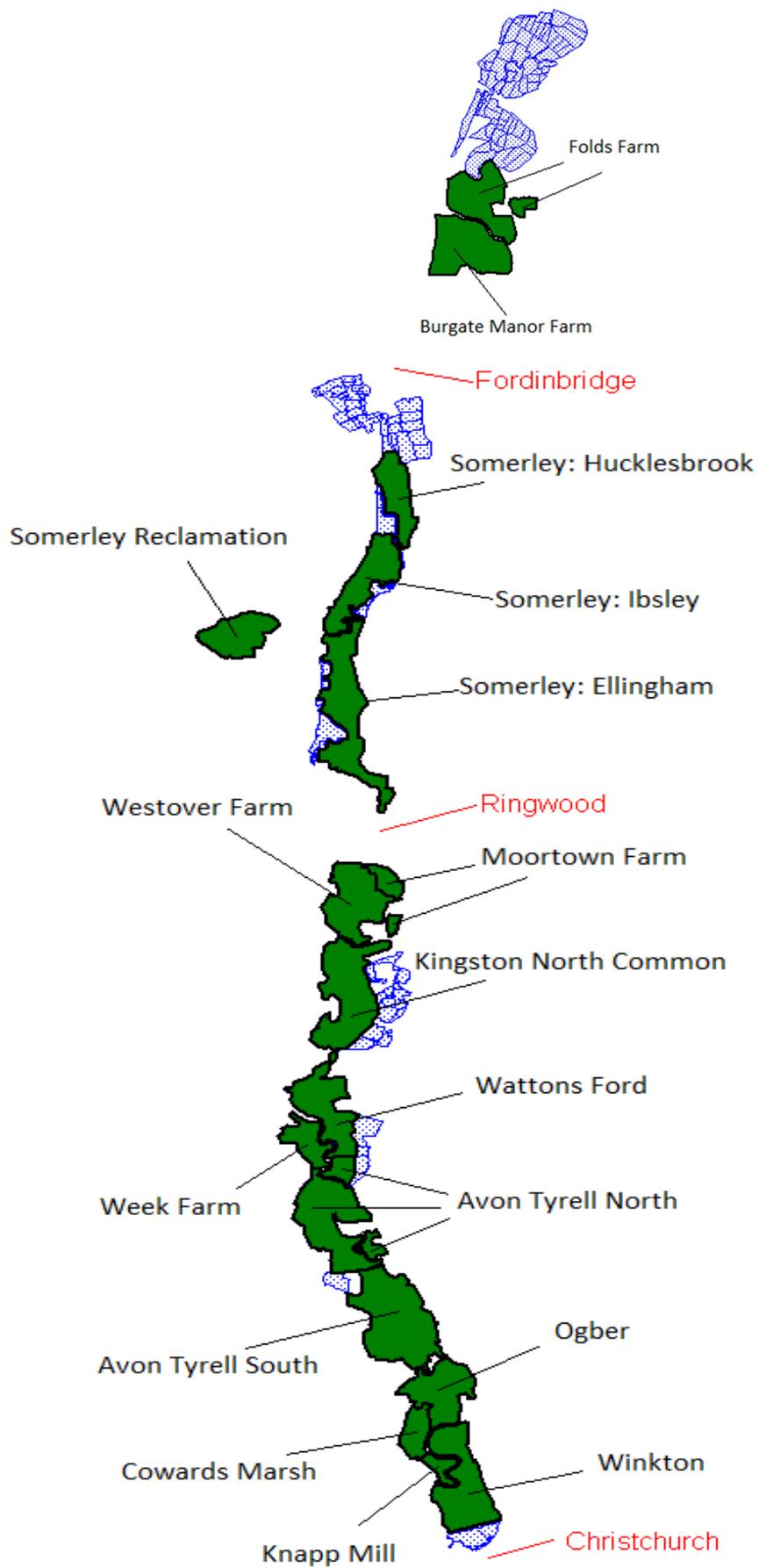


Fig 1.3 Field sites

1.3 Study aims and hypotheses

The aims of this study are as follows:

1. To detail patterns of productivity, spatially and temporally.
2. To assess which habitat features are important for lapwing site selection.
3. To explore factors affecting productivity both at the clutch and brood stages
 - Habitat features (mean sward height; variation in sward height, vegetation composition, soil penetrability, stocking densities, foot-drain densities).
 - Predator densities (corvids, gulls, herons, raptors, foxes).
4. To ascertain if there is certain landscape features in the field that impact productivity and predator densities (boundary score, perch density, length of woodland boundary, and level of aggregation).

The hypotheses are:

1. The number of birds and productivity are decreasing.
2. Pairs, nests, broods fledged and overall productivity will be aggregated into certain sites, so some sites will be consistently higher in all three years.
3. Fields with birds present will have significantly different habitat to those that do not.
4. Fields currently managed specifically for breeding waders will experience highest numbers of breeding pairs and highest daily survival rates.
5. Certain habitat features will be important for site selection, nest, and brood survival, although these will differ across the life history stages.
6. Fields with higher predator densities will have lower productivity.
7. Nests that hatch will be positioned differently in the field from those that fail.
8. Presence of certain landscape features will impact survival rates and predator densities.

It is hoped that once an understanding of settlement and productivity patterns is established, it will be possible to make spatially focused habitat management recommendations to allow for continued nesting and to reduce incidence of predation.

2. Background

2.1 Agri-environment schemes

Agri-environment schemes have been developed in many European countries. The initial and most basic aim of these schemes has been to curb agricultural intensification (Hodge and Reader 2010). Over time schemes have evolved and now will often also involve an element of environmental enhancement. Currently, there are around 26 out of 44 European countries with agri-environment schemes (Kleijn and Sutherland 2003). All 25 member countries of the European Union (EU) must implement locally tailored agri-environment schemes taking specific wildlife and societal needs into consideration (Wilson et al 2007). Around 20% of EU farmland is under agri-environment scheme agreement; this has cost around 24 billion Euros between the years 1994 and 2003 (Wilson et al 2007). Agri-environment schemes were introduced to the UK in the mid 1980's (Hodge and Reader 2010). By the end of 2007, around 47% of the agricultural area of the UK had been entered into an agri-environment scheme (Hodge and Reader 2010).

The schemes operate by offering farmers a payment to avoid intensive production practices and environmental degradation. The payments are based on compensating farmers for the profit forgone by following prescriptions as well as a small percentage as an incentive (Ausden and Hirons 2002). In the UK, agri-environment schemes started with the introduction of Environmentally Sensitive Areas (ESA's) in 1986 (Dobbs and Pretty 2008). ESA's offered a voluntary fixed price contract to farmers who could meet specific land management conditions (Hodge and Reader 2010). The ESA programs included measures to improve habitat for birds, increase biodiversity, and preserve landscape beauty and historic features (Dobbs and Pretty 2008). In 1991 ESA was joined by Countryside Stewardship Scheme (CSS), with slightly more emphasis on the enhancement of environmental features (Hodge and Reader 2010). CSS intended to sustain the beauty and diversity of the rural landscape, preserve wildlife, create new habitats and restore neglected land and features (Dobbs and Pretty 2008).

ESA and CSS were replaced in 2005 by Environmental Stewardship (ES) (Hodge and Reader 2010). There are three levels of ES, Organic Entry Level Stewardship (OELS), Higher Level Stewardship (HLS), and Entry Level Stewardship (ELS). HLS is similar to CSS but with more specific and tailored prescriptions (Hodge and Reader 2010). ELS represents a new approach to

agri-environment schemes as it aims to extend the coverage of schemes to bring in a greater proportion of farmland – a wide, narrow approach – with a flat rate payment of £30 per hectare (Vickery et al 2004; Hodge and Reader 2010).

Agri-environment schemes have been subject to some criticism. Broadly, the problem of additionality is often noted in the literature (see Kleijn and Sutherland 2003; Hodge and Reader 2010). The relaxed guidelines and voluntary approach makes many schemes open to exploitation by landowners whose practices already fit within the guidelines no additional benefits for biodiversity occur. Kleijn and Sutherland (2003) note that scheme uptake is often highest in areas where biodiversity is already high and is lowest in areas of poor initial levels of biodiversity. It is not taken into account how much effort is put into meeting prescriptions nor is the degree of change considered when allocating payments. Thus schemes can be seen to maintain the status quo and offer little incentive for some of the most intensive and harmful areas to change.

More specifically to HS, the introduction of ELS has brought new concerns to light regarding the value in having large areas of average quality land and giving little incentive for entry into HLS – the quality versus quantity debate (Vickery et al 2004). Wilson et al (2007) found less expensive habitat maintenance options, such as those included in ELS, have limited benefit for waders such as lapwing and snipe. This may be partly because wet feature creation is only an option for HLS (Bradbury and Kirby 2006). ELS represents a paradigm shift in agri-environment schemes to become more inclusive and extensive in their coverage. However, it is clear there are legitimate concerns that require investigation. In addition to this, it is possible that even HLS offers too general guidelines and prescriptions and that a more bespoke case-by-case review of the needs of agriculture and the biodiversity of the area would be more successful (Ausden and Hirons 2002; Teunissen et al 2008).

Monitoring farms managed under schemes is essential to ensure quality is maintained and recommendations for improvement can be made. Agri-environment schemes have been criticised for being poorly monitored (Bradbury and Kirby 2006). Good monitoring should generate data that allows for spatial and temporal comparisons to be made. Assessing the impacts on biodiversity temporally can reveal which areas are having the greatest additional benefits to biodiversity each year. Spatial analysis allows for an understanding of which management options are producing greatest results and can help identify hotspots for conservation – thus addressing whether quality of land or quantity of land entered is most effective for promoting biodiversity.

2.2 The lapwing (*Vanellus vanellus*)

The lapwing is a wader bird that derives from the order Charadriiformes (Shrubb 2003). The lapwing makes an excellent study species as it is extensively studied so its ecological requirements are well understood (Sheldon et al 2004). Through agri-environment schemes, there is the opportunity to integrate conservation measures aimed at the species and agricultural practices (Sheldon et al 2004). The charismatic nature of the species and its popularity amongst the general public and farmers makes the success of such measures more probable if they are presented as a flagship species.

Globally, the lapwings distribution spreads from Europe to parts of Asia and it is found throughout the UK. Hotspots in the UK include lowland areas of Northern England and the Borders and Eastern Scotland (RSPB 2010). In winter they migrate to the warmer South Coast (RSPB 2010). The breeding season commences in early spring – late March or early April – and runs through to late June (Shrubb 2003). Lapwings breed in open habitat including wetlands, moors, pastures and arable land (Cramp and Simmons 1983). Each clutch consists of four eggs on average, although towards the end of the season clutches tend to diminish in size (Hart et al 2002). Once laid, eggs require around 26 days incubation before hatching. During this time females incubate the nests while the male remains close by to watch for potential predators. If a nest should fail, birds will usually re-lay within two weeks (Berg et al 1992).

Shortly after hatching, the parents will lead the chicks to good foraging areas (Blomqvist and Johannsen 1995). Chicks will usually remain within 100m of the nest site until fledging (Johansson and Blomqvist 1996). Optimal nesting and chick rearing habitats are thought to differ. As chicks will tend to remain relatively close to the nest site, it is preferable if good quality brood rearing habitat is near to nesting sites. The primary food source for the lapwing is soil and surface invertebrates; therefore, habitat rich in these species is ideal for chicks (Johansson and Blomqvist 1996). Chicks usually fledge after around 35 days (Shrubb 2003). The only method of defense available to lapwing chicks is to hide from predators. Adults will sound a warning call to alert the chicks and in some cases may attack or attempt to distract predators away from areas where chicks are present (Elliot 1985). Once the chicks have fledged, the birds move on from nesting sites in large feeding flocks (Shrubb 2003).

The British Trust for Ornithology (BTO) and the Royal Society for the Protection of Birds (RSPB)

conducted a survey in 1988 which estimated around 63,000 breeding pairs of lapwings were present in the UK and Wales. This showed a decline of 49% in the species numbers since the same survey was conducted in 1967. Further to this, the Common Bird Census (CBC) of the British Trust for Ornithology (BTO) and the Joint Nature Conservation Committee (JNCC) indicates that Lapwing have been continuously declining in the UK since the mid 1980's. Peach et al (1994) found, in ringing recoveries, that lifespan of the species has actually increased from 2-4 years between 1909-1952 to 3-5 years between 1969-85. Declines are therefore not a result of reduced adult or first year survival. It is widely accepted that the leading cause of decline is reduced productivity as a result of poor breeding success (Peach et al 1994; Seymour 2003; Macdonald and Bolton 2008). To replace annual adult losses and have a sustainable population, lapwings should produce around 0.6-0.97 fledglings per breeding pair each year (Peach et al 1994; RSPB 2010). In recent years, this has not been achieved.

Table 2.2: Nest success: as taken from Mayfield (1975)

Stage	Process
1	Survival during the building of the nest
2	Survival during the egg-laying period
3	Survival during incubation
4	Hatching of eggs
5	Survival of young to fledging

Mayfield (1975) has noted that breeding success may be viewed in 5 stages, as outlined in table 2.2. Conservation efforts will be most effective if focused around increasing the success at each of these five stages. Habitat quality is an important factor influencing breeding success. Habitat can positively impact productivity of the lapwing in two ways. Firstly, good habitat that allows for nesting and has a proximity to a good food source will attract more birds and permit breeding at higher densities. Secondly, habitat can be manipulated and managed to reduce attractiveness to predators and so, give the species the greatest chance of survival. Habitat that can provide some concealment to chicks and has few perches for predators may prove to be more productive.

2.3 Habitat

When selecting fields to nest, important considerations include risk of predation and availability of prey (Devereux et al 2004). Lapwing behavior and survival strategy is best suited to a shorter sward, around 10cm high (Hart et al 2005; Durrant et al 2008) since lapwings employ active nest defense towards potential predators. This requires good visibility so predators can be detected as early as possible (Vickery et al 2001). Furthermore, lapwings search for prey using a pause-travel search method, where a stationary scanning period is followed by movement to prey (Butler and Gillings 2004). Sparse and short swards allow greater visibility for the detection of predators and prey and provide the most efficient terrain for foraging as mobility is easier meaning less energy is expended when moving towards prey (Butler and Gillings 2004; Bradbury and Kirby 2006).

A shorter sward that permits easier movement is particularly important for broods. Devereux et al (2004) note that chick foraging rates declined as sward height increased. The short legs of chicks means movement is greatly restricted in a longer sward and requires a significantly larger input of energy to forage effectively. Additionally, Whittingham and Evans (2004) note that dense tall vegetation can impose greater energetic demands following rain as more moisture is retained which will wet the plumage of chicks and thus increase heat loss for chicks moving through it. As chicks cannot thermo-regulate, this can have devastating consequences on productivity should precipitation occur (Shrubb 2003).

Cattle can be beneficial to lapwing as their grazing keeps the sward short. Durrant et al (2008) found a positive relationship between stocking density in early spring and field selection. However, intensive grazing can reduce botanical diversity by favouring species that can tolerate repeated defoliation and a uniformly short sward can mean nests are more visible to predators (Vickery et al 2001; Hart et al 2005). A homogenous short sward can also reduce the ability of chicks to shelter from potential predators (Baines 1990). While fields with a predominantly short sward are essential for lapwing, some provision of areas of longer sward for chicks to hide in is thought to be ideal (Butler and Gillings 2004; Devereux et al 2004). Intermediate levels of seasonal, rather than continuous, grazing can promote sward heterogeneity with short areas for nesting and foraging and taller tussocks for cover (Vickery et al 2001; Van der Wal et al 2008). Additionally, intermediate levels of grazing can increase botanical diversity by keeping the sward open and creating gaps for seedlings to establish (McCracken and Tallowin 2004).

Concerns have been raised regarding the impact of trampling by cattle. Vickery et al (2001) found a stocking rate of approximately 2.5 cows per ha leads to approximately 70% of redshank (*Tringa totanus*), 60% of snipe (*Gallinago gallinago*) and 35% of lapwing nests being trampled. This is significant, but stocking densities have decreased on average since the 1990's (Chamerlain and Crick 2003). At the densities specified under HLS, which is currently between 0.4 and 1 LU/ha, trampling by livestock is not generally found to be a problem so the benefits afforded by cattle grazing outweigh the risks (Baines 1990; Natural England 2010).

Agricultural intensification has resulted in increased use of chemical insecticides, herbicides and fertilizers. The use of inorganic fertilizers, insecticides and herbicides has reduced the diversity of plant and insect species found in many agricultural areas. Insecticides have the direct impact of directly killing the prey of the lapwing (Vickery et al 2004). Herbicides remove insect host plants thus decreasing the numbers of prey available (Vickery et al 2004). Fertilizer and use of high yielding plant species encourage the rapid growth of competitive species and excludes many other plant species thus reducing the diversity of plant and insect species (Vickery et al 2001; McCracken and Tallowin 2004). Reduced use of chemicals permits greater species diversity, and so, greater prey availability. Nest crypsis is also increased, as nests are more obvious to visual predators when placed in the middle of a completely homogenous grass field (Evans 2004; Macdonal and Bolton 2008).

Areas of penetrable soil are important to waders. Agri-environment schemes that fail to increase water tables have proven to be less effective at attracting breeding lapwing (Bellabaum and Bock 2009). Areas of wetness will increase the availability of prey as aquatic invertebrates become available and remain closer to the surface, and soil is more easily penetrated by the bills of waders – this is particularly important for snipe and black-tailed godwit (*Limosa limosa*) (Milsom et al 2002; Bradbury and Kirby 2006; Elington et al 2008). Flooding can suppress vegetation growth, thus providing areas with greater visibility and mobility for foraging (Elington et al 2008). However, not all aquatic invertebrates can survive periods of prolonged flooding as the soil can become anaerobic. Therefore, prey diversity may decrease under prolonged flooding (Auden et al 2001; Bradbury and Kirby 2006).

Due to the feeding and chick rearing benefits, lapwings tend to nest closer to rivers and areas of damp soil than would be expected by chance (Berg et al 1992). Elington et al (2008) found fields with high footdrain flood densities attracted significantly higher densities of lapwing and nests

tended to be located on drier ground, but close to foot-drain floods. For lapwing, damp and partially flooded soil is particularly important later in the season when broods are present. Chicks tend to forage more in damp soil and areas of bare ground (Elington et al 2008). Bellabaum and Bock (2009) found broods which had access to wet features and moist soil throughout the chick rearing period had a 75% success rate while dry sites had only a 31% success rate. Additionally, Smart et al (2006) note that mammalian predators are less likely to enter fields if they must travel over wet soil.

The literature, therefore, suggests a mosaic of habitat is best for lapwing as the nesting and brood rearing periods have different requirements. A short but species rich sward is needed for nesting, while areas of long grass are ideal for chicks to shelter from predators. Dry soil is required for nesting and to provide surface invertebrates, while damp soil and flooded areas are good for chicks to forage for aquatic invertebrates and afford additional benefits for probing waders such as snipe (Ausden et al 2001). Currently, the provision of a diverse habitat mosaic is not recommended under any ES prescriptions. This is thought to negatively impact the success of such schemes.

2.4 Predation

Agri-environment schemes focus on habitat protection and enhancement, but this may not be enough to ensure increased breeding success (Isaksson et al 2007). Studies demonstrating the devastating impacts of predation are numerous. Seymour et al (2003) reported lapwing clutch loss due to predation to be 47%, similarly Macdonald and Bolton (2008) found 50% and more recently Hart et al (2002) and Bellabaum and Bock (2009) reported rates of 90 and 91% respectively. Teunissen et al (2008) found predation to be the cause of 75% of all reproductive losses in lapwings. To make matters worse, Chamberlain and Crick (2003) note predation rates increased more in the 1990's than any other decade. Agri-environment schemes are often criticized for failing to address the issue of predation when it is so often clearly impacting lapwing productivity (Van der Wal et al 2008).

Broadly, predators of lapwing nests and chicks can be considered in two categories, mammalian and avian. A list of common UK predators is shown in table 2.4. It is widely accepted that red foxes *Vulpes vulpes* are the predominant mammalian predator of lapwing nests, although in some areas Stoats *Mustela erminea* are also common (Seymour et al 2003; Teunissen et al 2008). Foxes are common throughout the UK, with 240,000 adult foxes and 425,000 cubs born in Britain each year (Baker et al; 2002). The main predators of broods are thought to be avian, particularly buzzards,

grey herons and carrion crows (Teunissen et al 2008; Elington et al 2009). Although these broad trends have been identified in the literature, both avian and mammalian predators are a threat to lapwing at both the clutch and brood stages.

Table 2.4 Common Lapwing clutch and brood predators in the UK

Mamalian	Avian
Red Fox <i>Vulpes vulpes</i>	Kestrel <i>Falco tinnunculus</i>
Stoat <i>Mustela erminea</i>	Buzzard <i>Buteo buteo</i>
Weasel <i>Mustela nivalis</i>	Grey Heron <i>Ardea cinerea</i>
American Mink <i>Mustela vison</i>	Little Egret <i>Egretta garzetta</i>
Brown Rat <i>Rattus norvegicus</i>	Cormorant <i>Phalacrocorax carbo</i>
Hedgehog <i>Erinaceus europaeus</i>	Gull (Black Headed <i>Larus ridibundus</i> , Common <i>Larus canus</i> , and Lesser Black Backed <i>Larus fuscus</i>)
Badger <i>Meles meles</i>	Carrion Crow <i>Corvus corone</i>
	Rook <i>Corvus frugilegus</i>
	Magpie <i>Pica pica</i>
	Jackdaw <i>Corvus monedula</i>

In some instances, predator control methods have been employed. Foxes may be shot and fences may be placed around fields with high breeding wader numbers to reduce accessibility. Fencing, however, does not deter avian predators and can even act as a perch for predators from which to observe (Isaksson et al 2007). Crows can be caught in Larsen cage traps which use a decoy crow to attract other territorial crows into the cage (Bolton et al 2007). However, these methods of predator

control have limited success. While overall declines in predator numbers can occur, Bolton et al (2007) found a 40% decline in adult fox numbers and a 56% reduction in crows, higher survival of clutches and broods is rarely experienced (Fletcher et al 2005; Bolton et al 2007; Bellabaum and Bock 2009). This may be because other mammalian and avian predators fill the niche (Fletcher et al 2005; Bolton et al 2007; Bellabaum and Bock 2009).

Clearly, predator control is not always effective. Additionally, predator control can be expensive and time consuming and lethal measures are problematic due to the negative public response they can evoke (Bolton et al 2007; Isaksson et al 2007). It has been suggested that predation rates are affected by anthropogenic habitat changes which usually favour predators (Evans 2004; Wallender et al 2006). Certain field features may be conducive to predators or provide optimum hunting conditions. Managing the landscape to reduce these effects may be a more efficient and permanent method of reducing predation rate than lethal control methods (Wallender et al 2006).

Avian predators may use certain habitat features such as trees and fence lines as vantage points. To increase the chances of success, it has been found in some instances, that lapwings nest further away from field boundaries and predator perches (Salek and Smilauer 2002; Sheldon et al 2004; Wallender et al 2006). The relationship between nest distance to predator perch and nest success is tenuous and one that requires further investigation. Seymour et al (2003) found no effect of proximity to avian perches and nest success. While Wallender et al (2006) state nest survival does increase with distances from perches and Macdonald and Bolton (2008) found a relationship between nest predation rate and the distance of a nest from a boundary. Boundaries can be particularly perilous to lapwing as avian predators can perch on them and foxes tend to walk along boundaries (Macdonald and Bolton 2008).

It has been found that lapwings nesting in aggregations will experience lower nest predation rates (Salek and Smilauer 2002; Macdonald and Bolton 2008; Elington et al 2009). Berg et al's (1992) study found 92% of lapwings bred in aggregations. There are two key benefits to nesting in aggregations. First, groups are more vigilant and can detect potential predators early (Elliot 1985). Second, lapwing employ an aggressive mobbing technique when feeling threatened; nesting at higher densities is thought to make this more effective (Macdonald and Bolton 2008). However, it has been suggested that aggregations can be honey pots for predators (Elington et al 2009). The impacts of aggregations must be considered on a site by site basis to avoid inaccurate assumptions concerning the optimal nesting strategy.

3. Methods

Data was made available from 2008 and 2009 concerning nest distribution and productivity of fields. This was used in the analysis in addition to the data collected in 2010. All calculations for hatch dates, densities and survival rates can be found in the appendix.

3.1 Nest Finding

Each field in the study site was visited in early April, May and June to determine lapwing presence. The fields were observed from a distance of at least 100 meters, and the number of birds counted. Lapwing could be sexed using plumage patterns on their head and breasts and from the length of the head crest (Cramp and Simmons 1982; Milsom et al 2002). From this it was possible to estimate numbers of pairs per field that may lay or have a nest. Behavior such as scraping and displaying was also noted as this is a good indicator that nests will be present on the field within the next few days.

Fields where pairs were present were revisited and observed for up to an hour at a time. Nests could be located by watching adults return to their nests; as lapwing only sit when incubating nests (Hart et al 2002). Once a nest was suspected, a detailed sketch map was drawn so nests could be easily identified on subsequent visits. Nest sites were then marked with a GPS. Previous studies have marked nests with canes or even buried foil in the ground so a metal detector can locate nests, but GPS markings with sketch maps are highly efficient and accurate and so this was the method selected for this study (Galbraith 1987; Green et al 1987). The number of eggs was counted and a numbered temperature logger placed in each nest cup, held in place with a nail glued to the base of the logger.

3.2 Hatch date

Each eggs width and length was measured with dial calipers and weighed with portable digital scales. Egg volume was then calculated from the Galbraith formula (Galbraith 1988a), which allowed mean egg density to be calculated for each clutch. Egg density decreases with incubation mainly due to water loss (Galbraith 1988) so it is possible to estimate hatch date from this information. Once hatch date was estimated it was possible to work backwards and estimate laying

date as many nests were found several days after laying. Nests could then be visited more frequently closer to the hatch date to allow for more accurate conclusions to be drawn concerning the fate of the nest.

3.3 Productivity

Fields were re-visited every three to four days to check on nests and later in the season, broods. This allowed for a productivity to be calculated in accordance with Mayfield (1975). Birds in areas where nests were known were observed to see if they returned to the nest. If a no incubating adult was located on a nest on the second consecutive visit, the nest was walked out to using the GPS and sketch map and checked. Both Fletcher et al (2005) and Galbraith (1987) found that approaching lapwing nests and even handling eggs had no significant effect on clutch survival. Visits to nest were, however, minimised as far as possible for reasons of animal welfare and to reduce the incidences of flushing incubating adults on nearby nests as it has been suggested this can reveal nest location to predators. Hart et al (2002) found risk of predation was correlated with the frequency with which incubating adults were flushed from the nest. During times of rain or particularly cold periods, nests were not disturbed as this may have lead to nests perishing. This became particularly important when checking broods, as chicks are not able to thermo-regulate (Shrubb 2007). Fortunately, the spring of 2010 was particularly warm and dry so few visits were missed.

If nests had failed the suspected cause of failure was recorded following the method of Chamberlain and Crick (2003) and is explained in table 3.3. Of course, this is somewhat subjective, but in most cases the cause of nest failure was fairly obvious and could be assigned to one of the four categories with some confidence. In instances where loggers were lost or unavailable it was assumed the date of failure was the midpoint between the last known time an incubating adult was present and the date the nest was found to have failed. As nests were checked every three to four days this date could be predicted with a fair degree of accuracy. Where temperature loggers were present it was possible to detect the exact time of nest failure; the time of failure was recorded as the time when nest temperature ceased to fluctuate and fell to ambient temperature (Bolton et al 2007; Bellabaum and Bock 2009; Eglington et al 2009).

Table 3.3: Causes of nest failure as taken from Chamberlain and Crick (2003)

Cause	Explanation
Abandoned	Contents undamaged but eggs cold to the touch
Failed due to weather	Same as above, but only if abandoned during a period of extreme rain or frost
Destroyed	Such as by trampling – contents and nest destroyed but not removed
Predated	Contents of nest partially or completely removed before earliest possible hatch date, and in some cases larger fragments of egg around the nest

The nest was assumed to have hatched if the nest was found with eggshell fragments of 1-3mm diameter in the nest lining, since this is produced as the chicks hatch out of the egg, and the date was in line with the Mayfield calculation of hatch date (Green et al 1987). In the first 14 days following hatching, the chicks remain close to the nest (Milsom et al 2002). In fields with shorter swards it was possible to observe the chicks and predict the nest from which the chicks had hatched from. In fields with longer swards it was possible to tell a brood was present from listening for the females distinctive alarm call to their chicks. If this occurred around the same time as a nest appeared to have hatched it was assumed the brood was from that nest.

Brood monitoring was conducted similarly to nest monitoring, with visits to fields with chicks present every four days. The alarm call of the female differs from the display call and so the number of broods present could often be established from walking through the field to disturb the birds and counting the number of birds alarm calling. Where possible chicks were observed and their ages estimated from their size to try and establish an idea of which broods had survived. If there was no adults alarm calling on two consecutive visits the brood was assumed to have failed or fledged depending on the number of days observed. Broods take approximately 35 days to fledge (Yalden 1991). The daily survival rate is the probability of a nest or brood surviving a day, overall survival is the probability of a nest or brood surviving to hatching or fledging respectively. Both can be calculated at the field level using the Mayfield method (Mayfield 1975).

3.4 Habitat quality

In the middle of the lapwing breeding season (mid May) all 208 fields in the study site were visited and habitat variables recorded. A random transect was walked through the middle of each field and 30 measurements were taken of sward height, soil penetrability, and composition of vegetation. Sward height was recorded with a sward stick and soil penetrability was measured with a penetrometer, (PERSOLA macro-line 80020). For each of the 30 measurements the vegetation present in a meter quadrat around the point of measurement was noted. Vegetation was divided into five simple categories; grass; dicotyledon; sedge; weed; and rush. Bare ground was also recorded. For simplicity, each was weighted equally to work out percentage cover for the whole field. Information on the management of each field was obtained from Natural England, Hampshire.

On fields with lapwing present, further habitat measures were taken. Length of foot-drains was calculated by taking GPS start and finish points to plot them onto MapInfo for measurement. Foot-drain density could then be calculated by dividing the length of the foot-drain by the field area. Area of field could be calculated using MapInfo for fields where birds were present. Stocking densities (LU) were calculated by noting the number of cows, horses, calves and sheep. These were then weighted to provide the livestock unit score (LS), as shown in table 3.4. The date that cattle or sheep were present and the date that they were removed was recorded as the midpoint from the previous visit and the visit after the situation had changed. The proportion of days present (D) was calculated by the number of days cattle were present divided by the total number of days in the breeding season (87 days in 2010). This information, along with the area of the field and the number of fields the cattle had access to, allowed for stocking densities to be calculated.

Table 3.4 weighted livestock units as taken from Chesterton (2006)

Species	Score
Cow	1
Calf	0.6
Horse	0.6
Sheep	1.5

3.5 Predator densities

In instances where predation was suspected to be the cause of nest failure it was sometimes possible to infer the likely predator from the nest remains following the methodology of Green et al (1987). They noted avian predators will often carry the eggs out of the range of the attacking parents, so in cases where nests were partially predated or there was little sign of damage to the nest and an absence of shell fragments it was noted an avian predator was likely. Mammals will occasionally leave larger fragments of shell near to the nest with evidence of tooth marks, although this varies, but where larger chewed fragments were present it was noted a mammalian predator was the likely culprit. The temperature loggers were also referred to; nests that were deserted at night are more likely to have been predated by mammals and those deserted in the morning by avian predators (Bellabaum and Bock 2009). The failure of broods is more difficult to determine, particularly in fields where broods were not easily visible. Broods commonly fail due to starvation, cold weather and predation.

To determine predator densities (PD), four, one hour watches in fields where birds were present were conducted. All avian predators were identified and noted as they flew overhead in five minute slots. Broadly, avian predators fell into one of four categories: corvid, gull, heron and raptor. PD is the number of each predator type per minute, per hectare. In late May and then again in mid June, fox scat routes were walked for all sites with birds present. The routes followed the same routes used in 2009 and were adapted where necessary. The routes generally circled the edges of fields with birds present as well as any obvious pathways on the site (Cavallini 1994). This is because foxes will tend to leave scats to mark territory around fields (Cavallini 1994). Scats are usually left in fairly prominent places – such as the middle of paths or the ends of bridges – therefore scats could be located quite easily and with confidence that few were missed (Cavallini 1994). Where foxes were observed or dens found this was also noted. Foxes were used as the main mammal predator as they are easier to detect than any other smaller mammal predators. From this information it was possible to estimate fox density for each site following Baker et al (2002). It was only possible to calculate fox density on the site as opposed to the field level.

3.6 Landscape features

A range of landscape features that may influence the abundance and impact of predators were investigated in the hope that management recommendations may be able to be made to manage fields to reduce incidence of predation. First, the number of perches per field was counted. Perches were considered to be trees or shrubs that would provide a vantage point for avian predators (Berg et al 1992). These features were marked with the GPS so their positions could be mapped on MapInfo and distances from nest to nearest predator perch could be calculated (Macdonald and Bolton 2008). For analysis at the field level, the features were ranked. A similar method was employed by Milsom et al (2000) to rank features along boundaries. Trees of over 3 meters received a score of 4, smaller trees a score of 3, shrubs of over 2 meters and man-made structures a score of 2, and smaller shrubs a score of 1. This gave a total perch score, which was then divided by field area to give the perch density.

Second the boundary score for each field was calculated following the methodology of Durrant et al (2008). Boundary score equals length of boundary divided by area of field. Boundary was considered to be the parts of a field with a fence line. Woodland boundaries were measured and considered separately. This is because woodland boundaries are thought to be more detrimental to lapwing as they can provide habitat and refuge to predators and offer vantage points to avian predators. A woodland boundary was defined as an area that consisted of at least a 3 meter wide and 5 meter long area of dense, medium and tall trees.

Finally, the level of aggregation of nests was calculated following Galbraith (1988b) and Berg et al (1992). This method requires calculating the number of nests active within a 100m radius of any given nest. Once level of aggregation had been calculated for each nest, the total could be calculated at the field level by combining the scores for each nest in the field.

4. Results

Data was analysed in R2.9.0.

4.1 Distribution and productivity

The number of breeding pairs, nests hatched and broods fledged were compared over the three years 2008-2010. Lapwings that were found in male and female pairs or demonstrating breeding behavior in the same field on two consecutive visits were recorded as breeding pairs, in accordance with Salek et al (2002). The fields where pairs, nests hatched and broods fledged were present were monitored over time to assess whether activity is aggregated to certain sites.

4.1.1 Temporal analysis of distribution

In total, 208 fields were monitored across 17 sites in the Avon Valley. 105 breeding pairs were located in 41 fields on 13 of the 17 sites between the 5th of April and the 25th of June 2010. Due to the short data set, it was not possible to assess statistically whether distributions were changing over time. Descriptive statistics have been used to illustrate settlement patterns, see fig 4.1.2.1-3.

Key: *2008 *2009 *2010

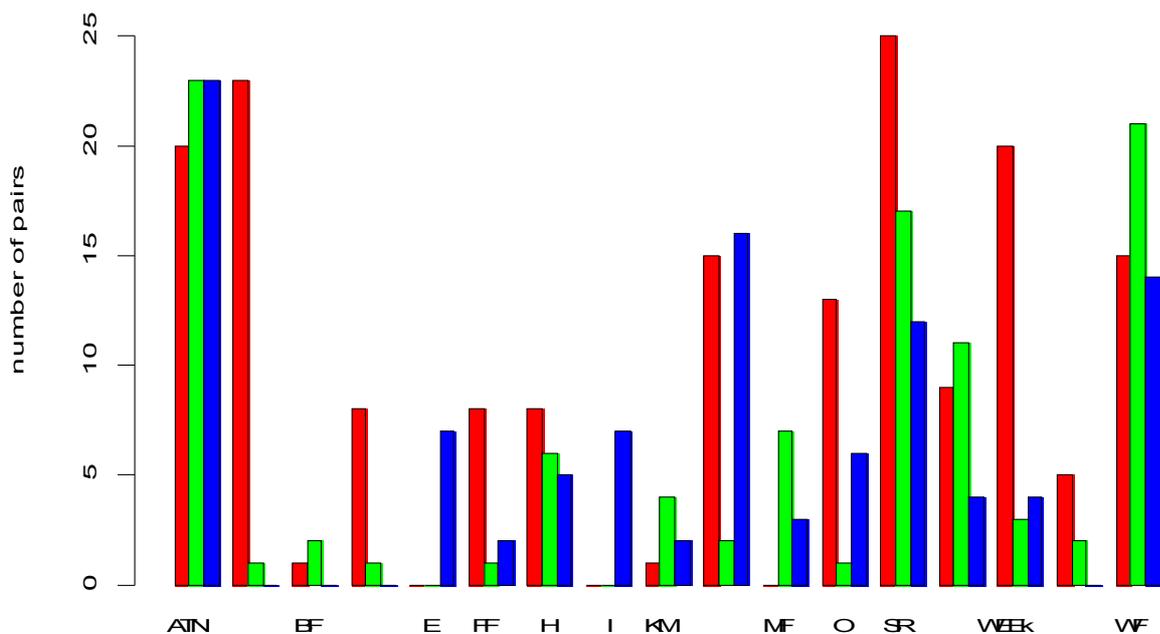


Fig4.1.2.1 Number of lapwing pairs per site per year

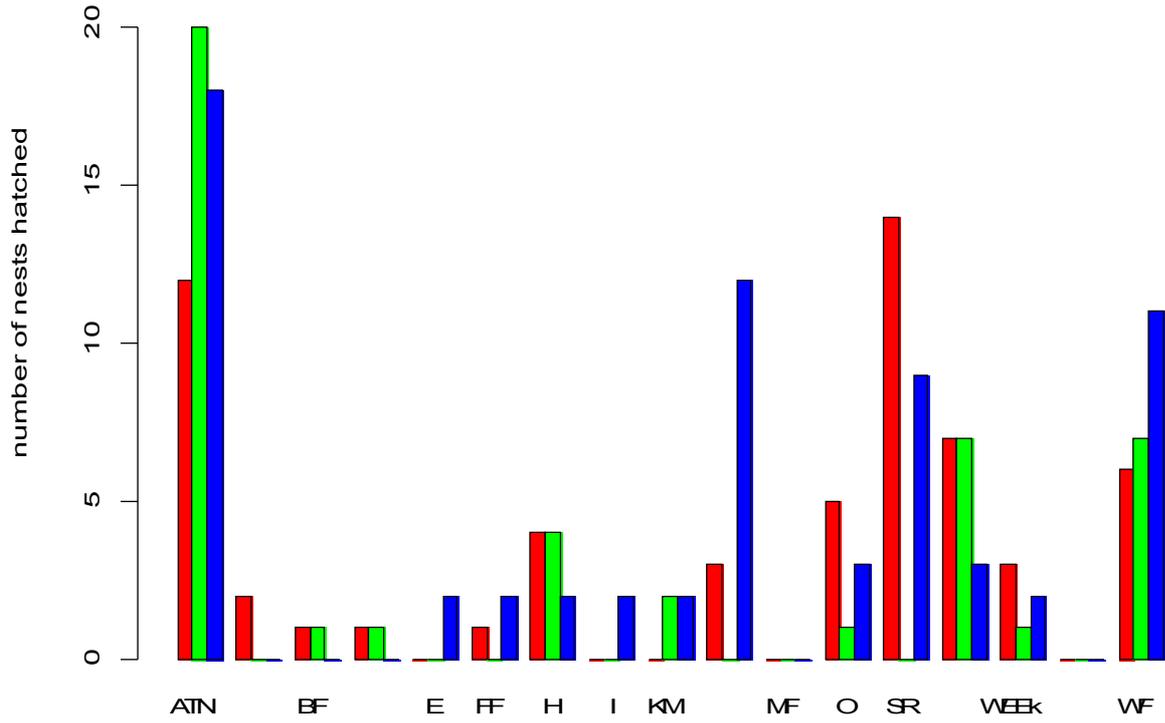


Fig 4.1.2.2 Number of lapwing nests hatched per site per year

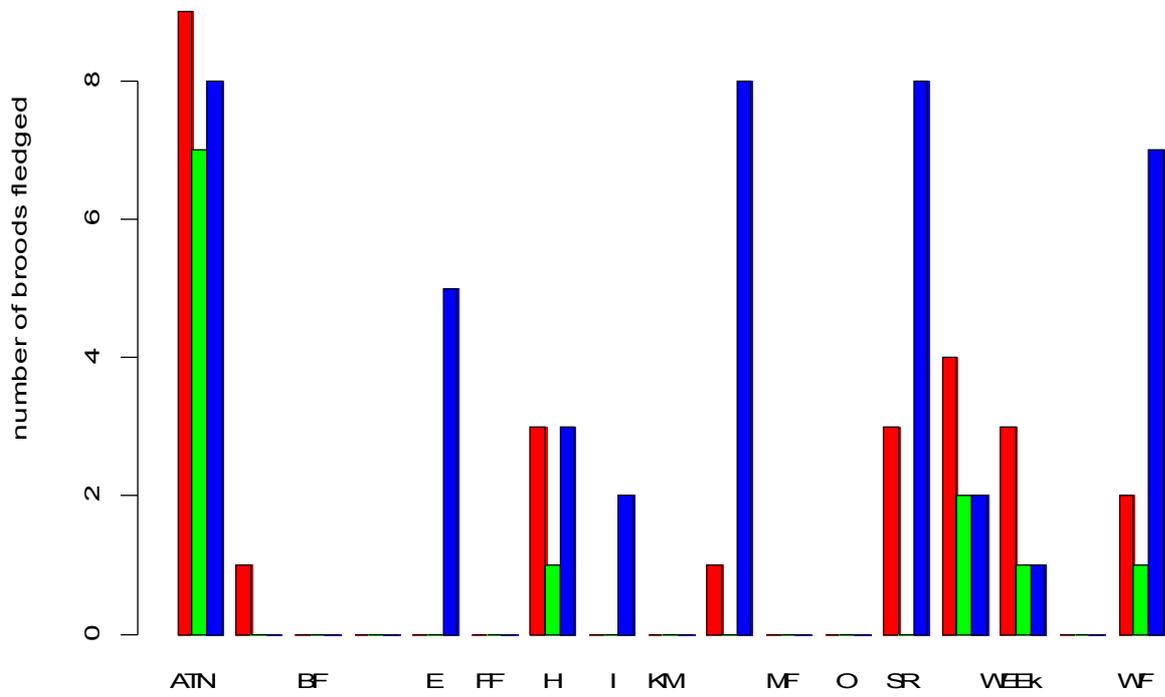


Fig 4.1.2.3 Number of lapwing broods fledged per site per year

Fig 4.1.2.1 shows in 2008 most pairs were located on Somerley reclamation with high numbers of pairs also found on Avon Tyrell South and North and Week farm and Wattons Ford. The distribution appears to have changed slightly in 2009 and 2010 with far fewer birds found on Avon Tyrell South and Week Farm. As the overall number of pairs has declined since 2008 it is possible these sites were previously supporting birds that have now moved elsewhere in the Valley or further afield. Alternatively the sites may be of a poor quality and so poor returns to them may be a result of poor productivity on them and subsequent death of those adult birds.

The number of nests hatched is highest in 2008 on Somerley Reclamation, there is also a large number of nests hatched here in 2010, no nests hatched in 2009. Avon Tyrell North has a high number of pairs in all three years. In 2010 there were a large number of nests hatched in Kingston North Common, but not in the preceding years. The number of broods fledged is highest in every year for Avon Tyrell North, although in 2010 there were just as many on Somerley Reclamation and Kingston North Common and almost as many on Wattons Ford.

Although there are yearly variations in distribution, there were only five sites of the 17 that had activity at all three stages in all three years – (ATN, H, W, Week and WF). Somerley Reclamation had high numbers in 2008 and 2010, but a complete absence of hatched nests in 2009, which is thought to be somewhat anomalous.

4.1.2 Temporal analysis of productivity

The total number of pairs decreased from 171 in 2008 to 105 in 2010, although the difference in pairs between 2009-10 has not changed greatly. A one way analysis of variance reveals the change in number of pairs over the three years has not changed significantly ($F=1.57$, $DF=2:48$, $P<0.22$). The number of nests hatched and broods fledged is highest in 2010 despite the lower number of pairs present when compared to 2008. The number of nests hatched has not changed significantly over the three years ($F=0.37$, $DF=2:48$, $P<0.7$). The number of broods fledged is also not significantly different over the three years ($F=2.36$, $DF=2:48$, $P<0.11$). Although a Tukey multiple comparison of means found the difference between 2009 and 2010 is almost significant ($P<0.09$).

The productivity of lapwing pairs on each site was calculated by dividing the number of broods that survived to fledging by the total number of pairs present per field. The proportion of pairs that fledged a brood across the Valley in 2010 was 0.42. The productivity of lapwings in the Avon Valley

is significantly different over the three years ($F=4.72$, $DF=2:48$, $P<0.01$). A Tukey multiple comparison of means found the productivity in 2010 was significantly higher than in 2009 ($P<0.01$) and almost significantly higher than in 2008 ($P<0.07$). The number of pairs, nests hatched, broods fledged and productivity over the three years is outlined in table 4.1.1.

Table 4.1.1: Numbers of pairs present, nests hatched, broods fledged and productivity (broods fledged/pairs) from 2008-2010

Year	Pairs	Nests hatched	Broods fledged	Productivity
2008	171	59	26	0.15
2009	102	44	12	0.12
2010	105	46	44	0.42
Average	126	50	27	0.23

4.1.3 Probability of success

The probability of a nest hatching was calculated by taking the daily survival rate and multiplying it to the power of 26, as eggs are usually incubated for 26 days before hatching (Galbraith 1988a). Across the Avon Valley in 2010 the nests had a 41% chance of hatching. In 2009 this was 27% and in 2008 it was 39%. The probability of a brood fledging was calculated in the same way as the probability of a nest hatching, but was multiplied to the power of 35 as broods take on average 35 days to fledge (Yalden 1991). The probability that a lapwing chick would survive to fledging across the whole Avon Valley in 2010 was 34%. In 2009 the chance was 22% and in 2008 it was 53%.

A linear model was fit to the probability of a nest hatching and the probability of a brood fledging in 2010. Although there is a slight positive relationship (Fig 4.1.3, $Cor0.16$), it is not significant ($F=0.29$, $DF=1:11$, $P<0.6$) and the model only explains 6% of the variation in the data ($R^2_{adj}=0.06$). Sites with high nest survival do not necessarily have good fledging success, and some sites have poor nest success but good fledging success. Suggesting there may be different factors influencing success at the two life history stages.

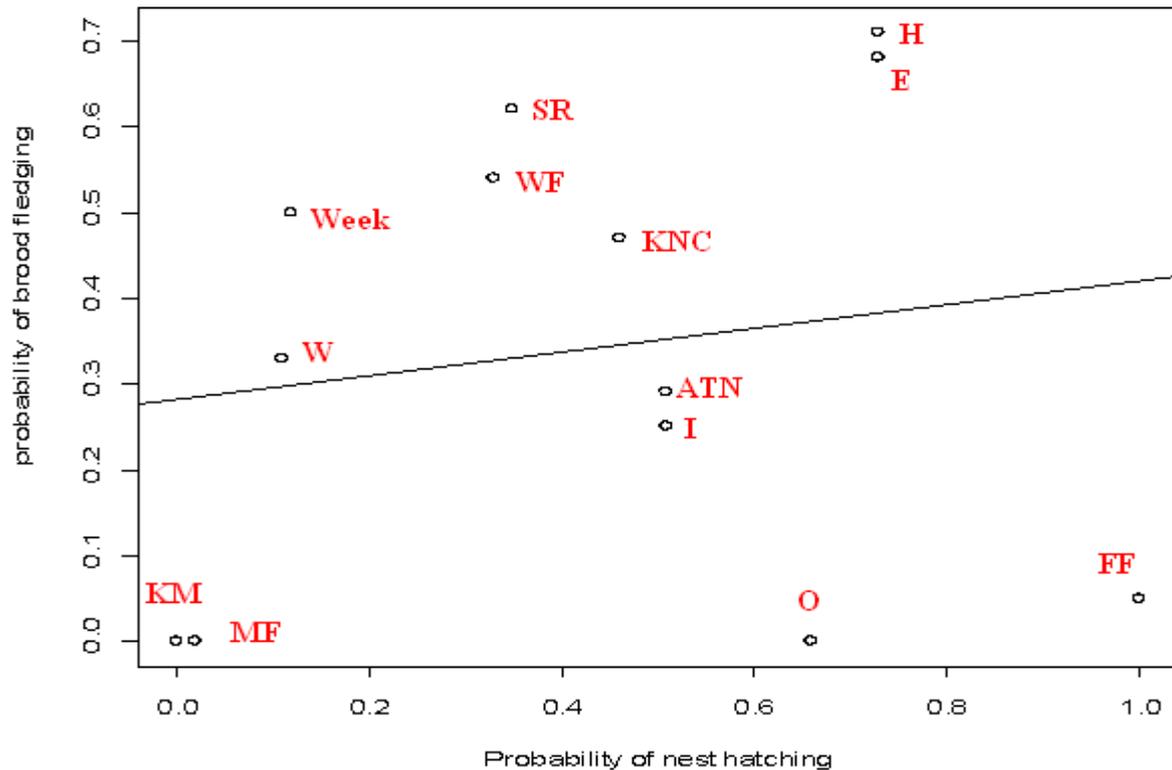


Fig 4.1.3 The relationship between the probability of a nest hatching (nest daily survival 26) and probability of a brood fledging (brood daily survival 35) in 2010 , with field sites marked in red

4.2 Site selection

Habitat features that may influence site selection by lapwing were investigated to gain an understanding of habitat requirements. Data is from 2010.

4.2.1 Presence of breeding lapwing

Breeding lapwings were considered to be present if nests or broods were located on the field. A generalised linear model with a binomial distribution was run with presence as the dependent variable and habitat features as the explanatory variables. Only mean sward height was found to differ significantly (residual deviance=195.66 on 206DF, $P < 0.04$); with lower mean sward heights on fields with lapwing present. This result is shown graphically in fig 4.2.1.1; the difference is only very slight and explains only 6% of the variation in the data. Standard deviation of sward heights was slightly lower ($P < 0.61$), and penetrability of soil slightly higher ($P < 0.55$) on fields where lapwing were present, but these results were not significant.

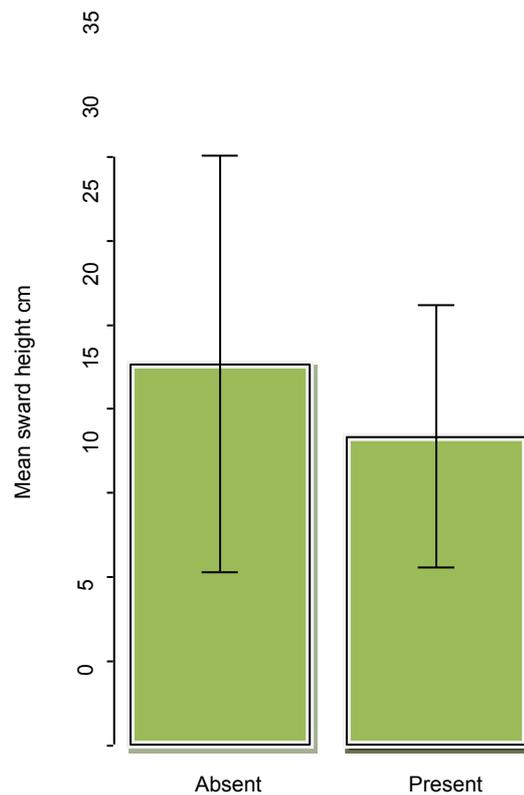


Fig 4.2.1.1 Mean sward height (cm) on fields where lapwings were present and absent, with error bars

A compositional analysis was run to assess whether the composition of vegetation in fields where lapwing were present differed significantly from those where they were absent. This method is in accordance with Aebischer and Robertson (1992). It was found that vegetation composition did vary significantly ($F=2.718$, $DF=5:201$, $P<0.02$). T-tests were then run to locate where the significant variation occurs. For this to be possible the data was arc-sine transformed; the results are summarised in table 4.2.1. The proportion of bare ground coverage was the only result found to be significantly different ($T=2.03$, $DF=54.23$, $P<0.05$). Grass coverage was almost significantly different ($T=1.97$, $DF=55.5$, $P<0.06$). Lower proportions of grass coverage and higher proportions of bare ground were found on fields with lapwing present, as shown in fig 4.2.1.2.

Table 4.2.1 summarised results from T-tests of proportions of vegetation coverage per field

Species group	Direction of relationship	Significant	T value	P value
Grass	Lower proportion on fields where present	Near	1.97	0.06
Dicotyledon	Higher proportion on fields where present	No	1.32	0.19
Sedge	Higher proportion on fields where present	No	0.96	0.34
Weed	Lower proportion on fields where present	No	1.71	0.09
Rush	Lower proportion on fields where present	No	0.28	0.78
Bare ground	Higher proportion on fields where present	Yes	2.03	0.05

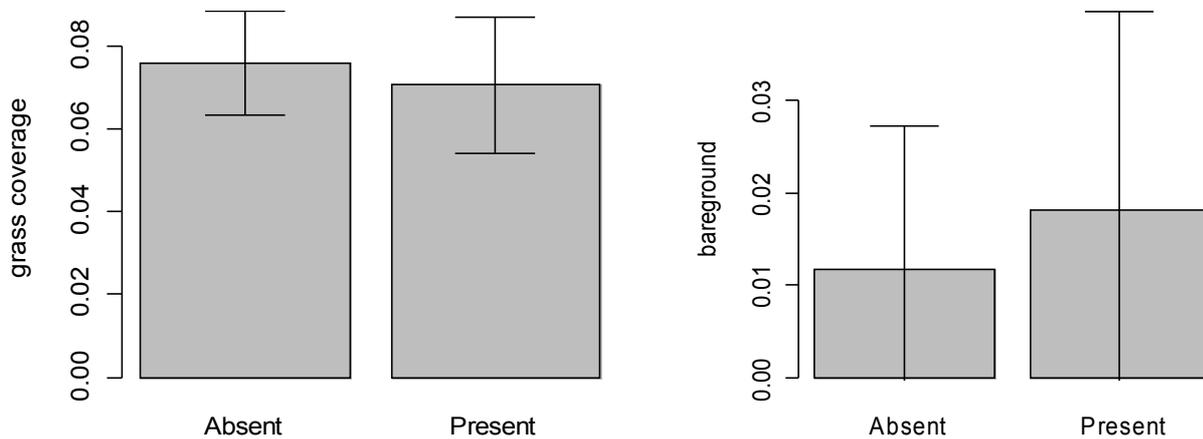


Fig 4.2.1.2 Proportions of grass coverage and bare ground (arc-sine transformed) on fields where lapwing are present and absent, with error bars

4.2.2 Management of fields

Management type was divided into four categories, fields under no management; fields under CSS, ESA or ELS; fields under HLS; and fields under HLS with specific prescriptions for breeding waders (HK11). The management was divided in this way as HLS is thought to be the most beneficial to biodiversity. This division of management types allowed for a hierarchy, with highest proportion of fields with breeding lapwing present expected in HLS fields with specific management prescriptions for breeding waders and lowest in fields with no management prescriptions. Of the 41 fields with lapwing present, five were under no management; seven were under CSS, ESA or ELS; four were under HLS and 25 were under HLS with specific prescriptions for breeding waders. The results are shown in fig 4.2.2.

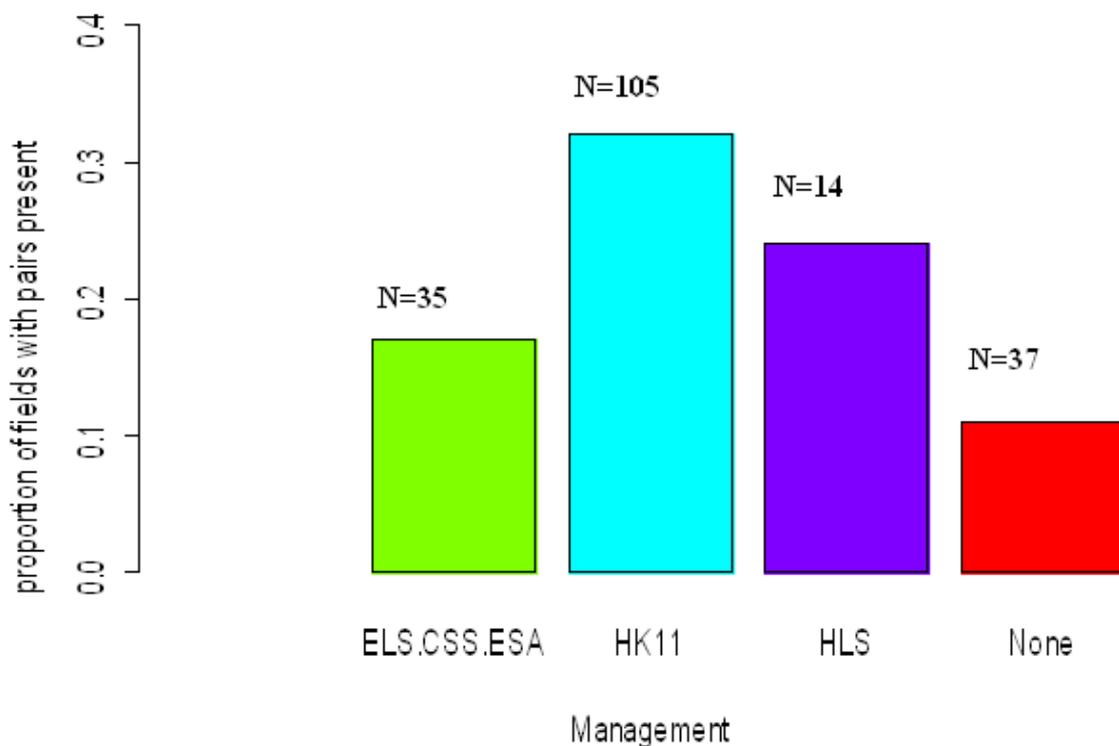


Fig 4.2.2 Proportion of fields with birds present under each management type

It would appear that fields managed for breeding waders do seem to have a greater proportion of fields with lapwing present than would be expected by chance ($\chi^2 = 1.78$, $df = 3$, $p < 0.62$). A one way analysis of variance was performed to see if management type affected the mean daily survival rate of nests and broods. Neither the mean daily survival rate of nests ($F=0.24$, $DF=3:22$, $P < 0.87$) or broods ($F=1.73$, $DF=3:30$, $P < 0.18$) differed significantly as a result of management type.

4.2.3 Pair densities

Pair densities were calculated for each field by dividing the total number of breeding pairs by the area of the field. The ranges of these factors for fields with breeding pairs present are outlined in table 4.2.3. A generalised linear model with a quasi-poisson distribution was then run against these habitat variables to see which were influencing density of breeding pairs, the results are also shown in table 4.2.3. The only factor having a significant impact is proportion of bare ground ($t=4.23$, $P<0.02$). The model explains 18% of the variation in the data. A greater proportion of bare ground is associated with a higher breeding pair density, as shown in fig 4.2.3

Table 4.2.3 Summarised results from generalised linear models with density of pairs as response variable

Feature	Range	Correlation	Significant	T value	P value
Mean sward height (cm)	5-38	Negative	No	-0.17	0.1
Standard deviation of sward height	2.37-26.96	Positive	No	1.45	0.16
Soil penetrability (kgF)	5.33-12.92	Negative	No	-1.61	0.12
% Bare ground	0-39.72	Positive	Yes	1.62	0.02
Stocking density (LU/ha)	0- 5.52	Negative	No	-0.27	0.79
Footdrain density (m/ha)	0- 0.38	Negative	No	-0.06	0.95

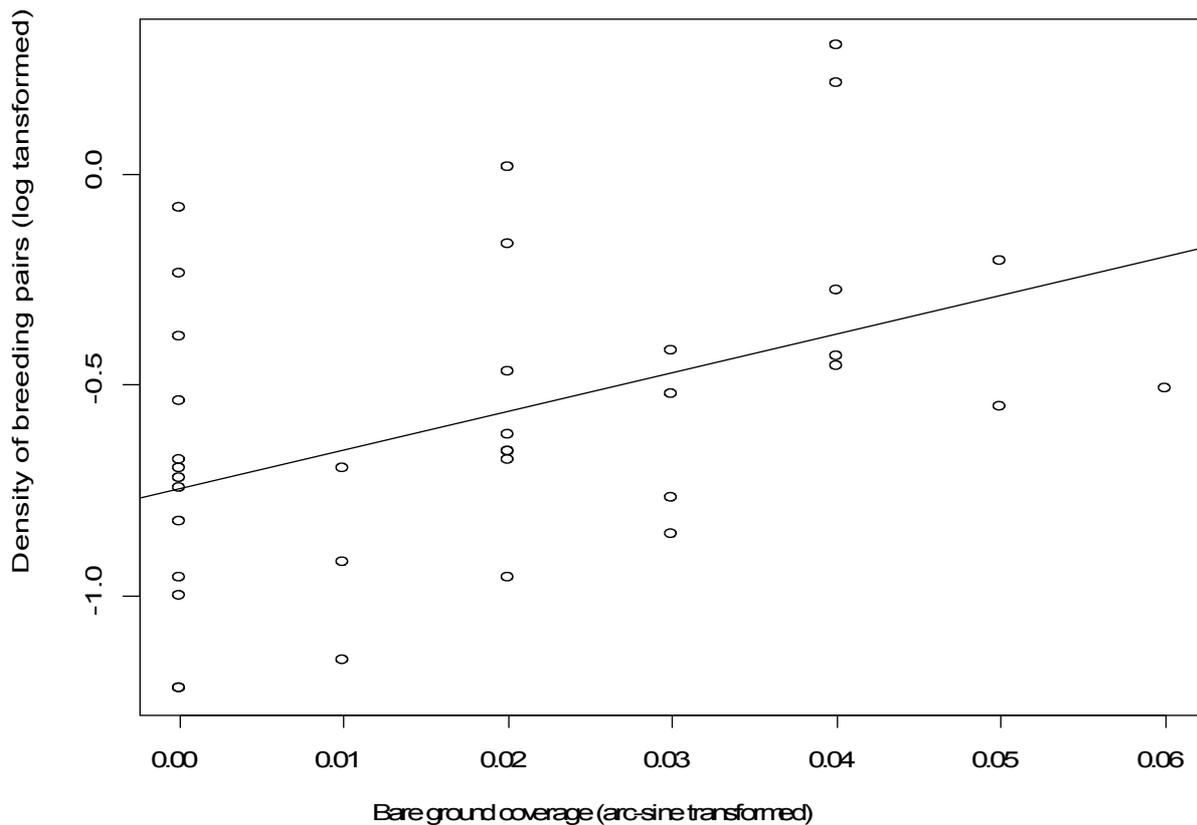


Fig 4.2.3 Relationship between bare ground coverage on the field and density of breeding lapwing pairs (log transformed) (cor=0.36). 0.5= a pair density of 2.03 pairs per ha and -0.15= a pair density of 0.04 pairs per ha

4.3 Habitat and daily survival

Generalised linear models with a quasi-poisson distribution were run with daily survival rates of nests and broods on each field as response variables and habitat features as explanatory variables.

4.3.1 Habitat variable and daily survival rates of nests

The impact of habitat features on daily survival rates of nests is outlined in table 4.3.1. The only feature found to be having a significant effect on nest success is the mean sward height ($t=0.12$, $P<0.05$). The relationship was found to be positive and the model explains 17% of the variation in the data. On assessment of the diagnostic plots, the model was found to contain one overly influential residual. This was removed as it was thought to be anomalous. With this point removed, the relationship is no longer significant ($t=1.61$, $P<0.13$) and less of the variation in the data is explained (12%). More data is required to investigate this relationship with greater confidence,

particularly as the error bars are so wide. The relationship is still found to be positive, and is shown in fig 4.3.1. Although the results of this model must now be treated with caution as the relationship is no longer significant with the residual removed; the consistency in the direction of the relationship would suggest a higher daily survival rate tends to occur where average sward height is higher. Lapwing only occurred in fields with a sward range of 5-38cm; so it would appear optimum daily survival occurs at the upper limit of this range.

Table 4.3.1 Summarised results from generalized linear models with daily survival rate of nests as response variable

Habitat variable	Correlation	Significant	T value	P value
Sward height average (cm)	Positive	Yes	2.12	0.05
Sward standard deviation	Positive	No	0.09	0.93
Soil penetrability (kg/F)	Positive	No	0.85	0.41
Bare ground coverage	Negative	No	-0.42	0.28
Stocking density (LU/ha)	Negative	No	-1.61	0.13
Foot-drain density (m/ha)	Positive	No	1.11	0.68

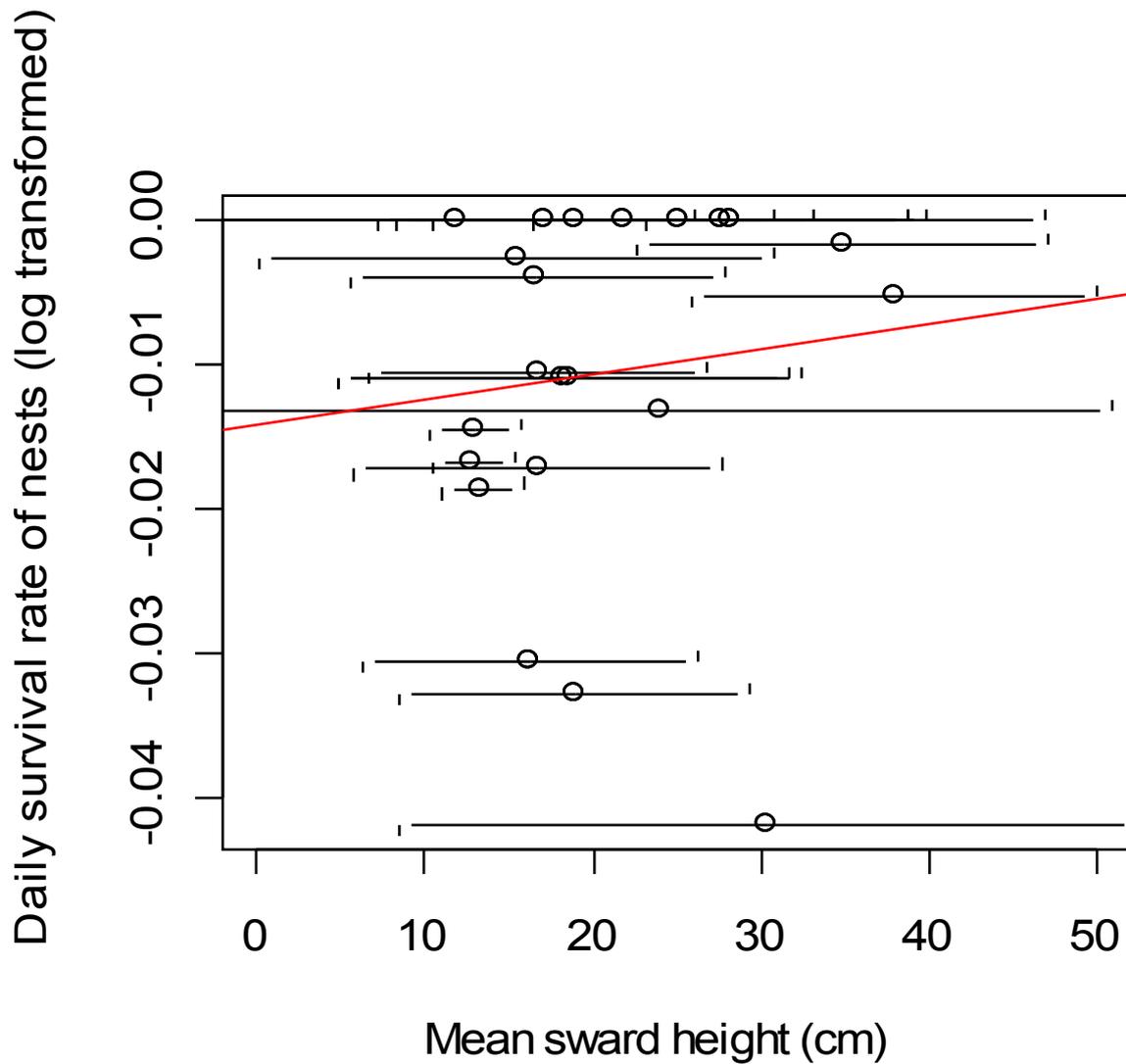


Fig 4.3.1 Relationship between mean sward height (cm) and daily survival rate of nests (log transformed), with influential residual removed and error bars (Cor=0.34) (0= daily survival rate of 1 and -0.04= daily survival rate of 0.927)

4.3.2 Habitat variables and daily survival rates of broods

The effects of habitat variables on brood productivity are outlined in table 4.3.2. Only standard deviation of sward height was significant ($t=-2.36$, $P<0.03$). The model explains 16% of the variation in the data and the relationship is negative. On assessment of the diagnostic plots, it became evident there is one overly influential residual. With this residual removed the relationship is no longer significant ($t=-1.32$, $P<0.2$) and the amount of the variation explained by the model is reduced to just 6%. More data is required to draw any firm conclusions concerning this relationship. With the influential residual removed the direction of the relationship is still negative, as shown in

fig 4.3.2. This suggests optimal brood survival appears to be in fields with a sward standard deviation of around 10cm.

Table 4.3.2 Summarised results from generalised linear models with daily survival rate of broods as response variable

Habitat variable	Correlation	Significant	T value	P value
Sward height average (cm)	Positive	No	0.106	0.92
Sward standard deviation	Negative	Yes	-2.42	0.02
Soil penetrability (kg/F)	Positive	No	0.41	0.68
Bare ground coverage	Negative	No	-0.95	0.35
Stocking density (LU/ha)	Positive	No	0.56	0.58
Footdrain density (m/ha)	Positive	No	1.26	0.22

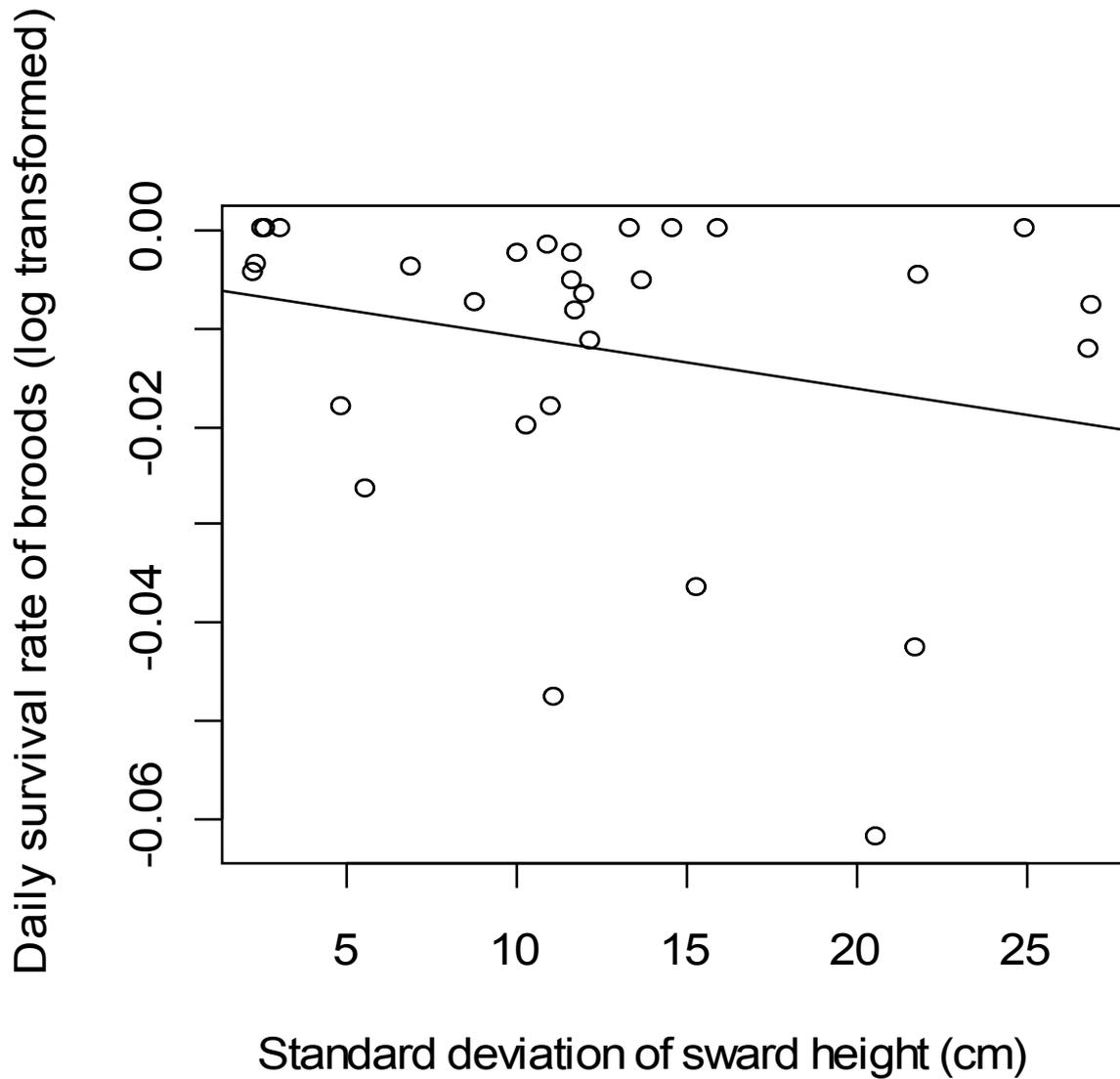


Fig 4.3.2 Relationship between standard deviation of sward height and daily survival rate of broods (log transformed), with influential residual removed (Cor-0.24), (0= daily survival rate of 1 and -0.06= daily survival rate of 0.867)

4.4 Predator densities and daily survival

So far different habitat features have been shown to be influential at different life history stages. However, the processes influencing productivity may be more complex than just habitat. Predation of lapwing eggs and chicks can be high and may be having significant impact on lapwing productivity.

4.4.1 Predator densities and daily survival rates of nests

Of all 77 known nests, 46 hatched, while 31 failed. The cause of failure was determined and is shown in fig 4.4.1.1. Of the failed nests, 29 were predated, cattle trampled one and one was lost to frost and abandoned. In most cases the predator could not be identified, of those where predator was determined, mammals predated 7 and 4 were destroyed by avian predators.

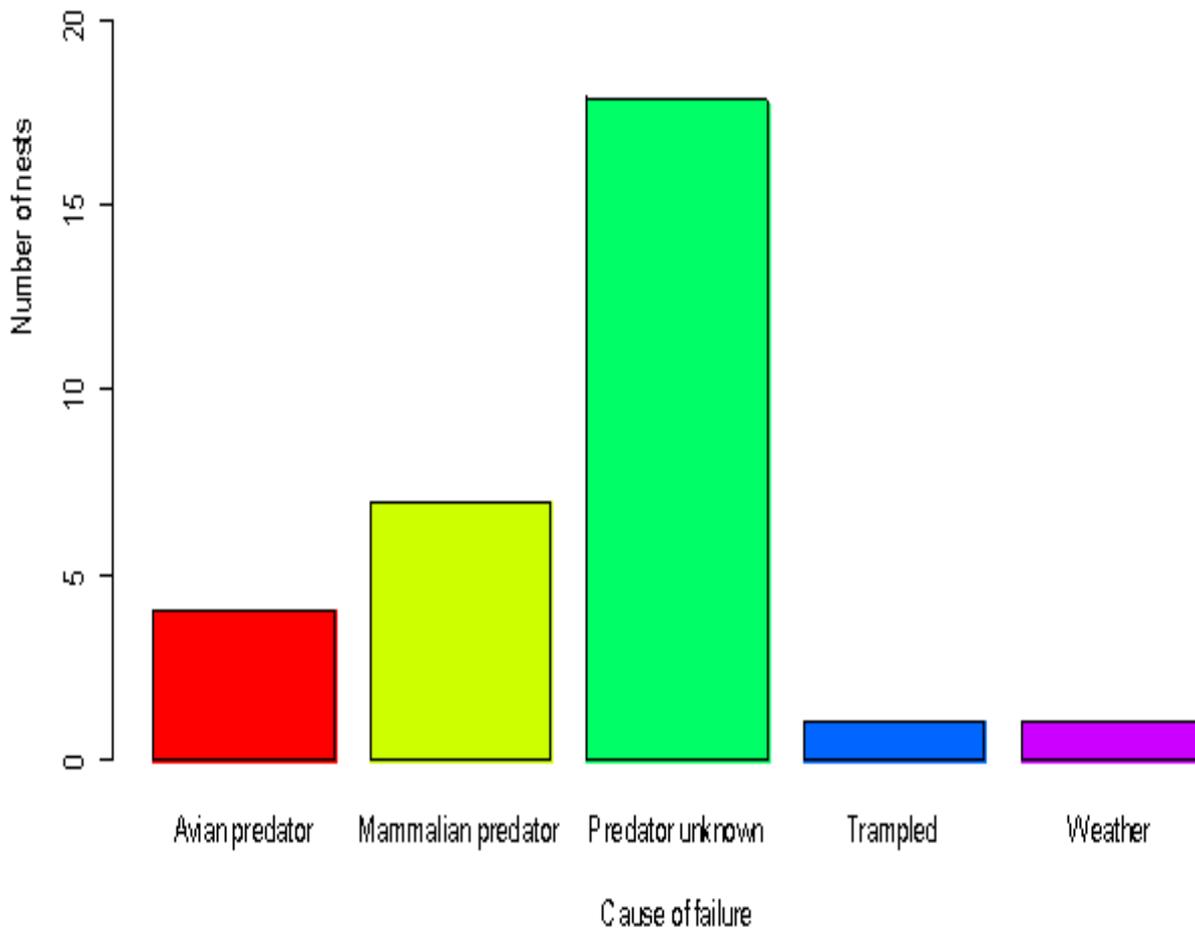


Fig 4.4.1.1 Cause of failure of nests

The daily survival of nests for each field was analysed against predator densities. No one group of predators appears to be having a significant impact. In previous years Crow ($F=9.08$, $DF=1:7$, $P<0.02$) and Black headed gull ($F=7.35$, $DF=1:7$, $P<0.03$) densities were significantly negatively correlated with daily survival rates. The result for 2010 was surprising given that fig 4.4.1.1 shows that predation was the main cause of nest loss.

The daily failure rate for each field was calculated in accordance with Salek and Smilauer (2002). The data was analysed as 1-daily failure rate as in many fields the failure rate was 0 and to normalise the data for the graph, a log transformation was necessary. A generalised linear model with a quasipoisson distribution was then run to assess whether the density of any predator was correlated with the 1 - daily failure rate. Only gull density was found to have a significant relationship with 1-failure rate ($t=-2.229$, $P<0.02$). The model explains 19% of the variation in the data. The relationship between failure rate and gull density is negative and is shown in fig 4.4.1.2. Higher rates of nest failure are associated with higher densities of gulls.

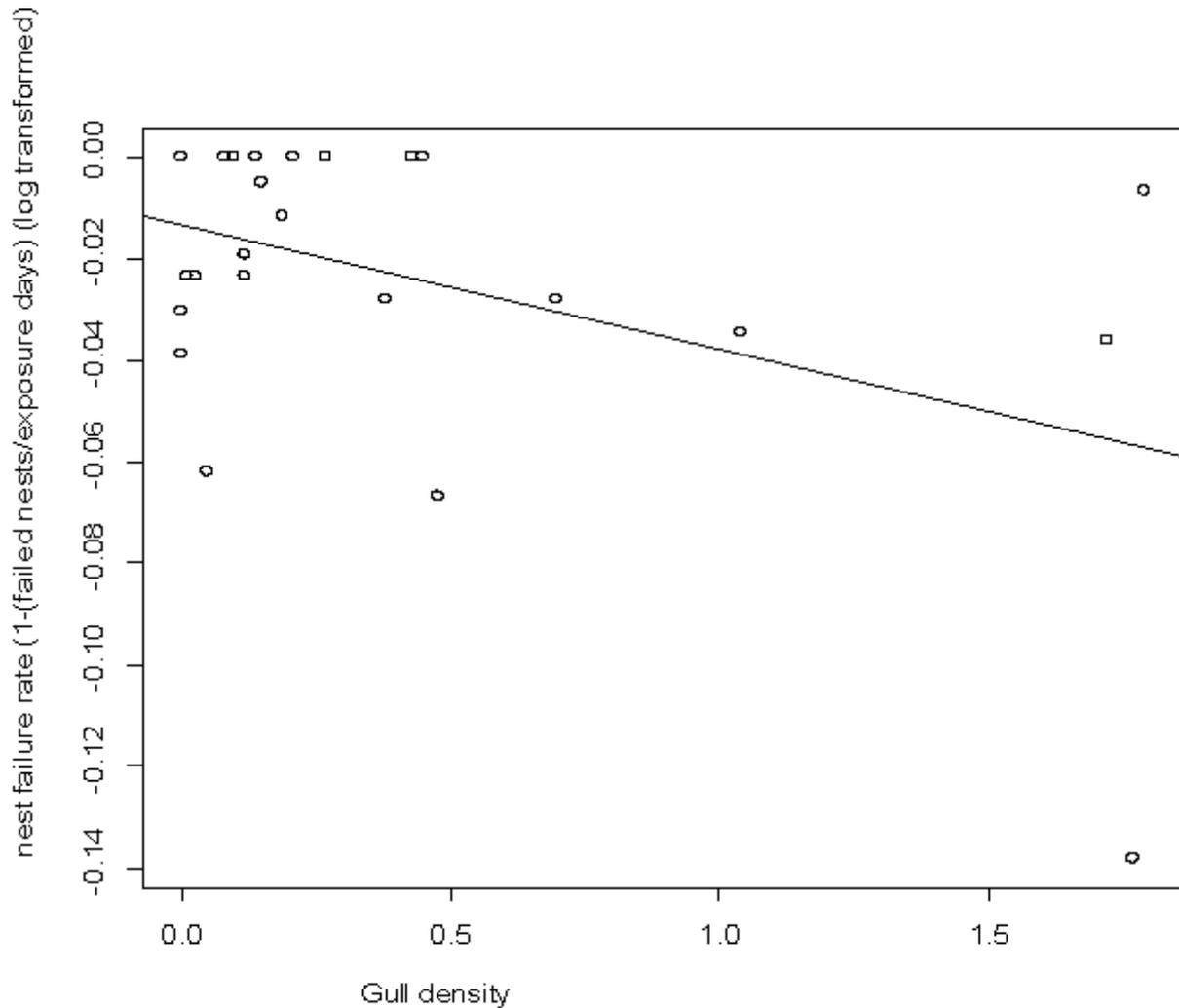


Fig 4.4.1.2 Relationship between Gull density and 1-nest failure rate (log transformed) (Cor=-0.45), Nest failure rate is calculated by dividing the number of failed nests by the number of exposure days (in accordance with Salek and Smilauer 2002), (0 = daily failure rate of 0 and -0.14 is a daily failure rate of 0.27)

4.4.2 Predator densities and daily survival rates of broods

The same generalised linear model with quasipoisson distribution was run for daily survival rates of broods. It was not possible to determine the cause of failure of broods as often nothing would remain. Previous years did not show any significant relationship. In 2010, Gull densities appear to be significantly negatively correlated with brood productivity ($t=-4.95$, $P<4.28e-05$). The model explains nearly 50% of the variation in the data. However, on closer inspection of the diagnostic plots it is clear the model relationship is dependent on three influential fields that had high gull densities. With these removed there is no significant relationship ($P<0.95$) and the model explains an insignificant amount of the variation in the data. The model is not a good fit and great caution should be exercised when making inferences from it. However, it is interesting that there was a relationship with failure rate of nests and gull density. Generally it does seem high gull densities will negatively impact lapwing breeding success.

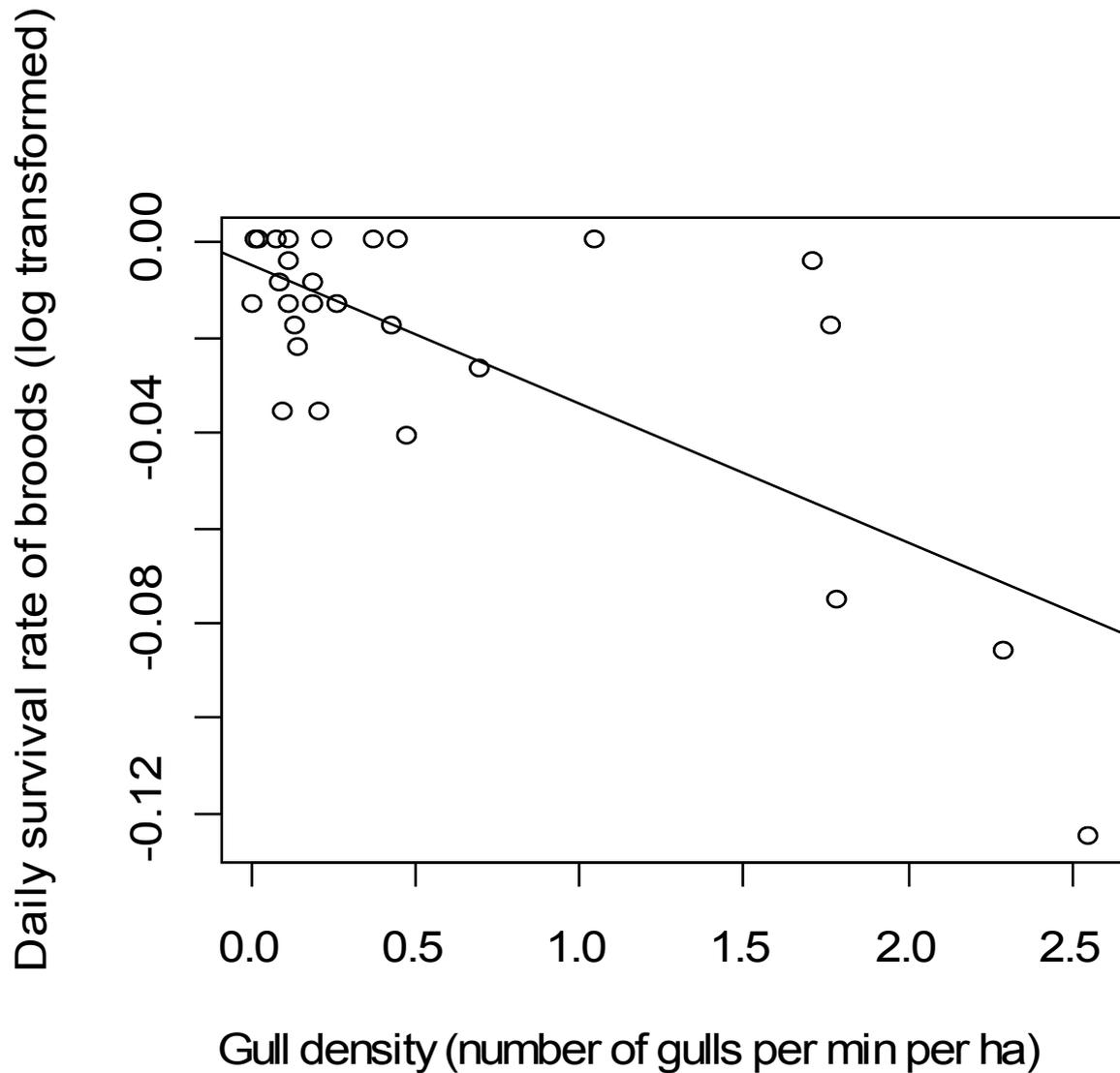


Fig 4.4.2 Relationship between gull density (number of gulls per min per ha) (log transformed) and daily survival rate of broods ($Cor = -0.72$) (0=daily survival rate of 1, -0.12=daily survival rate of 0.75)

4.5 Landscape features

It has been suggested that certain landscape features can impact daily survival rates (Salek and Smilauer 2002; Sheldon et al 2004; Wallender et al 2006). Some of these factors were investigated.

4.5.1 Landscape features and daily survival rates of nests

Nests were categorised as hatched or failed. A generalised linear model with a binomial distribution was run to see if there is a significant difference in landscape features between nests that hatched and nests that failed. The landscape factors considered are distance of nest to nearest predator perch (m), number of perches within 100m of a nest, and number of active nests within 100m. The results are outlined in table 4.5.1. Only level of aggregation was found to be significantly different (Residual deviance=100.11, DF=75 $p < 0.04$) with hatched nests having more neighbouring nests within 100m than failed nests, as shown in table 2.0.

Table 4.5.1 summarised results from generalised linear models for features of hatched and failed nests

Factor	Direction of relationship	Significant	Z value	P value
Distance to perch	Hatched nests further from perch	No	1.07	0.28
Number of perches 100m	Hatched nests have more in 100m	No	0.44	0.66
Number of nests 100m	Hatched nests have more nests in 100m	Yes	1.44	0.04

At the field level, a generalized linear model with a quasipoisson distribution was run with survival rate of nests as the dependent variable and landscape features as the explanatory variables. The landscape features considered were: Boundary score, length of woodland boundary (km), number of perches in the field and level of aggregation. Boundary score is the ratio of boundary to field area, as calculated by Durrant et al (2008). Level of aggregation was calculated by combining all the individual nest aggregation scores of each nest. None of these factors were found to be having a significant impact on daily survival rates of nests at the field level.

4.5.2 Landscape features and daily survival rates of broods

The same generalized linear model with a quasipoisson distribution was run with daily survival of broods as the dependent variable. Again, no significant result was found. Interestingly, for both nests and broods the last remaining factor in the model was amount of woodland border. Woodland border appears to be negatively correlated with daily survival rate of nests ($t=-1.02$, $P<0.32$) and broods ($t=-1.36$, $P<0.19$). Longer woodland boundary tends to mean lower daily survival rates of nests and broods as shown in fig 4.5.2. There is great spread in the data for daily survival rates of nests, so the model has poor explanatory power (4%). For brood survival, the model is driven by a few influential residuals, meaning the model is also poor at explaining the data (6%). Once these residuals are removed, the direction of the relationship is still negative. Although these findings are not significant, and the models are poor, it is nonetheless interesting that amount of woodland border should be the most significant factor in both models. Further investigation into this finding may yield interesting results.

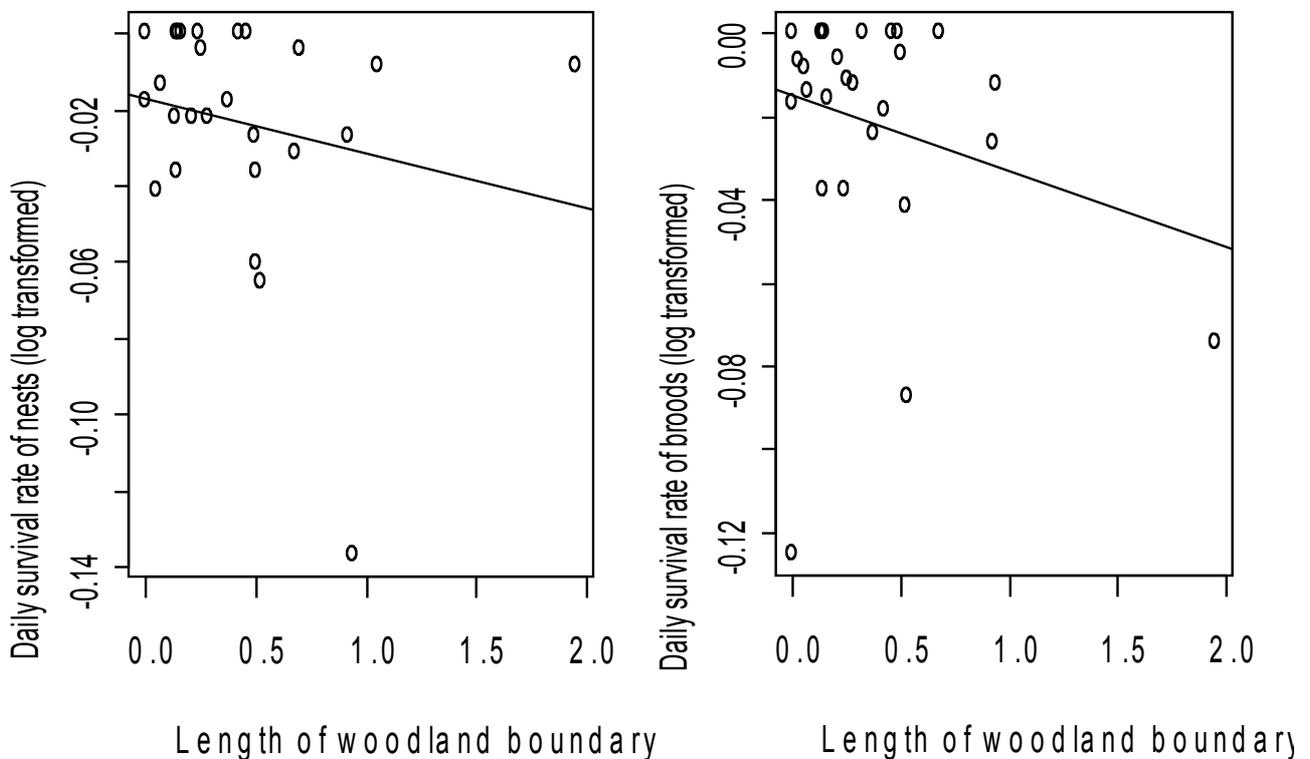


Fig 4.5.2 Relationship between length of woodland border (km) and daily survival rates of both nests (Cor=-0.21) and broods (Cor=-0.27) (0= daily survival rate of 1, -0.14=daily survival rate of 0.73)

4.5.3 Landscape features and predator densities

Generalized linear models with quasipoisson distributions were run with different predator densities as the dependent variable and landscape features as explanatory variables. No landscape feature was found to be affecting gull, heron or fox densities. Boundary score is found to be correlated positively with corvid ($t=2.75$, $P<0.01$) and raptor ($t=2.31$, $P<0.03$) densities. The model with corvid density as the dependent variable is a good fit and explains 22% of the variation in data. The relationship is positive and is shown in fig 4.5.3. The model with raptor density as the dependent variable explains 18% of the variation in the data, but there are overly influential residuals. When these influential residuals are removed the relationship is no longer significant ($t=0.6$, $P<0.56$) and explains an insignificant amount of the variation in the data. The relationship is still positive, but due to the poor fit of the model the relationship is not shown graphically. Again, more data is required to investigate the relationship between boundary score and raptor density. The results presented here suggest fields with a greater amount of fence boundary to field area will experience greater densities of corvids and, possibly, raptors.

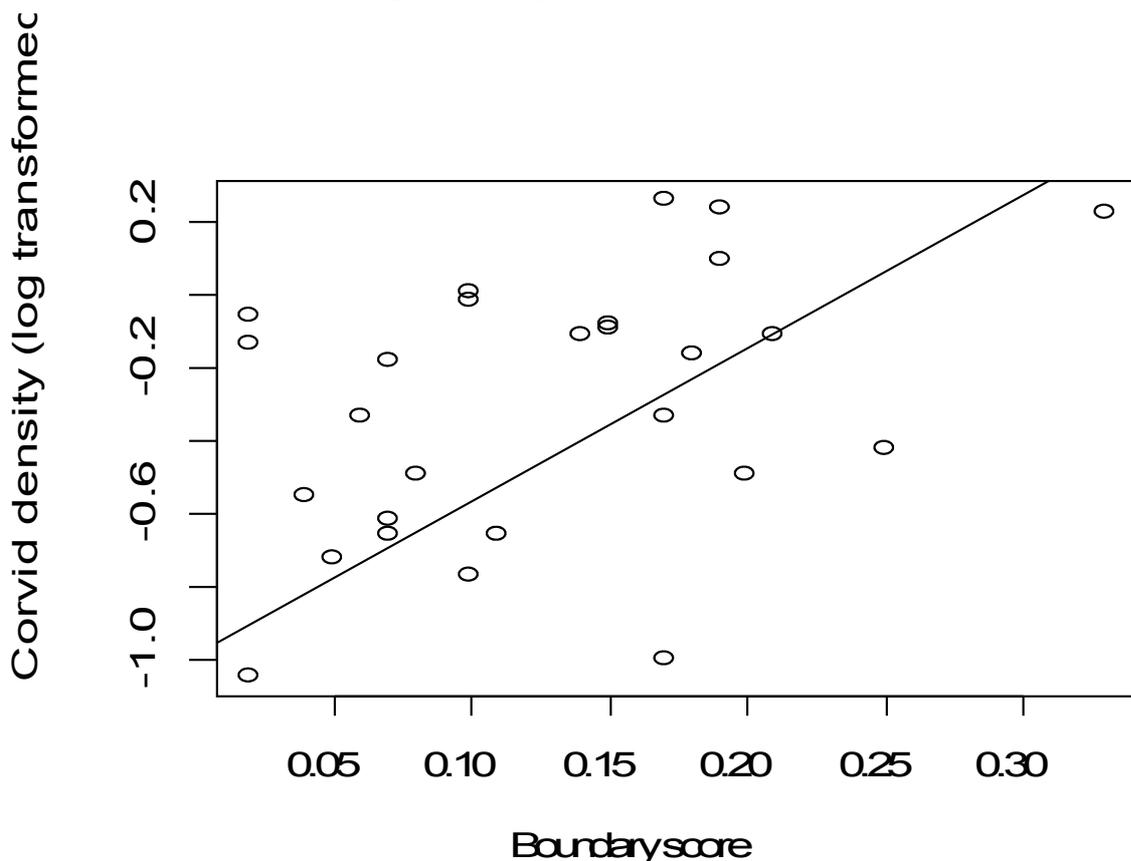


Fig 4.5.3 Relationship between the boundary score (length of fence boundary (km) / area of field (ha)) and the density of corvids (number of corvids per min per ha) (log transformed) (Cor=0.48) (0.2= 1.8 corvids per min per ha, -1=0.09 corvids per min per ha)

5. Discussion

5.1 Distribution of lapwing over time in the Avon Valley

The number of breeding pairs of lapwing per site has not changed significantly over the past three years, although numbers of breeding pairs were highest in 2008. Without tagging information it is not possible to confirm what has caused the decline. One possible explanation is that some birds have moved into the New Forest and other suitable breeding areas (Hoodless pers. com). A wider study area and a longer time series could help to confirm or reject this hypothesis. Number of nests hatched, broods fledged, and thus, overall productivity has increased since 2008, although, it appears breeding success in 2009 was unusually poor, while in 2010 breeding success was good. The great variation between these two years accentuates the necessity for a longer data series to draw any conclusions concerning population trends. From the data available, it would, however, seem that while the number of breeding pairs may have decreased since 2008, productivity has increased.

It has been stated by the RSPB that lapwing must produce 0.6 fledglings per pair per year for the population to be stable (RSPB 2010). This is a low estimate when compared with that of Peach et al (1994) who suggest lapwing must produce between 0.83-0.97 fledglings per year to be stable. It was not possible to ascertain how many chicks fledged per brood, but generally only 25-40% of chicks hatched will survive (RSPB 2010). As most clutches had 4 eggs that hatched, within this range it can be inferred that in 2010 lapwings produced between 0.42 and 0.67 fledglings. Although there are obvious dangers when making inferences of this nature as they are so heavily based on assumptions; it would appear that even when taking a conservative estimate, lapwing in the Avon Valley are potentially still falling short of producing enough fledglings to stabilise the population. Clearly conservation measures for the species are still required as the population cannot be considered to be stable.

Activity would appear to be somewhat aggregated over the three years. Although the time series is short, only five of the seventeen sites experienced lapwing activity at the breeding, nesting, and brooding life stages, with one further site experiencing activity at the three stages in two of the three years (2008 and 2010 in SR). It would appear the lapwing population in the Avon Valley is demonstrating preference for certain sites. When analysis was run to see if habitat features were

significantly different on fields where lapwing were present, the only significant difference was in the mean sward height. Jackson and Jackson (1980) found the distribution of lapwing in Hampshire to be very patchy with some seemingly suitable sites completely devoid of lapwings. The same situation may be occurring over the past three years in the Avon Valley. One particular example of this would be Avon Tyrell South. This site contained many large, damp fields that were grazed to keep the sward within the range lapwings prefer. Despite this, no birds settled here in 2010 and only one pair was found in 2009, which failed to hatch a nest. It has been suggested that lapwing practice site fidelity and will return to the same fields year after year (Thompson et al 1994). It may be that this is the case in the Avon Valley.

Understanding lapwing site fidelity is important so management efforts can be focused and money and efforts spent most efficiently. As the population is, potentially, not stable, breeding success can still be improved to achieve a stable population. Arguably the habitat prescriptions under HLS are not enough to achieve this. A narrowly focused, bespoke, approach to management instead of a broad-brush approach may be better. It does not seem to be the case that there is a lack of suitable habitat as breeding lapwings are still avoiding sites with seemingly suitable habitat. Given this, it seems advisable to focus money and efforts where the lapwings are present. It is possible that a more specialised and expensive system, both in terms of time and money, could help to achieve the goal of a stable population. This may be to the detriment of farming practices; understanding which sites waders consistently choose is essential to compensate appropriate farms.

It was found that the chance of a nest surviving to hatching and the chance of a nest surviving to fledging were not significantly correlated. Some sites have a higher success rate for nests, while others have a higher success rate for broods. Monitoring should be undertaken to identify whether there is a life history stage where a site is not so successful. Management can then be structured to improve the environment for this life history stage, or to provide new habitat specifically for the life history stage that is having poor success in adjacent fields. Any management should take into consideration the greatest gain on investment. Through developing a detailed knowledge of wader site selection and life history it is possible to increase the return on investment and improve the chances of a stable population being reached.

5.2 Habitat

Fields with lapwing present tended to have a lower sward height, more saturated soil and lower standard deviation of sward height. The only feature found to be significantly different was mean sward height. Mean sward heights on fields where lapwings were present ranged from 5.27 to 38cm. Previous studies have found that lapwings prefer to nest on a shorter sward of around 10cm (Hart et al 2005; Durrant et al 2008). Generally a shorter sward is preferred, 38cm was somewhat of an anomaly and most fields had a mean sward of around 10cm. Fields with lower mean sward height tended to support a greater density of breeding pairs. Although this finding was not significant, it was in accordance with Durrant et al (2008), who found sward height to be one of the main predictors of nest site choice for lapwings.

Lapwings were found on fields with a slightly lower standard deviation in sward height, although, this finding was not significant. Breeding lapwings may prefer a somewhat homogenous sward height when nesting so visibility is not reduced and predators can be detected as soon as possible. Pair densities were, however, higher where sward height was more variable. Lapwings were found in fields with a standard deviation of sward height of 2.37-26.96 centimeters. The higher densities of pairs at the upper limit of this range suggest there may be an optimum level at the higher end for site selection. Fields where lapwings were present had an almost significantly lower proportion of grass coverage. A lower proportion of grass means a greater diversity of plant species will be present. This can be beneficial as a greater diversity of prey is associated with greater floral diversity and the field is visually more heterogeneous meaning nests may be less obvious (Vickery et al 2001; Macdonald and Bolton 2008). Some heterogeneity in sward structure and composition would appear to be preferred by breeding lapwings.

Mean penetrability of soil on fields where lapwings were present ranged from 5.33 to 12.92 kg/F and was generally more saturated. Fields with a damper soil also supported a higher number of breeding pairs. Neither of these findings are significant, but their concordance does suggest a lower penetrability of soil is preferred. Lapwings, like most waders, have been found to prefer a damper soil because it is easier to probe for prey (Milsom et al 2002; Bradbury and Kirby 2006; Elington et al 2008). A particularly damp soil may, however, make the ground unsuitable for nesting due to the greater energetic demands to incubate the eggs. This could explain why breeding lapwings were not found on fields with a mean penetrability of below 5.33 kg/F; and the positive relationship found between lapwing daily nest survival and penetrability. Nests experienced higher daily survival rates

on fields with a drier soil; although this result was not significant.

Fields with lapwing present tended to have a significantly higher proportion of bare ground coverage than fields where lapwings were absent. A generalised linear model revealed that the amount of bare ground was the only factor significantly correlated with pair densities. Evidently, bare ground is an important factor for lapwing site selection. Bare ground may be important to lapwings as they are often used as foraging areas (Elington et al 2008). During the 2010 breeding season, adult lapwings were often observed feeding on bare ground. Lapwing may select to breed on areas with good foraging potential as it minimises the amount of time spent off the nests foraging in further fields by adults (Evans 2004).

Mean sward height is the only factor significantly correlated with daily survival rates of nests. Within the range of 5.27-38 cm, a field with a higher mean sward was generally found to have higher survival rates. This may be explained by nests being less obvious to visual predators when in a slightly longer sward (Macdonald and Bolton 2008). Standard deviation of sward height is the only variable significantly correlated with brood daily survival rates. Within the range 2.37-26.96cm, fields with a lower standard deviation were generally found to have higher daily survival rates. Some variability in sward height is thought to be beneficial as areas with longer vegetation can provide shelter to chicks when predators are near (Baines 1990). Too much may, however, be detrimental as movement may be compromised and following precipitation longer grass can wet the plumage of chicks and increase the chances of hypothermia (Butler and Gillings 2004; Whittingham and Evans 2004; Bradbury and Kirby 2006).

Although not significant, both the daily survival rate of nests and broods are improved on a drier soil with less bare ground but higher foot drain densities. It is uncertain why brood survival is improved under these conditions as a drier soil makes probing more difficult and areas of bare ground are thought to be good for feeding. However, it is possible that chicks feed on surface invertebrates and feed almost exclusively in foot drains. Over the brooding season chicks were often observed feeding in foot drains. Thus, bare ground and penetrability of soil may not be so important for brood survival. The directions of the relationships with daily nest survival are less surprising as a drier soil is generally warmer and bare ground is not necessary and may only increase nest visibility to predators.

Table 5.2 direction of correlations with pair densities, and daily survival rates of nests and broods as dependent variables and habitat features as explanatory variables. Significant results are shown in red

Habitat feature	Pair density	Possible explanation	Daily survival rate of nests	Possible explanation	Daily survival rate of broods	Possible explanation
Mean sward height	Negative	Easier detection of predators (Hart et al 2005; Durrant et al 2008)	Positive	More concealed from predators (Vickery et al 2001; Hart et al 2005)	Positive	Higher sward may provide better hiding places and less obvious to predators
Sward standard deviation	Positive	More variation in structure may mean more variation in prey	Positive	More concealed from predators (Vickery et al 2001; Hart et al 2005)	Negative	Easier movement and foraging (Butler and Gillings 2004; Bradbury and Kirby 2006)
Penetrability of soil	Negative	Easier probing of soil (Milsom et al 2002; Bradbury and Kirby 2006; Elington et al 2008)	Positive	Possibly easier to keep nests warm on drier ground and less chance of nests flooding	Positive	Unsure why this is the case – may be feeding in foot drains meaning soil penetrability is less important, or on surface invertebrates
Proportion of bare ground	Positive	More areas for foraging (Redfern 1982)	Negative	Too open for nests (Vickery et al 2001; Hart et al 2005)	Negative	Chicks may avoid foraging in open ground as may be too visible
Foot-drain density	Negative	Unsure why, but adults may prefer bare ground	Positive	Parent lapwings spend less time off nests when foraging (Evans 2004)	Positive	More areas for foraging and reduced time moving around the field, making chicks more visible to predators and imposing greater energetic demands (Evans 2004; Elington et al 2008; Bellabaum and Bock 2009)
Stocking density	Negative	May provide too much disturbance to adults (Hart et al 2002)	Negative	Cattle disturb incubating adults revealing nest locations by flushing adult off nest (Hart et al 2002)	Positive	Potential that mammalian predators avoid fields with larger animals

What is particularly interesting is the direction of relationships, shown in table 5.2. There is not a single incidence where the direction of the relationship is the same across all three life history stages. This poses particularly complicated management challenges to create habitats that can support lapwing through the whole breeding season, from breeding to fledgling. It is widely accepted that a heterogeneous habitat with a mosaic of features is most conducive to breeding wader success and biodiversity more widely (Benton et al 2003; Whittingham and Evans 2004). A mosaic of habitat may be the only way to ensure habitat is provided for all stages and can also act as a buffer for temporal variations in resource availability (Benton et al 2003).

This study has found a higher proportion of fields with lapwing present on fields managed specifically for breeding waders under HLS. Similarly, Ausden and Hirons (2002) found higher tier options supported more pairs of wading birds per pound of grant received and Klein and Sutherland (2003) found 13 of 29 studies reported positive effects of agri-environment schemes on bird species richness or abundance. However, it is important to note that the numbers of breeding pairs on the fields managed specifically for breeding waders is not known before the field was entered into such a scheme. It may be the case that these fields had lapwings present before entry into HK11 and so the schemes are not providing any additional biodiversity benefits. An assessment of additionality was not possible in this study due to the short time series. It cannot, therefore, be stated that fields under HK11 are more successful at attracting breeding pairs, only that proportionally they contain more fields with breeding pairs present.

The management prescriptions currently recommended under HK11 are outlined in Table 5.2. It is concerning that there is no suggestion that a mosaic of habitat may be best. Currently, provision of a mosaic of habitat is not recommended under any HLS prescription. This study found no difference in survival rates of nests or broods depending on management. This study would suggest there is room for improvement by focusing on providing habitat for the different life history stages. In the case of agri-environment schemes for breeding waders, it is not a case of one size fits all.

Table 5.2 Current HLS prescriptions under HK11 (Natural England 2010)

1	Controlling in field and ditch water levels in the spring and early summer
2	Maintaining/restoring ditches and existing field drainage systems
3	Creating varied sward structure by the end of the growing season by grazing or late hay cut
4	Restricting stocking density in the nesting season
5	Avoid heavy poaching (although small areas of bare ground are acceptable)
6	Avoid disturbances to birds

5.3 Predation

A common criticism of agri-environment schemes is their failure to address the issue of predation. In the Avon Valley in 2010 the impact of predators on nests was clear. 40% of known nests were thought to have been predated. Previous studies have found similar results. Baines (1990) found predation to be the cause of loss of 47% of nests observed. Although in most cases it was difficult to identify whether the nest predator was mammalian or avian, of those nests where it could be determined, mammals took more nests. Indeed, much of the literature would support this (Elington et al 2008; Teunissen et al 2008). Bellabaum and Bock (2009) found 65% of unsuccessful nests were taken at night and Bolton et al (2007) found 88% of unsuccessful nests were predated in darkness. Mammals are thought to hunt at night while avian predators favour the morning (Macdonald and Bolton 2008).

58% of broods failed. Although exact cause could not be confirmed, previous studies have demonstrated the devastating impact of predators on lapwing broods (Seymour et al 2003). Additionally, in mid June a kestrel was observed predated a lapwing chick on Week Farm. This, combined with the high predation rate of nests, suggests predation is responsible for a fair proportion of the 58% of failed broods.

Predator densities did not appear to be having any impact on daily survival rates of nests. Nest failure rate was, however, positively correlated with gull density. In 2008, gulls were found to be having a negative impact on daily survival rates of nests, and in 2009 carrion crow abundance was positively correlated with nest failure. Daily survival rate of broods was negatively correlated with gull density, although this was driven by a couple residuals. No correlations were found in 2008 or 2009 for daily survival rates of broods. It is difficult to draw any firm conclusions from this finding, but gull density does appear to be having negative impacts on both broods and nests, suggesting higher gull densities are detrimental to lapwing productivity in the Avon Valley.

It is important to note that it cannot be inferred that gulls or crows are the principal predator. Just one fox could have devastating impact on nests or broods in a field. It is also possible that gull densities are acting as an indicator of another variable in the habitat or landscape that is impacting survival rates. The analysis in this study is based on predator densities. While this is generally accepted to be a good measure of risk level, for some species, such as foxes and raptors, density may be less important. Perhaps a more accurate measure would be the home ranges of the predator

species.

With the possible exception of gulls, predator densities do not appear to be affecting daily survival rates of broods or nests. As abundance does not appear to be a problem, methods of lethal predator control are not recommended. Predator control measures are more likely to result in increased daily survival in areas where predator densities are high and impacting survival rates (Bolton et al 2007). Culling has been found to have limited success in the past. Bolton et al (2007) found crow control measures did not result in significant reduction in total crow numbers; this was attributed to influx of birds replacing those that survived. It was found, however that there was a cumulative effect of predator removal for fox densities (Bolton et al 2007). While this suggests fox culling may be useful, other studies have found fox removal does not result in higher nest or brood survival as other mammalian predators fill the niche (Fletcher et al 2005; Bellabaum and bock 2009).

The problems associated with culling are widely understood and perhaps explain why agri-environment schemes have, thus far, been reluctant to address the issue. More recently, softer forms of control have been being explored. For example, a reserve in Merseyside has placed llamas in fields with lapwing present to deter predators with their highly territorial behavior (BBC news, 2010). More practically, perhaps, it may be possible to manipulate the environment to minimise the chances of predation incidences. Boundaries and perches are thought to negatively affect the survival of nests and lapwings by providing vantage points to visual avian predators and obvious walkways to mammals such as foxes which tend to move along fence lines (Wallender et al 2006).

There was no significant difference found between nests that hatched and failed and their distances from perches or fence lines. One explanation offered for this is that lapwings tend to nest far enough away from these structures for the risk to be sufficiently low (Wallender et al 2006). The only significant difference found between nests that hatched and those that failed, was the level of aggregation. Nests that hatched tended to be positioned closer to other active nests than those that failed. This finding is in accordance with that of Berg et al (1992), Salek and Smilauer (2002), and Eglington et al (2009). It is possible that birds nesting at higher densities are more effective at deterring predators. This finding adds further weight to the focused, bespoke, approach to management. As aggregations appear to have better survival rates, attracting lapwing to a smaller number of well managed sites at high densities would be recommended.

The daily survival rate of nests and broods at the field level was not significantly affected by any of

the factors explored. Interestingly for both daily survival rates of nests and broods, length of woodland border was the most significant factor in the model. Longer woodland borders tended to result in lower daily survival rates. Woodland can provide nesting sites to corvids and raptors and den sites to foxes and other mammalian predators (Elington et al 2009). It is therefore not surprising that woodland is associated with lower survival. This finding poses contentious management issues. Woodland areas provide crucial habitat to a range of species and are widely thought to be beneficial to biodiversity. Removal of woodland under agri-environment schemes would not be recommended. It may be possible, however, to exclude fields with longer woodland borders from management prescriptions specifically focused at breeding waders in an attempt to deter breeding waders from selecting to breed in these fields. The lapwing in the Avon Valley did not appear to be deterred by woodland borders. 28 of 41 fields with lapwing present had a woodland border; and 17 fields had woodland borders and were managed under HLS with specific prescriptions for breeding waders.

Density of corvids and raptors was significantly correlated with boundary score. The relationship with raptor density should be viewed with caution as it is largely driven by a few overly influential residuals. More data would be required to draw firm conclusions. It is possible that both corvids and raptors are drawn to fields with a high density of fence-line border as fence-lines can provide vantage points from which to observe prey. Although no significant relationship was found with either of these two predator densities and daily survival rates of nests or broods, it may be worthwhile to attempt to attract waders away from small fields with high boundary scores. Alternatively, fence-lines can be removed where possible. Hucklesbrook once contained many fence-lines, but in 2010 many of these were removed, as they were not necessary. Removal of unnecessary fence-lines is not currently recommended under HK11 prescriptions.

The findings concerning the potential impacts of woodland and fence-lines are in their infancy for the Avon Valley. Data on length of woodland and fence-lines were not collected in previous years. Therefore, it is difficult to comment with any conviction on the true impact these features are having. Particularly as the impact of woodland border on daily survival rates is not significant and explains only a small amount of the data, and the relationship between boundary score and raptor density is driven by overly influential residuals. The existence of the observed trends highlights the importance of the wider landscape and is encouraging for the potential of utilising softer management options to minimise predation incidences on breeding waders.

5.4 Implications for management

A narrowly focused approach to management may be better than the current broad-brush approach. Only five, possibly six, sites had activity at all three life history stages. It is these sites that should be targeted for lapwing conservation measures. Focusing efforts intensively instead of extensively has additional benefits, as lapwings were found to have a higher breeding success in aggregations, as reported here and in other studies (Berg et al 1992; Salek and Smilauer 2002; Eglington et al 2009). Focusing efforts to bring breeding lapwing together in a smaller area at greater densities is, therefore, recommended. This is particularly important when the needs of other waders are considered. Red shank and snipe are also found in the Avon Valley and are thought to have quite different habitat preferences (Wilson et al 2007). Management aimed at breeding waders is perhaps too general. Instead the needs of the different species present in any site should be considered and catered for. A Site specific approach based on the agricultural needs and the biodiversity of the site, rather than countrywide measures will be likely to be most effective, as has been previously suggested (Ausden and Hirons 2002; Teunissen et al 2008).

Agri-environment schemes currently do not mention provision of a mosaic of habitats. This study has shown the different life history stages of the species have different habitat requirements. The whole breeding season should be considered to identify which stage is having low success. Management can then be structured around providing suitable habitat for this stage. A mosaic of different habitats is recommended as a safeguard to maximise breeding success by providing suitable habitat for each stage. In larger fields a mosaic of habitats can be provided side by side. In smaller fields a more integrated approach is recommended, where two or more adjacent fields provide different habitats for different life stages.

Agri-environment schemes also fail to address the issue of predation currently. This study has found that in the Avon Valley, densities of most predators are not correlated with daily survival rates of nests or broods. Therefore, culling is not recommended. Predator control is a contentious issue and it is easy to see why schemes have avoided it. By considering the wider landscape it may, however, be possible to reduce predation incidences. Although more data would be required for firm recommendations, this study has suggested large open fields with few boundaries and absence of woodland at the boundary will have a higher productivity and a lower predation rate. Therefore, it is recommended that attempts are made to attract lapwing to fields with these characteristics and to consider removing unnecessary boundaries in fields with high densities of breeding pairs.

5.5 Limitations

A number of limitations were experienced during the study. These are explained in below.

1. Time - As the lapwing breeding season is comparatively short and there were many sites to monitor it was not always possible to dedicate as much time as needed to observing behavior and locating nests.
2. Availability of data – The study was limited to a three year data set and this made it difficult to understand population dynamics and distributions over time. Some analysis was therefore not possible, and comments on population trends are of limited value and must be treated with caution.
3. Nests – The fate of nests was difficult to determine. While it was possible to state whether a nest had hatched or failed with confidence, it was not always possible to determine whether the predator was mammalian or avian.
4. Broods – The fate of broods was even more problematic. Broods can fail due to predation, starvation and other factors (Jackson and Jackson 1980). It was impossible to tell what had caused failure. In addition to this, calculating how many broods had fledged was based only on our observations and how many days we had been observing for.
5. Habitat – habitat assessments were based on one measure taken at the middle of the season. Ideally measures would have been taken at several points throughout the season to avoid analysis being based on a snapshot of data.
6. Avian predators – Avian predator surveys were limited from between 09.00 and 17.00. Results may have been different if surveys were taken at different points throughout the day and night.
7. Mammals – Although scat routes are arguably the simplest and most efficient method of calculating for density; it could be difficult to locate and identify scats. Particularly when the scats were several days old and the vegetation was overgrown. Ideally, more than two routes per site would be walked to gain a more accurate measure.

5.6 Suggestions for future research

1. Continuation of the current study - A longer time series based on population trends and dynamics is needed so a greater and more accurate understanding can be formed. Now is an interesting time to study agri-environment schemes as many farms are changing management from the old system to the new tiered system. A study of how the population responds to these changes could yield beneficial information on optimum management prescriptions and additionality.
2. Nests – Placing cameras on some randomly chosen nests and ensuring loggers are used in all other nests could help understand cause of failure with greater accuracy and even help identify principal predators. This is something the Game and Wildlife Conservation Trust are hoping to complete in 2011.
3. Broods – A study of brood survival with the use of ringing and even radio tagging could help to understand habitat use and cause of death as well as allowing more accurate measures of number of birds fledged. Tagging of chicks could also reveal interesting insights as to the distribution of adult lapwing following the breeding season. Chick body condition measurements could also be taken to see if some sites tend to generate healthier, larger chicks.
4. Waders – This study only looked at lapwing, but red shank and snipe are also present in the Avon Valley. These species are thought to have different habitat requirements to lapwing. A study that broadened the species focus could yield interesting and beneficial results.
5. Landscape – The lack of firm results from this study on the impact of landscape, but the suggestion that certain landscape features are influential, highlights the importance of continuing the data series and investigating the impact of woodland and boundaries, in particular, in more detail.

6. Conclusion

From the results of this study, agri-environment schemes can be seen to be somewhat superficial and even vulgar. Emphasis is placed on bringing as great a quantity of land under agreement as possible. While this is a noble aim, the greatest return on investment should be considered and what can realistically be achieved in terms of additional benefits to biodiversity. Quality rather than quantity should be the ultimate goal. Emphasis is also placed on attracting large numbers of breeding waders. This only scratches the surface; a superior goal would be to produce as many fledglings as possible by looking at the whole life history of the species and providing necessary habitat for each stage. This may not be possible with broad-brush prescriptions. Instead a more integrated approach that creates a mosaic of habitat is recommended. Finally, embracing novel approaches to managing difficult issues such as predation is recommended. While managing the wider landscape to reduce predation incidences is in its infancy, this study has suggested exploration of these options may be beneficial.

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Useful websites:

- Biodiversity Action Plan <http://www.ukbap.org.uk/> accessed 28/8/10
- Department for the Environment, Food, and Rural Affairs (DEFRA) <http://ww2.defra.gov.uk/> accessed 23/8/10
- Natural England <http://www.naturalengland.org.uk/> accessed 23/8/10
- Royal Society for the Protection of Birds (RSPB)
<http://www.rspb.org.uk/wildlife/birdguide/name/l/lapwing/index.aspx> accessed 23/8/10

Appendix

Formulas used:

Egg Volume from Galbraith (1988a)

length x width² x 0.457

Egg Density from Galbraith (1988b)

mean egg weight / mean egg volume

Number of days until hatching (1988b)

(150.84 x density) – 140

Days since layed from Furness and Furness (1981)

25 – number of days until hatching

Daily Survival rate from Mayfield (1975)

$1 - ((T - F) / E)$

total number of nests or broods (T)

number of failed nests or broods (F)

total exposure days (E)

Productivity

number of breeding pairs present / number of fledged broods

Stocking Densities (LU)

$((LS \times D) / A) / F$

Livestock score (LS)

Proportion of days present (D)

Area of the field (A)

Number of fields cattle have access to (F)

Fox densities from Baker et al (2002)

S/KD

number of scats (S)

walk length (K)

length of time between walks in days (D)

Avian predator densities

$((P/4)/60)/A$

Total number of predators over the four one hour watches (P)

Area of field (A)

Perch densities

Weighted perch score / Area of field

Boundary score from Durrant et al (2008)

Length of boundary / Area of field

Daily failure rate (Salek and Smilauer 2002)

total number of failed nests / exposure days