FOOTPRINT ECOLOGY

Beach-nesting Ringed Plovers and their conservation in England: guidance for site managers

Durwyn Liley

FOOTPRINT ECOLOGY, FOREST OFFICE, BERE ROAD,
WAREHAM, DORSET BH20 7PA
WWW.FOOTPRINT-ECOLOGY.CO.UK
01929 552444

FOOTPRINT
ECOLOGY

Footprint Contract Reference: 595
Date: 30th September 2022
Version: Final
Recommended Citation: Liley, D. (2021). Beach-nesting Ringed Plovers and their conservation in England: guidance for site managers. Report by Footprint Ecology.

Summary

The Ringed Plover is a familiar shorebird, widely distributed on muddy, sandy and shingle shores throughout the year. It is now a red-listed UK bird of conservation concern, Threatened (Vulnerable) outside the breeding season and Near Threatened within it at a GB scale. Breeding in England is now largely confined to the least disturbed sand and shingle beaches and areas where conservation management is in place.

This report summarises the breeding ecology and typical habitat used for nesting and then summarises different options for management to protect the species and enhance breeding success, focussing on measures to reduce disturbance and impacts from recreation, ways to minimise the impacts of predation, measures to address flooding of nests and ways to improve habitat.

Contents

Acknowledgements

The work was funded by the LIFE Programme of the European Union as part of the project LIFE on the Edge: improving the condition and long-term resilience of key coastal SPAs in S, E and NW England (LIFE19 NAT/UK/000964) and also by the RSPB and Natural England as part of the Action for Birds in England (AfBiE) partnership.

I have drawn heavily from a paper published in British Wildlife in December 2021 and thank fellow authors of that paper, Andy Brown (Natural England), Wynona Legg, Leigh Lock and Jim Scott (all RSPB) for their discussion and comment.

I am grateful to the following for useful discussion and for sharing information, reports and images: Mark Nowers (RSPB), Daniel Piec (RSPB), Gwendolyn Potter (National Trust), Kevin Wilson (Lincolnshire Wildlife Trust).

Much of the recent work at Snettisham referred to here has been funded through the Borough Council of King's Lynn and West Norfolk Habitats Monitoring & Mitigation Fund, and the project made possible by a partnership with Wild Ken Hill to enable fencing on the upper beach owned by the estate. The project was also supported by Natural England and the Norfolk Coast Partnership. Nest monitoring and protection through 2021 has involved a range of RSPB staff and volunteers.

My original work in the 1990s was undertaken as part of a NERC funded PhD, supervised by Bill Sutherland. The late Derek Ratcliffe kindly shared his data in the 1990s. Data for Norfolk sites shown in Figure 1 kindly provided by Neil Lawton.

1. Introduction

Overview

1.1 This report sets out guidance for management and monitoring of breeding Ringed Plovers on beaches in the UK. Ringed Plovers are rapidly declining as a breeding species around the English coast and there are a range of measures that will aid breeding success and conservation management. This report summarises the breeding ecology and the range of interventions available to site managers to protect the species.

Status

1.2 Ringed Plovers breed around the UK coast, favouring sand and shingle beaches, shell banks and machair. A small number breed inland around gravel pits, lakes and reservoirs and, at least historically, they have bred on lowland heaths, arable farmland and even in montane habitats.

1.3 The UK population has most recently been estimated at 5,438 pairs, with 1,688 pairs in England (Conway et al., 2019), although this was based on a national survey in 2007. The species is a Red-listed Bird of Conservation Concern (Eaton et al., 2015) reflecting the marked a decline in the non-breeding population, but the numbers breeding have also declined and the species' breeding population is Near Threatened in a GB context (Stanbury et al. 2017) The 2007 survey suggests a UK decline of 37% since 1984 and this may well be an underestimate, as direct comparisons of counts from well-monitored sites suggest much greater declines (Conway et al., 2019). Observers of ringed plovers consider them amongst our most rapidly declining coastal species.

1.4 In England, coastal breeding is mainly on the east and south coast, with notable concentrations of breeding pairs at Lindisfarne, at Gibralter Point, around the Wash and North Norfolk and on the Essex Coast. As a breeding species it is only a qualifying feature for three Special Protection Areas in England (the Blackwater Estuary, the Colne Estuary and Foulness), all on the Essex coast.

1.5 The Norfolk coast held around 17% of the England total in 2007. As elsewhere, there has been a marked decline in the number of pairs (Figure 1Figure 2) , with totals in recent years about half to a quarter of those in the 1980s and 1990s.

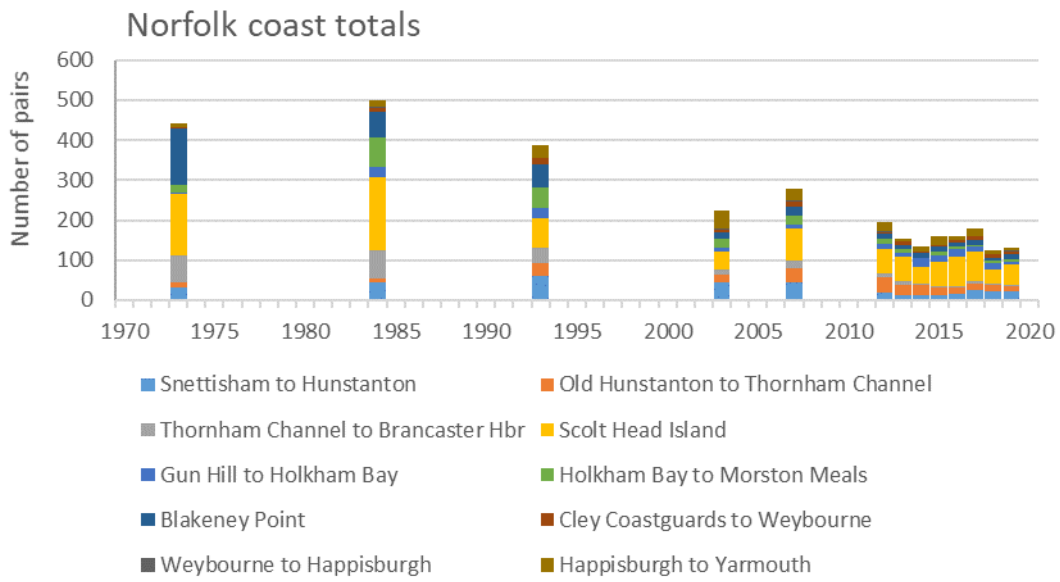

Figure 1: Norfolk-wide totals for years when full surveys undertaken.

1.6 It has disappeared from many coastal sites in England and protection measures such as fencing and nest protection tend to only happen where the beach is in conservation management and other species (such as nesting terns) are present. In the UK, the Ringed Plover has received insufficient attention, perhaps because it is not globally threatened, typically occurs at a relatively low density and quantitative data on population change for many areas are lacking or of poor quality.

Beach nesting plovers: global context

1.7 The issues faced by Ringed Plovers are not unique – they apply to nesting shorebirds around the world. Globally, there are around 21 species of beach-nesting plovers (see Table 1): 1 is Data Deficient (DD), 1 Endangered (EN), 2 Vulnerable (VU) and 5 Near-threatened (NT), with just over half (12 species) of Least Concern (LC). The Threatened species tend to have limited geographical ranges or occur in areas where there is a high human population. Where coastlines have been developed or are subject to high levels of recreation, habitat change, disturbance and high predation rates are common drivers of decline.

1.8 Some species, such as Piping Plover on the eastern seaboard of the USA and Hooded Plovers in south Australia have been subject to targeted action intended to halt and reverse losses, with nest protection, wardening, education, awareness-raising and direct habitat management variously playing a role in the conservation effort. For Piping Plover, Snowy Plover and Hooded Plover there is a large volume

of published material on protection and management, much of which is relevant to Ringed Plover.

Table 1: Beach-nesting plovers, adapted from Fraser and Catlin (2019). Taxonomy and Red-list categories from the BirdLife website data zone[1]. Endangered, Vulnerable and Data Deficient species are highlighted in red. See text for Red List category codes

English name	Scientific name	Global IUCN Red List category
Northern Red-breasted Plover	*Charadrius aquilonius*	NT
Common Ringed Plover	*Charadrius hiaticula*	LC
Semipalmated Plover	*Charadrius semipalmatus*	LC
Little Ringed Plover	*Charadrius dubius*	LC
Wilson's Plover	*Charadrius wilsonia*	LC
Killdeer	*Charadrius vociferus*	LC
Piping Plover	*Charadrius melodus*	NT
Black-banded Plover	*Charadrius thoracicus*	VU
Madagascar Three-banded Plover	*Charadrius bifrontatus*	LC
Kentish Plover	*Charadrius alexandrinus*	LC
White-faced Plover	*Charadrius dealbatus*	DD
Snowy Plover	*Charadrius nivosus*	NT
Javan Plover	*Charadrius javanicus*	LC
Red-capped Plover	*Charadrius ruficapillus*	LC
Malay Plover	*Charadrius peronii*	NT
Collared Plover	*Charadrius collaris*	LC
Two-banded Plover	*Charadrius falklandicus*	LC
Double-banded Plover	*Charadrius bicinctus*	NT
Rufous-chested Plover	*Charadrius modestus*	LC
Hooded Plover	*Thinornis cucullatus*	VU
Shore Plover	*Thinornis novaseelandiae*	EN

[1] http://www.birdlife.org accessed on 15/02/2022

2. Breeding Ecology of Ringed Plovers

2.1 This section provides a summary of information on the breeding ecology of coastal nesting Ringed Plovers, drawing largely on a study undertaken in the 1990s at Snettisham in Norfolk (Liley et al., 2021).

Breeding ecology (largely based on intensive monitoring from Snettisham in the 1990s)

2.2 Birds arrived from February and immediately commenced territorial behaviour, often returning to the same territories they had occupied in the previous year. Territories were defended until late July.

2.3 Nesting occurred from mid-April. Nests were simple scrapes on sand (81%) or shingle (14%), though they were sometimes lined with tiny shell fragments (e.g. Figure 2). Clutches varied from 1-4 eggs, with most (46%) of 4 eggs (but note that some authors have occasionally reported clutches of 5, e.g. Pienkowski, 1984).

2.4 Incubation duties were shared by both sexes, taking around 25 days for the eggs to hatch. Chicks left the nest soon after hatching (Figure 2) and then were mobile, remaining in the territory and guarded by both the adults for a further 24 days or so to fledging (i.e. fly strongly). Pairs would renest within the season, through into July, typically after a nest failed. Just one pair raised two broods in one season.

2.5 At the end of the breeding season birds dispersed widely, with colour-ringed sightings showing birds moving north (Scotland), west (Irish sea and north Devon) or south (Brittany). Adults are long-lived, for example one of the females at Snettisham was known from colour-rings to be at least 19 years old.

2.6 Less than half of all nests hatched, with predation the main cause of nest loss (Figure 2).

Figure 2: Ringed Plover nest, newly hatched chicks in the nest and young chick

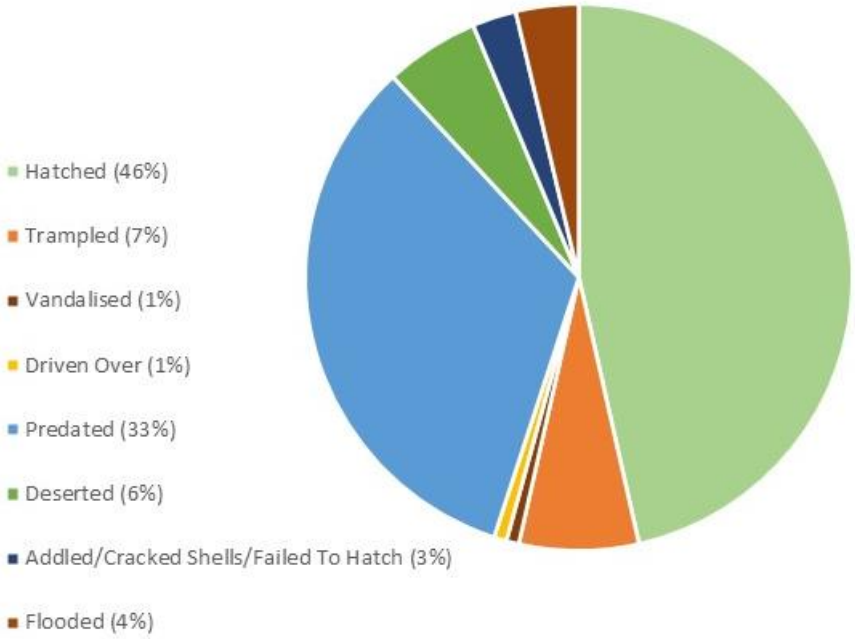

Figure 3: Nest outcomes from 1996-1998 at Snettisham (data from 269 nests).

Habitat

2.7 In general, the literature relating to beach nesting plovers (see Fraser and Catlin, 2019 for review) highlights the importance of prey availability (for adults and chicks) and reducing predation risk as key factors influencing habitat choice for breeding beach-nesting plovers.

2.8 Key components of good quality habitat are therefore likely to include:

- Fresh-water input (Ogden and Dowding, 2013) or intertidal habitat that providing feeding areas (M. L. Stantial et al., 2021);
- Sparse or no vegetation (Zeigler et al., 2021);
- Greater cover of beach debris such as driftwood, shells, stones etc that provide broken ground/cover for incubating adults (Hardy and Colwell, 2012; Webber et al., 2013);
- Open ground, allowing easy access to nest, good visibility and reduced risk of predation of incubating adults (Ehmke et al., 2016; Webber et al., 2013);
- Wider beaches, which provide greater range of nest sites and mean predators moving along the beach have a lower probability of encountering the nest (Patrick and Colwell, 2014).

2.9 Pienkowski & Pienkowski (1989) recorded reduced nest densities of Ringed Plovers over time in response to changing habitat with shingle becoming sandier. As a result, they suggested that open shingle is a key factor limiting nest density and there is a general suggestion for many species that the availability of suitable breeding habitat may be a limiting factor (Fraser and Catlin, 2019). At Snettisham in the 1990s, Ringed Plover territory occupancy and breeding success were linked to those sections of beach that were wider, gently sloping with a wide tideline (i.e. considerable tideline debris) and characterised by a low percentage of vegetation cover between the tideline and top of beach. The highest densities were in the areas of wide-open shingle. The adults fed on the exposed mud flats at low tide and the chicks, when feeding would tend to be around the water's edge, the tideline or occasionally on the mudflats. Access to the waters edge and intertidal habitat was probably also a key factor.

2.10 Some examples of breeding habitat for Ringed Plovers at a range of sites are shown in Figure 4. In general, very exposed sandy beaches such as the Ross Sands example will tend to support lower densities than more sheltered shingle sites with lagoons or food-rich intertidal habitat nearby.

Figure 4: Examples of Ringed Plover breeding habitat: clockwise from top left: the Solent, Lindisfarne NNR (Ross Sands), Snettisham, Snettisham (Heacham), Walberswick and Solent.

Predation

2.11 Predators are easily seen on the open beaches. Studies of Kentish Plover nest locations on beaches has shown they select locations with good visibility of approaching predators (Gómez-Serrano and López-López, 2014). Ringed Plovers use the terrain to ensure they have a good view allowing the adults to respond to approaching predators and relying on crypsis and diversionary tactics to avoid nest/chick predators.

2.12 Incubating adult Ringed Plovers can be hard to see and move away from the nest swiftly at the approach of a potential predator. The eggs are well-camouflaged and chicks are mobile, roaming the beach and able to run fast. They stay close to the adults whose alarm calls send them running for cover (such as provided by clumps of Marram *Ammophila australis* or Shrubby-sea blight *Suaeda vera)* or to lay flat and motionless among beach debris.

2.13 Whole nests, individual eggs, chicks and even incubating adults (the latter occurring on 4 occasions at Snettisham in the 1990s) were predated, with a third of nests failing due to predation, principally from mammalian predators.

2.14 Wide sections of beach give particular advantage to birds and most chicks fledged from nests on such beaches, so good territories were fought over and prime areas were repeatedly contested. Wide beaches offer a greater choice of nest location, with the whole width from near the tideline to the top of the beach available for nesting. Foxes and other predators were occasionally observed moving along the beach, often along the tideline or just above it. On narrow beaches there is the risk of all the nests along a given stretch being in a line, just above the strandline, potentially meaning a single predator walking that line would find all the nests.

2.15 Nest predation varied markedly between years and was higher in the latter part of the season. Re-nesting occurred less often on beaches with more predation, providing a means for pairs to mediate the effort they put into breeding according to the level of risk.

2.16 Population modelling indicated that were nest predation to be entirely eliminated along the whole study area the population would be 134% higher.

Disturbance

2.17 The study area at Snettisham was (and remains) popular for recreation. There were three large car parks, a sailing club and caravan parks, houses and holiday homes were directly adjacent to the beach. Recreational use was varied and included walking, dog walking, beach activities, jogging, cycling, bird watching and

boat use. Levels of activity were much higher around the main car-parks and peaked during the school summer holiday period.

2.18 The strongest effect of recreation on Ringed Plovers was on settlement patterns. Adult birds, with the exception of those with no prior experience of breeding on the site, avoided settling on the busy sections of beach. Adults settle in February, when recreation levels are low, so avoidance is triggered by previous experience. Territories were larger and nesting attempts fewer on busier sections – and the pairs that did try and nest in very busy areas were typically young birds with no prior experience of breeding at the site, they failed and they did not return to those areas in later years. Despite a general avoidance by birds of busier beaches, 7% of nests were still trampled by people.

2.19 Population models suggested that if nests were protected from trampling, e.g. with fencing, the population would be 8% higher. If people were altogether absent from the beach, the population would be 85% higher whilst if the levels of recreation doubled (but the distribution of access did not change) the population would decrease by 23%.

Target productivity

2.20 We know from the Snettisham study in the 1990s that breeding success needs to be around 2.6 chicks hatched per pair per year to maintain the population.

3. Management options to reduce impacts from access

3.1 Even though people do not usually pose an actual threat, the presence of people and dogs is likely to mean that Ringed Plovers will perceive areas of otherwise suitable habitat as high-risk areas in which to breed. In this way people are effectively acting as predation-free predators (after Beale and Monaghan, 2004). There is evidence that management to reduce disturbance can reverse declines in beach-nesting plovers (Kwon et al., 2021; Michel et al., 2021).

3.2 Visits to the natural environment have shown a significant increase in England as a result of the increase in population and a trend to visit the countryside more (O'Neill, 2019). The Covid-19 pandemic has further had a marked effect on how people use local greenspaces and many locations across the UK have seen a marked increase in recreation use during the pandemic (Burnett et al., 2021) and brought into focus the challenges of managing access sustainably at many sites.

3.3 If managed sustainably, visitor use can be a positive agent for nature conservation for example through enforcing pro-environmental behaviours and a greater respect for the world around us (Richardson et al., 2016). Access also brings wider benefits to society that include benefits to mental/physical health (Keniger et al., 2013; Lee and Maheswaran, 2011; Pretty et al., 2005) and economic benefits (ICF GHK, 2013; ICRT, 2011; Keniger et al., 2013; The Land Trust, 2018). Nature conservation bodies are trying to encourage people to spend more time outside and government policy is also promoting countryside access in general (e.g. through enhancing coastal access). There is therefore a difficult balancing act to provide opportunities for recreation and tourism of sufficient quality that allow people to experience protected sites while minimising the negative impacts.

3.4 There are 4 broad approaches to minimising impacts from recreation (adapted from Leung et al., 2018):

- Increasing access provision in time or space, to dilute or spread the pressure;
- Reducing impacts of visitors by modifying behaviour or activities;
- Increasing resilience, in essence 'hardening' or increasing durability;
- Limiting problematic visitor use through rules, regulations and restrictions.

3.5 Some examples of these approaches relevant to coastal sites with Ringed Plovers are summarised in Table 2 and key issues are discussed in more depth in subsequent text.

3.6 It is likely that a range of different interventions and approaches to management will be necessary and will provide the greatest confidence of success, for example warden presence on the beach, cordons to restrict access to some areas and a package of awareness raising measures may complement each other.

Table 2: Options to reduce disturbance impacts for Ringed Plovers

Intervention	Description	Scale	Examples	Advantages	Disadvantages	Evidence for success	References
Increasing access provision in time or space							
Creation of alternative sites for recreation ('SANGs' Suitable Alternative Natural Greenspace)	Dedicated spaces for recreation use, for example dog walking provided in areas that are not sensitive to disturbance.	Landscape	Widely used for heathland sites such as around the Thames Basin Heaths and Dorset Heaths. Coastal examples include Dawlish Countryside Park (designed to draw people away from the Exe Estuary) and Alver Valley near Gosport, on the Solent;	Positive intervention creating more opportunities for access; may be wider benefits in terms of opportunities for managing flood risk; water quality and even biodiversity.	Expensive and possibly difficult to implement; May be challenging to find good alternative destinations. Likely to take many years to work.	Growing evidence from visitor surveys and other analyses on success and also informing necessary design criteria. Likely to draw daily dog walkers, joggers etc. but perhaps less likely to deflect those travelling from further afield.	Allinson (2018); anon (2020); anon (2021).
Reducing impacts of visitors by modifying behaviour or activities							
Changes to how sites and locations are promoted	Low key promotion of areas with beach nesting birds compared to others may result in fewer visitors	Landscape/ site-level	North Norfolk coast sites have been working to influence websites that promote dog walking sites with aim of ensuring some sites are not promoted or suggested as good sites to let dog off-lead	Relatively simple and can be targeted to direct particular activities (such as dog walking) to specific areas	May be hard to direct use and may be difficult where social media or word of mouth have led to people becoming set on visiting specific locations	Limited evidence specifically around promotion	
Education and awareness raising	Use of social media campaigns, websites, printed material, talks, guided walks to raise awareness and influence behaviour	Landscape/ site-level	Widely used across the country. A good example is Bird Aware Solent which undertaken extensive social media work;	Enables people to connect and better understand reasons for restrictions etc. Involves community and local people	Can be hard to reach relevant audiences, especially if visitors are occasional or holiday makers	Considerable evidence for different approaches to influence behaviour change	Williams *et al.* (2009); Wu *et al.* (2018); Gruas *et al.* (2020); Rare and the behavioural insights team (2019); Mengak *et al.* (2019)

Intervention	Description	Scale	Examples	Advantages	Disadvantages	Evidence for success	References
Signage and interpretation	Can include temporary signs, A frames and more permanent interpretation	Site level and targeted to specific locations	Widely used in reserves. Lindisfarne NNR places A frame signs in the middle of the beach where the no access zone starts	Ensures clear communication and temporary signs can be deployed easily and in specific circumstances	Relies on visitors passing and reading the signs, can be unsightly.	Widely used as part of package of measures. Signage shown to reduce disturbance to seabirds. Rimmer study tests different designs.	Medeiros *et al.* (2007); Ham *et al.* (2009); Rimmer *et al.* (2013); Allbrook & Quinn (2020)
Parking charges	Manipulating parking charges may redistribute visitor use to areas where parking cheaper/free	Landscape	No known examples from UK where charges manipulated to change visitor numbers and reduce bird disturbance.	Possibly cost effective;	Increased charging likely to be unpopular and antagonise visitors;	Very limited. Some evidence locations that charge actually busier. Could result in increased verge parking. May create sense of access only for those well-off	Weitwoitz et al (2019)
Changes to parking to redistribute access	Could involve some coastal car parks or relocating them further back from coast or in less sensitive locations, potentially expanding others.	Landscape or potentially at site level	Limited examples where undertaken to relieve disturbance pressure at coastal locations, but other examples include: • Car parks have been seasonally closed in the New Forest to reduce disturbance for breeding birds: • At Burnham Beeches parking was rationalised and the main parking area relocated to a less sensitive part of the site.	Potential to reduce vehicle use in general; Can enhance some parking areas and improve access overall	May deflect access; many antagonise visitors; focussed on those visitors arriving by car	Little evidence in the literature.	
Increasing resilience							

Intervention	Description	Scale	Examples	Advantages	Disadvantages	Evidence for success	References
Viewing facilities	Screens and viewpoints allow people to view birds and create a destination while protecting birds from disturbance	Site-level	Very few. Many tern colonies have a view point, for example Long Nanny has a viewing platform	Clear focal point for engagement and viewing birds; may limit impact of restricted access	Only of relevance to those interested in the birds and wanting to view them		
Path infrastructure	Paths routed away from birds to provide continued access or circular route. Provision of boardwalks or marked routes may help funnel access.	Site-level	Inland route provided at Long Nanny at back of dunes, providing access at high tide away from birds; .	Positive access provision; may facilitate engagement; may reduce overall footfall in sensitive locations (e.g. by providing a simple and direct access to beach);	Costly and infrastructure such as boardwalks may need annual maintenance and replacement due to dynamic habitats	Path surfacing in uplands has been shown to limit people straying from the path and result in change in bird distribution	
Nest cages	Small cages around nests, designed to exclude predators and prevent trampling	Individual nest	Used at a range of sites to protect Ringed Plover nests from trampling and predation, e.g. Gibralter Point, Scolt Head, Holme Dunes.	Portable, relatively quick and easy to deploy, cost effective	Draw attention to nests, may draw people to investigate, can result in increased predation of adults and desertion	Range of studies for different plover species with some (but not all) showing increased hatching success and overall benefit. See later section of report for further discussion	Anteau *et al.* (2022)
Limiting problematic visitor use							
Caps on visitor numbers	Limits on visitor numbers through permits, advanced booking etc.	Site-level	Very limited use in UK and no recent examples	Allows visitor numbers to set in advance and carefully controlled	Unfeasible and impractical at many sites, especially where legal right of access		

Intervention	Description	Scale	Examples	Advantages	Disadvantages	Evidence for success	References
Sections of coast with no access	Entire sections of beach managed such that no public access	Landscape/ site-level	• At Lindisfarne NNR (Ross Sands) over 2km of open beach with no access (seals and breeding birds); • On the Exe Estuary there are two voluntary refuges for wintering waterbirds; • Church Norton Spit at Pagham Harbour is around 800m with no access (breeding terns and waders).	Creates clear, strong refuge areas.	May require policing; may antagonise visitors; may be impossible to implement.	Likely to work where practical to implement.	Saunders & Liley (2021);
Cordons	Fenced areas, often using single strand of rope or bailer twine. Can be around individual nests or long sections of beach. Shape and design vary widely and can include electric fence (doubling to provide protection from predation)	Site-level	Widely used around coast for Ringed Plovers, Terns etc.	Relatively cost effective and simple, flexible as can be adjusted (depending on design)	Unsightly, can be difficult to implement where dynamic habitat and high tides	Range of studies show improved breeding success within cordons for different species, however design and shape differ widely. Some evidence that people and dogs still enter (Depending on design). Evidence from Piping Plover study that implementation of protection buffers within which no access resulted in population increase.	Rooney & Eve 1993 in Mahon (1994);Witton (2018); Medeiros et al. (2007); Weston *et al.* (2012); Kwon et al (2021)
Wardens	Direct presence on beach to intercept visitors, influence behaviour and stop any	Site-level and can be opportunities	Dedicated engagement officers and wardens are employed at a range of sites,	Wardens can target particular individuals and	Costly, labour intensive.		Medeiros et al. (2007);

Intervention	Description	Scale	Examples	Advantages	Disadvantages	Evidence for success	References
	particular damaging activity. Can include volunteer staff.	to implement strategically	particularly those with breeding terns as well as waders. Some roles are Ringed Plover specific: e.g. Plovers in Peril (Snettisham RSPB);	activities and time can be adjusted as necessary to reflect site issues. Presence provides an enforcement role but also scope to influence people through engagement and awareness raising.			Liley & Panter (2017)

Strategic management of access at a landscape scale

3.7 Areas of wide, relatively flat beach with nearby cover and access to foraging areas provide ideal nesting sites for Ringed Plovers, but they avoided many such areas at Snettisham where recreation levels broadly exceed that of 1 person passing roughly every 190m when walking at a steady slow pace along the beach (based on the 1990s data and averaged over the period February – August). This is a relatively low level of use. It follows that the more access can be directed away from good habitat the better. This is challenging, as Ringed Plovers are territorial and do not nest in dense, discrete colonies and may therefore be dispersed across a wide area. At Snettisham, individual territories were typically spaced around at 100m intervals along the linear stretches of beach, but were smaller in the better-quality habitat with wider open shingle (such as Snettisham Scalp).

3.8 The clear implication is that even in the widest of beaches, low levels of access must be maintained over a wide area if a viable Ringed Plover population is to be retained. For many visitors, open beaches are a particular draw, perceived as ideal areas for a wide diversity of recreational and dog-related activities. Minimising such activity at a more landscape or strategic way, such that whole beaches are relatively quiet, is a challenge, requiring changing visitors' expectations and behaviour and potentially necessitating the regulation of visitor numbers or redistribution of access infrastructure such as car parks and access points. Such strategic approaches are most relevant at a coastline scale and likely to be best implemented through coast partnerships similar bodies, potentially difficult for individual reserves or sites. Strategic guidance on the management of recreation in protected areas and examples of best practice are provided by Leung *et al.* (2018).

Cordons and temporary fencing

3.9 Temporary fencing to protect important areas of suitable habitat is a commonly used approach. There is little to inform the choice of size and shape for these exclosures, however bigger areas maintained for longer are likely to be best. Such fencing can simply involve a single strand of rope and temporary posts and is ideally erected early in the season, before birds nest (i.e. February/March). Cordons can be more permanent or designed to also exclude predators (e.g. electrified).

3.10 During the early part of the spring there is a risk of storms and high tides damaging fencing and as such there may be a trade-off between avoiding the bad weather and tides while ensuring sufficient protection. Cordons should ideally be

established in similar locations each year rather than be dynamic in location, as adult birds are more likely to return to locations where they successfully bred in previous years. With cordons in similar locations each year they are more likely to be used and the number of pairs using them may increase over time.

3.11 Cordon examples include:

- Long Nanny: 14ha, 1700m perimeter, shorebird breeding area with no access
- Holme Dunes: 3 main cordons: 13.6ha,1981m perimeter, 12.7ha, 1905m perimeter and 5.7ha, 1407m perimeter.
- Gibralter Point: 'Sanctuary' zone fenced to protect around 10ha of coastal habitat, of which 0.5ha is suitable breeding habitat for Ringed Plovers.
- Rye Harbour: 64ha combination fence (electrified) protecting nesting habitat for a range of species (including terns and gulls) and excluding people and predators

3.12 As a last resort, cordons can be put round individual nests. In the Snettisham area in recent years individual nests have been cordoned inside temporary fenced squares of sides of around 30m (each approximately 0.09ha, 120m perimeter, in some parts of the beach cordons larger to cover multiple nests);

3.13 Fencing individual nests requires considerable effort to locate nests and where there is a sizeable population and repeated nesting attempts there is a likely requirement for lots of fenced areas that can then be difficult to maintain and unsightly. Such temporary cordons around individual nests merely minimise risks from trampling and repeated flushing and are likely to be the absolute minimum required, for example 50m cordons are used for Piping Plovers in Canada (Birds Canada, 2019). Visitors may assume they can walk up to and around fences and so lots of small exclosures may mean people still spreading across the beach.

3.14 Fencing nests or sections of the beach has the effect of reducing the beach area available for human recreation, with footfall channelled to the beach immediately above and below the cordon, meaning disturbance issues can still remain. Adults tend to access the nest by walking up the beach and chicks, of course, roam widely and key feeding areas along the tide-line or on the lower shore may, often of necessity, be unfenced and chicks can then be easily disturbed or even 'cut off' from their parents. Clearly the larger the area fenced the better.

Signs and wardening alongside cordons

3.15 A key challenge with cordons is that the fences can be ignored and do not deter off-lead dogs (Witton, 2018). Visitors may not understand the need for the cordons

any may be resentful when they feel their access is restricted. Signs and the presence of wardens is therefore likely to be necessary alongside the cordons (e.g. Medeiros et al., 2007; Weston et al., 2012).

3.16 It will be important for visitors to be aware of the cordons before they get close to the fence which necessitates the need for engagement at entry points and other key locations. Some examples of signs are shown in Figure 6. Such signage needs to be carefully designed and may need to be location specific in order to convey the right information about how to behave and where particular issues apply. It may be important to ensure signs are appropriately targeted (e.g. dog walkers may not necessarily think a sign with a picture of a bird is relevant to them). There is a large body of information on best practice for design and communication (Barker and Park, 2021; Ham et al., 2009; Rare and the Behavioural Insights Team, 2019), and these highlight the importance of understanding the motivations of visitors and the range of ways to influence their behaviour. Careful trialling and testing is likely to be important and signs may need to be specific to particular locations.

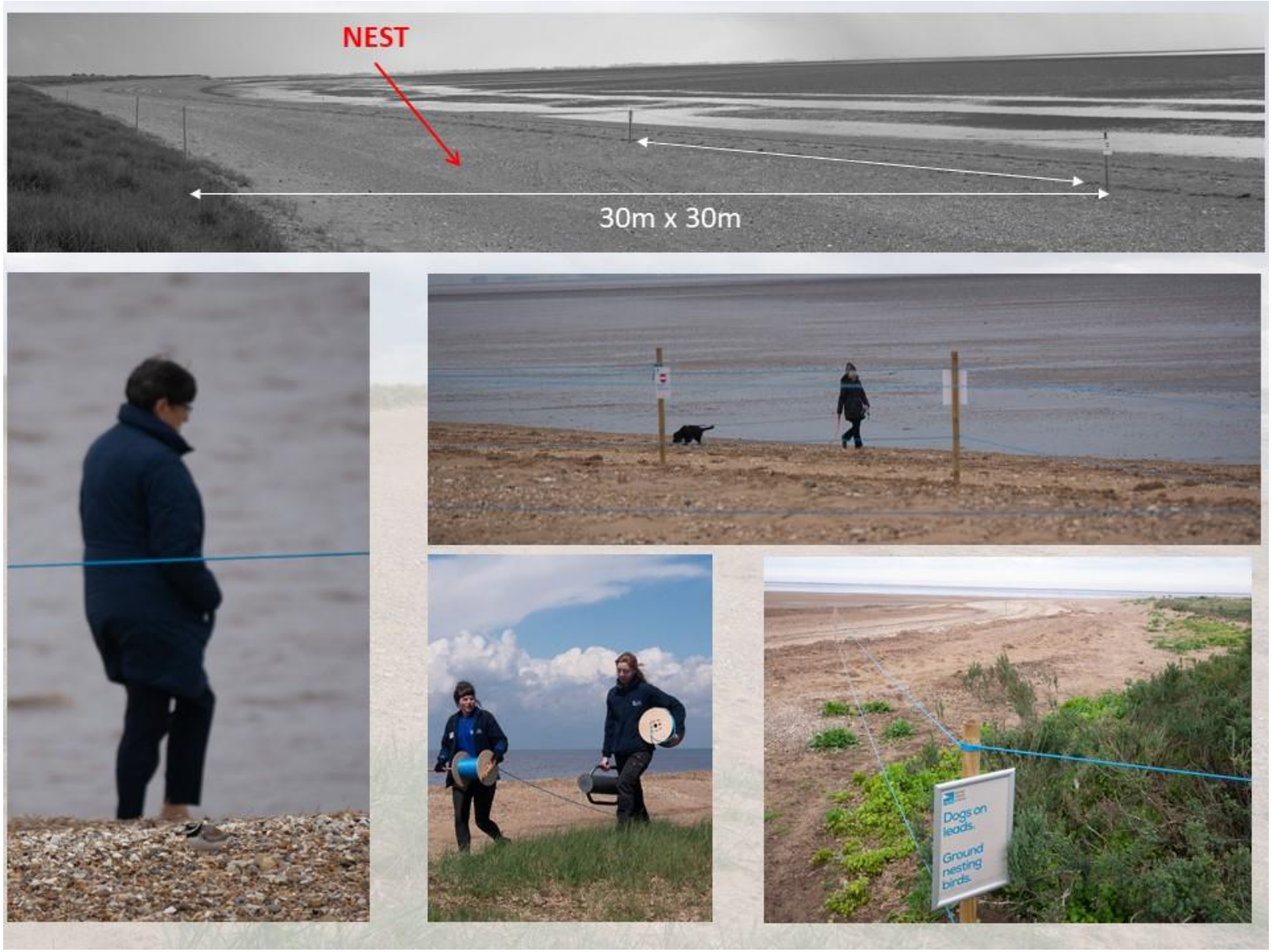

Figure 5: Images showing cordons in the Snettisham area in 2021.

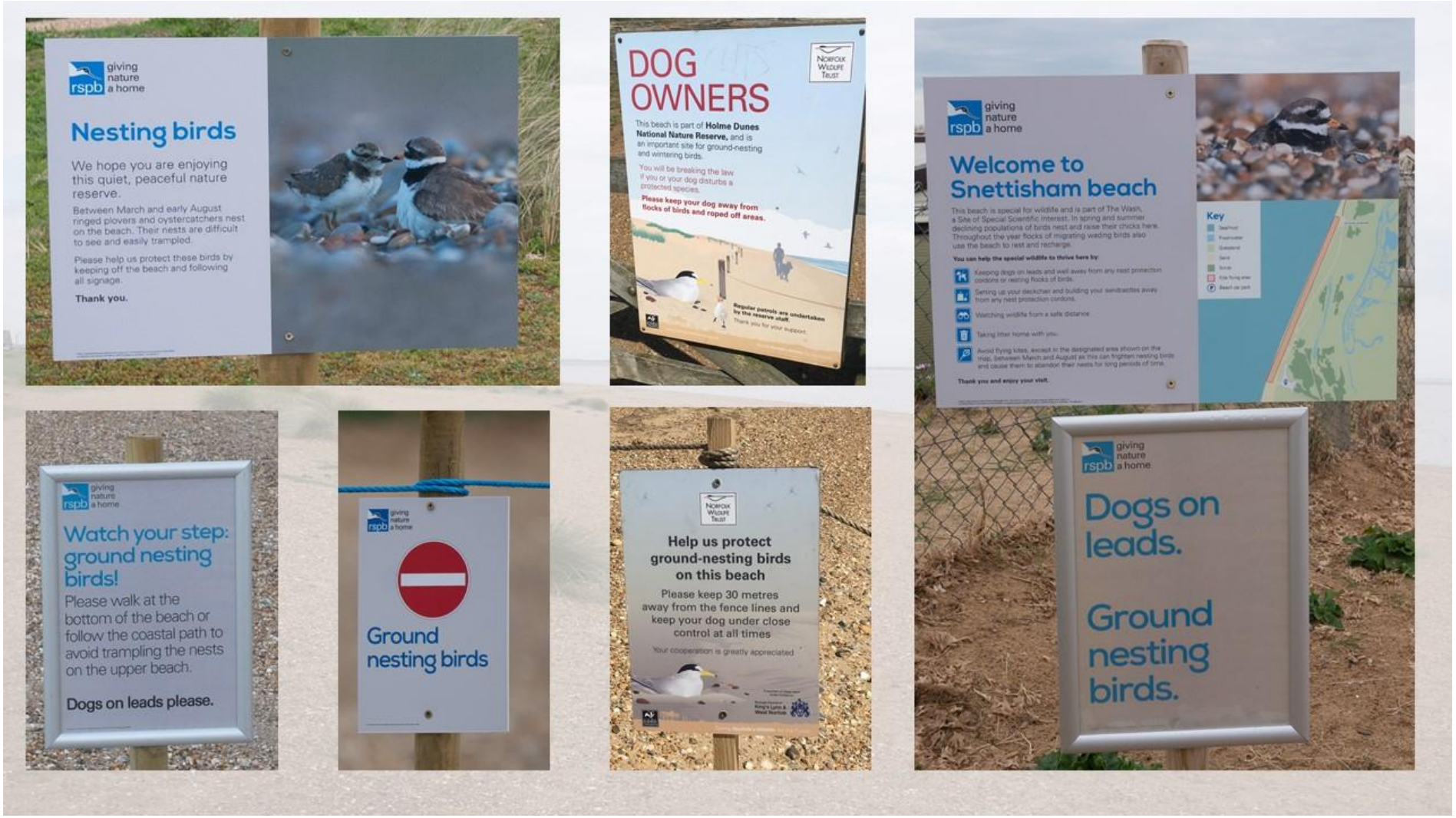

Figure 6: Examples of signs around cordons or at entry points onto sites. Middle two from Holme Norfolk Wildlife Trust Reserve. Others from Snettisham RSPB.

Dogs

3.17 Dogs are a particular concern at many sites. Dog walkers account for the majority of users at many beaches (Panter et al., 2017; Panter and Liley, 2016) and there are particular disturbance issues associated with dogs (Gómez-Serrano, 2021; Lafferty et al., 2006; Liley, 1999). Dogs off leads can roam widely (for example Schneider et al., 2020 show that off-lead dogs cover up to 33km on a walk and travel at speeds of up to 19km per hr) and impacts such as direct predation of chicks and flushing of adult birds are more likely with dogs off-lead. Even if dogs are on a leads incubating plovers respond differently compared to people without dogs (Lord et al., 2001).

3.18 Dog walkers may well be more regular visitors than non-dog walkers and be more local (Panter et al., 2017). The particular draw of beaches for many dog walkers is likely to be in part be the perception of the enjoyment their pet has from being able to run off-lead safely over a wide area (Edwards and Knight, 2006; Jenkinson, 2010). Understanding these motivations and drivers can help to inform communication and how to influence behaviour (Comber and Dayer, 2021). Some studies have found limited compliance with requirements to keep dogs on lead on beaches (Jorgensen and Brown, 2017; Schneider et al., 2020) and highlight the importance of carefully designed communication. Consistent messaging that is credible and clear is likely to be the most effective (Jenkinson, 2015) alongside provision of areas where dogs can be off-lead. Typical dog walks at coastal sites will be around 3km[2] and as such the provision of alternative spaces for dog walking will need to be involve large areas[3].

3.19 In some parts of the UK, dedicated projects aimed at dog walking in the countryside have been established, these help to promote responsible behaviour, highlight which sites to go to (and where to avoid) and raise awareness. Examples include Dorset Dogs[4], Devon Loves Dogs[5] and Humber Hounds[6].

---

[2] This is the median distance in Panter *et al.* (2016)

[3] A square with a 3km perimeter, i.e. providing a route length of 3km round the edge, would need to be around 56ha in size.

[4] https://www.dorsetdogs.org.uk/

[5] https://www.devonlovesdogs.co.uk/

[6] http://humbernature.co.uk/projects/humber-hounds

4. Management options to reduce impacts from predation

4.1 Predation is the key cause of nest loss, is likely to be a key cause of mortality for chicks and adults are also at risk while incubating. Predation risk is therefore likely to be a key factor in influencing Ringed Plover distribution, territory choice and breeding behaviour. The species is recognised as having high levels of nest predation and the long breeding season and multiple replacement clutches may be mechanisms to adapt to these (Wallander and Andersson, 2003). Large areas of open, dynamic coast will offer more opportunities for birds to nest and extensive areas of open habitat (including islands, bars, spits and open beaches) would perhaps pose less predation risk due to their inaccessibility. With more stabilised habitats, narrower beaches (due to coastal squeeze) and bird distributions more restricted due to disturbance, predation risk is likely to be exacerbated.

4.2 Disturbance may also affect the vulnerability of birds to predation, as for example on beaches with high levels of human access, Kentish Plovers have been shown to respond to potential predators at shorter distances (Gómez-Serrano and López-López, 2014).

Predators of breeding Ringed Plover

4.3 There are a wide range of potential predators of breeding Ringed Plovers on beaches (see Table 3 for possible predators cited in relevant literature). Different predators may be more prevalent in some years compared to others and therefore predation is likely to fluctuate between years.

4.4 The identification of predators from nest remains is difficult and may not always be possible (Green et al., 1987; Larivière, 1999) and nest cameras are likely to be necessary to give any confidence in the predator species involved in nest predation and relative frequency. Chick predation is rarely observed, difficult to record and few studies of wader chicks have been able to reliably identify chick predators (Mason et al., 2018; but see Teunissen et al., 2008).

4.5 Nocturnal/mammalian predation tends to be the main cause of nest failure for ground-nesting waders (Macdonald and Bolton, 2008) and Foxes are generally the most commonly cited and main predator of wader nests in the UK (e.g. Mason et al., 2018).

4.6 There are relatively few studies in the UK that provide evidence of key predators for breeding Ringed Plovers. In Pienkowski's study at Lindisfarne (Pienkowski,

1984), predation from Foxes was thought to have accounted for around 10% of the nest failure and Crows a further 9% (data from 1975 and 1976). Pienkowski also provided data from St. Cyrus in Fife from 1974 and 1975, where Crows accounted for 61% of nest loss and Foxes 5%. Bayes (1979) reported Crows as the main predator at Lindisfarne in 1977 while in 1979, on Holy Island at least, Foxes were believed to be the main predator. At Snettisham (1996-1998), at least 42% of predation events resulted in all eggs disappearing with no remains or evidence of the predator, and based on circumstantial evidence and the use of artificial eggs these were thought to have been predated by Fox (and to some extent Stoat). There was particularly high nest loss to predation at the site in 1998 and this was attributed to Foxes. Around 12% of predation was attributed to Hedgehog and in these cases the nests were in an area where Hedgehogs had been observed and there were broken shells and yolk in the scrape.

Table 3: Possible predators of Ringed Plover eggs, chicks and adults (while incubating) in the UK. Mammal list based on general literature on wader nest predation and species likely to occur on beaches. References that are underlined are ones that give evidence of predation of Ringed Plovers in the UK. References not underlined provide evidence of predation of other wader species in the UK.

	Eggs	Chicks	Adults	Selected references
Fox	✓	✓	✓	Pienkowski (1984); Liley (1999)
Weasel	✓	✓		Pienkowski (1984)
Stoat	✓	✓	✓	Pienkowski (1984); Liley (1999)
Badger	✓			Ausden *et al.* (2009); Laidlaw (2013)
American Mink	✓	✓	?	Laidlaw (2013)
Hedgehog	✓			Jackson (2000)
Rat	✓	✓		Teunissen *et al.* (2008)
Domestic Cat		✓		Teunissen *et al.* (2008)
Domestic Dog	✓	✓		Pienkowski (1984); Liley (1999)
Carrion Crow	✓	✓?		Pienkowski (1984)
Common Gull	✓	✓		Teunissen *et al.* (2008)
Great-black backed Gull	✓	?		Pienkowski (1984)
Kestrel		✓		Teunissen *et al.* (2008); Mason *et al.* (2018); Laidlaw (2013)
Peregrine		✓		Mason *et al.* (2018)
Sparrowhawk		✓		Teunissen *et al.* (2008)
Marsh Harrier	✓	✓		Teunissen *et al.* (2008); Mason *et al.* (2018); Laidlaw (2013)
Common Buzzard		✓		Teunissen *et al.* (2008); Mason *et al.* (2018); Ausden *et al.* (2009)

Reducing impacts of predation

4.7 The key to limiting predation is to identify predators and target interventions accordingly. Different approaches are possible and are reviewed by Colwell (2019) and are summarised in Table 4. The table does not include actions that relate to

the management of access or of beach habitat (both of which can influence predation risk) as these are considered in separate parts of the report.

Table 4: Examples of management actions taken to address impacts of predation and relevant to breeding Ringed Plovers. Adapted from Colwell (2019).

Intervention	Description	Advantages	Disadvantages	Evidence of success for beach-nesting plovers	References
Reduce food availability for predators	Removal of rubbish (e.g. car parks, nearby caravan sites etc) and carcasses on the beach that may draw predators	May need to be undertaken anyway and has other benefits	Likely to be of limited effectiveness and may not be relevant at some locations	Experimental study using artificial nests on Australian beaches showed higher predation rates by Ravens where discarded fish on beach	Rees *et al.* (2015)
Deterring or scaring predators	Predators discouraged from areas using scare tactics	Can be targeted to particular circumstances and predators.	Time consuming and difficult to undertake without disturbance to Ringed Plovers	Crow effigies (i.e. dead crows or artificial dead crows) have been shown to have slight effect as a deterrent to other crows. Lasers have been used on gull roosts in the UK.	Peterson & Colwell (2014)
Artificial shelters	Roof tiles, sections of pipe or wood (2 pieces at 90º) used to create refuges for mobile chicks	Simple, easy and cost effective	Only likely to work for aerial predators	Shown to increase Hooded Plover fledging success	Maguire *et al.* (2011)
Conditioned taste aversion	Non-lethal doses of poison or foul-tasting additives used in dummy eggs (e.g. quail eggs)	Does not require infrastructure.	May be difficult to find suitable dummy eggs and no control as to what might take them.	Shown to result in short term decrease in Fox predation of Hooded Plover nests	Maguire *et al.* (2009); Conover (1990); Avery & Decker (1994)
Olfactory habituation	Olfactory cues scattered prior to breeding season over area, meaning predators	Invisible and does not require infrastructure.	Only likely to work for mammalian predators. Novel, complex to administer and may be difficult to	Experimental study showed measurable improvements in breeding success for Wrybill and Double-banded Plover	Norbury *et al.* (2021)

Intervention	Description	Advantages	Disadvantages	Evidence of success for beach-nesting plovers	References
	associate smells with a lack of food		maintain through breeding season.		
Predator control	Direct control with the aim of reducing predator occurrence and abundance	Targeted and can focus on specific locations and individual predators	Kills predators. Ethical and moral concerns. May be opposed by public.	Evidence of increased fledging success for Snowy Plover, Piping Plover	Neuman *et al.* (2004); Cohen *et al.* (2009);Stantial *et al.* (2021)
Anti-predator fencing	Large areas of beach fenced to prevent access by predators	Once established can create large areas without mammalian predators. Effective for chicks and nests.	Expensive, difficult to maintain, especially where electrified and where public access and tide. Only effective for mammalian predators and not avian ones.	Electric fences have been shown to reduce mammalian predation of both chicks and eggs for Piping Plovers	Mayer & Ryan (1991); Larson *et al.* (2002); Murphy *et al.* (2003) ; White & Hirons (2019)
Nest cages	Small cages placed over nest, allowing access by Plovers but not predators	Portable, cheap, can be quickly deployed. No harm to predators.	Risk of desertion and some authors report increased predation of adults. Only works for nests.	Shown to be effective for a range of plover species and result in increased productivity.	Anteau *et al.* (2022)
Diversionary feeding	Predators provided with prey	Can be targeted to particular nests or predators and doesn't harm predators	Risk of boosting predator population. Time consuming and expensive.	No known examples where specifically targeted to protect plovers. Has been targeted at Kestrels predating Little Terns at sites also used by Ringed Plovers.	Smart & Amar (2018)

Nest cages

4.8 Nest cages warrant particular discussion as they are easy to deploy, cost effective are widely used and work to protect nests from both predators and people. The cages are placed over the nest with an opening at ground level that allows plovers to walk to the nest. The mesh prevents access by predators and cages can be buried to ensure predators cannot burrow to gain access.

4.9 Designs vary markedly and include circular, domed and square shapes (see Birds Canada, 2020 for discussion and further details) made of weld mesh, chicken wire or even welded bars (Isaksson et al., 2007). Comparisons of different designs suggest little variation in effectiveness (Dinsmore et al., 2014; R. K. Murphy et al., 2003; Vaske et al., 1994), however the Murphy study found less predation with large cages. Larger cages are therefore probably best but are harder to move, put up and store. Some examples of nest cages are shown in Figure 7.

4.10 The opening is typically around 5x10cm and at ground level and the cages are roofed. For Piping Plovers in Ontario mini cages of about 1m square and 50cm high are made of rigid mesh and can be deployed in around 2 minutes (see Birds Canada, 2019 for designs and detail) and tend to be used in the early stages of nesting (e.g. before the full clutch has been laid). The rapid deployment means that disturbance is minimised. Larger exclosures (up to 3m square) are also used. These are made of fruit-netting and can have an 'apron' around the base to prevent foxes or other predators burrowing under. These larger exclosures are only set up once the full clutch has been laid and are typically used on the beaches with high levels of human disturbance.

4.11 There is good evidence of their success in terms of increased hatching success (Dinsmore et al., 2014; Maslo and Lockwood, 2009; Smith et al., 2011). Some authors have, however, raised concerns, for example with respect to desertion (Neuman et al., 2004; Maslo and Lockwood, 2009) or increased predation rates over the longer-term (Murphy et al., 2003), presumably as predators associate the cages with a source of food. Burns *et al.* (2013) found no overall benefit for cages to protect St. Helena Plover nests and similarly Gaines *et al.* (2020) found no effect of cages when used for Snowy Plovers. Nonetheless, an experimental study over multiple sites and years on the use of nest cages on Piping Plovers (Anteau et al., 2022) found that cages produced a meaningful increase in nest survival with no side effects of reduced chick or adult survival. Thus, there would seem merit in their use, accompanied by careful monitoring and regular checking necessary to ensure predators do not use them as perches or cues to find nests and to ensure that the cages do not result in increased predation of adults.

Figure 7: Examples of nest cages. Lower left shows nest cage and signage for a Piping Plover nest (© USFW and [licenced for general use]). All other images © Kevin Wilson, from Ringed Plover nests at Gibralter Point, showing different designs including use of double cage.

5. Other options to increase breeding success or survival

Protection from flooding

5.1 At some sites, flooding can be a cause of nest loss. Where nests are known to be at risk from inundation (due for example to forecasts for particularly high tides) then nests can be raised or even moved. Ringed Plovers (O'Connell et al., 2014) and other species of Plover (Wiltermuth et al., 2009) have been reported moving their own eggs up the beach when threatened with inundation, but intervening and moving or raising nests deliberately should be seen as a last resort where nest failure is otherwise guaranteed.

5.2 Nests have been raised at Long Nanny using fishing crates filled with sand/shingle to prevent them being washed away (e.g. Figure 8). Tyres can also be used. Such structures provide a few centimetres of protection from inundation and the advantage of fishing crates is that they can be filled in advance away from the nest to limit time around the nest. At Long Nanny ramps are sometimes used (using drift wood) too allow the birds to walk to the nest or otherwise sand or shingle is piled up to create a ramp. Nest cages can be placed over the nest and nests have successfully hatched chicks when lifted into crates and cages placed over.

Figure 8: Example of raised nest from Long Nanny. Image © Mandy Fall and courtesy of Gwen Potter.

5.3 Moving nests has been successfully undertaken at some locations with the nests carefully moved up the beach above the tideline. Any such interference should only be attempted where no other options are available and the move should be as close as possible to the original nest location and at ninety degrees to the water. It may be best done incrementally (i.e. less than a metre at a time) but there is little guidance or experimental testing (but see Gratto-Trevor and Abbott, 2011; Prellwitz et al., 1995)

5.4 Creation of raised ridges on beaches to provide higher ground has been tried for Snowy Plovers and did not reduce nest loss to flooding (Koenen et al., 1996).

Habitat creation and management

5.5 Where the availability of suitable breeding habitat is limiting the population, any loss of habitat or degradation will reduce the population further. Disturbance, sea level rise and succession (e.g. Figure 9) can act to make areas unsuitable for breeding. One potential solution is to increase suitable habitat through habitat creation or management. New habitat can be created as part of coastal defence works or using dredging or other material to create open areas of shingle. Vegetation clearance and scraping can set back succession on existing, stabilised habitat but may need careful consideration and permission from Natural England if part of a SSSI.

Figure 9: Snettisham Scalp, late 1990s (left) and 2021 (right), showing the change in habitat over time (during which time the number of nesting pairs in this area has also declined).

5.6 Any such new habitat is likely to be used by relatively young birds, which may arrive later than older birds and will settle in areas to avoid competition (Fraser and Caitlin, 2019). Various studies have shown an increase in plover populations and breeding success on newly created habitat (Powell and Collier, 2000; Robinson, 2020), however such increases may be short-lived as vegetation change and discovery by predators may happen quickly (see Fraser and Caitlin, 2019 for review and discussion). Repeated intervention (e.g. vegetation removal) or habitat creation may be necessary to maintain the area of habitat available and any new creation could be targeted in areas with low levels of disturbance. There is little experimental evidence for the success of such interventions for Ringed Plover in the UK.

6. Recording and monitoring

6.1 Monitoring data are essential to inform how well a given population is doing and should be integral to any management. Key things to record include:

- The number of pairs;
- Breeding success and causes of failure;
- Interventions (such as use of cordons, nest cages or moving nests).

6.2 In addition, it may also be useful to systematically record visitor numbers, their behaviour and distribution.

Number of pairs

6.3 While Ringed Plovers may by present all year round on certain beaches, birds that are on territory will be apparent through their behaviour. Passage and wintering birds will tend to be in flocks and will typically gather to roost in flocks. Territorial birds will be spread out, often on their own or pairs. Territorial behaviour can start from around March (although birds can turn up throughout the spring) and include display flights and neighbouring pairs will often walk up and down the beach alongside each other.

6.4 Regular checks of suitable habitat will reveal the number of pairs and on busy sites it will be necessary to undertake repeated walks of suitable habitat and map pairs to obtain a reliable estimate of the number of pairs present.

Breeding success

6.5 Finding nests can be done by watching adults, paying attention to any birds that start walking up the beach. Another approach is to scan suitable habitat with binoculars or a scope from a distance and searching for adults that are sitting on the nest. These may simply be visible as the bird's head and shoulders among shingle. Where you pick up a nest or possible nest from a distance it is necessary to carefully note surrounding landmarks and it is sometimes a good idea for a second observer to help pin-point precisely where the nest is before approaching it. A third approach to finding nests is to simply cold search suitable habitat, walking slowly and checking the ground very carefully. In sandy areas trails left by the birds feet are sometimes a good clue. Birds will often alarm call if you are near a nest.

6.6 For all nests it is important to record the location accurately (e.g. grid ref from GPS) and a description (e.g. lining up to landmarks) so the nest can be mapped and can

be found again. Each nest should have a unique id (numbered sequentially as found).

6.7 Once found, nests should be checked regularly to determine what happens to them. This may be as simple as a check to see if the adult is sitting without necessarily going right to the nest. Eggs should take around 25 days to hatch and then the chicks a further 24 days or so to fledge. It's important to log each time the nest or chicks are checked in order to allow nest survival to be estimated (i.e. to accurately pin-point when the nest/chicks were lost). Identifying the cause of nest failure can be difficult and is not always possible without nest cameras, however noting any signs of damage to the nest or shell fragments can be clues and are worth noting.

6.8 Sample forms for recording nests and for logging nest checks are provided in Appendix 1. These are very basic and can be adapted as necessary. It is important to record management interventions (such as nest cages, cordons etc) and these can be recorded separately (e.g. cordons mapped). It may also be useful to note which nests were inside/outside cordons or which were caged and this can be added to the forms in Appendix 1.

Other data collection

6.9 Information on visitor use can be helpful, particularly if measures are put in place to influence of manage access. A range of options and approaches are relevant and the choice of how best to monitor will be site specific. It may require specialist help. Options include:

- Automated vehicle counters to log vehicles in and out of car parks or a system of visual counts of parked vehicles;
- Automated counters to record visitor flows at specific locations (e.g. through gates);
- Spot counts/vantage point counts to log activity types, distribution and behaviour (e.g. dogs off lead)
- Transects counting all people seen along a set route;
- Visitor interviews (which can ask where people have walked and gather a range of detailed information on visitor profile, motivations and behaviour);
- Handing out GPS units to visitors to record their route and time spent in different areas;
- Drone or aerial imagery to map the distribution of people;

- Use of data such as Strava[7] or AllTrails[8] where visitors upload their routes onto websites.

6.10 Alongside visitor data, habitat data may be useful to explain variation in bird use or success between years. Key variables relate to the width of the beach and the amount of tideline debris. Aerial imagery can be useful to show habitat change between years. Beach recharge, sea defence works or storms can all lead to marked changes in habitat between years. Weather and tides during the breeding season may also be useful factors and useful to record for future reference and comparison.

[7] https://www.strava.com/
[8] https://www.alltrails.com/

References

Allbrook, D.L., Quinn, J.L., 2020. The effectiveness of regulatory signs in controlling human behaviour and Northern gannet (Morus bassanus) disturbance during breeding: an experimental test. Journal for Nature Conservation 58, 125915. https://doi.org/10.1016/j.jnc.2020.125915

Allinson, E., 2018. The role of suitable alternative natural greenspace in protecting high value wildlife sites (PhD). Southampton.

anon, 2021. Guidelines for Creation of Suitable Alternative Natural Greenspace (SANG) – August 2021.

anon, 2020. Suitable Alternative Natural Greenspace (SANG) background paper. Hart, Rushmoor and Surrey Heath Councils.

Anteau, M.J., Swift, R.J., Sherfy, M.H., Koons, D.N., Ellis, K.S., Shaffer, T.L., Toy, D.L., Ring, M.M., 2022. Experimental evaluation of predator exclosures on nest, chick, and adult survival of piping plovers. The Journal of Wildlife Management 86, e22139. https://doi.org/10.1002/jwmg.22139

Ausden, M., Bolton, M., Butcher, N., Hoccom, D.G., Smart, J., Williams, G., 2009. Predation of breeding waders on lowland wet grassland - it is a problem? British Widlife 29–38.

Avery, M.L., Decker, D.E., 1994. Responses of captive fish crows to eggs treated with chemical repellents. Journal of Wildlife Management 58, 261–266.

Barker, J., Park, T., 2021. Using Behavioural Insights to Reduce Recreation Impacts on Wildlife: Guidance and Case Studies from Thames Basin Heath and the Solent (Natural England Commissioned Report No. 329). Behvioural Insights Team for Natural England.

Bayes, K.S., 1979. Some aspects of the ecology of the ringed plover Charadrius hiaticula during the breeding season (Masters). Durham.

Beale, C.M., Monaghan, P., 2004. Human disturbance: people as predation-free predators? Journal of Applied Ecology 41, 335–343.

Birds Canada, 2020. Rationale for mid-size exclosure use at Ontario's Great Lakes Piping Plover breeding sites.

Birds Canada, 2019. Manual B. Supplementary information for volunteers and staff. Ontario Piping Plover Conservation Program.

Burnett, H., Olsen, J.R., Nicholls, N., Mitchell, R., 2021. Change in time spent visiting and experiences of green space following restrictions on movement during the COVID-19 pandemic: a nationally representative cross-sectional study of UK adults. BMJ Open 11, e044067. https://doi.org/10.1136/bmjopen-2020-044067

Burns, F., McCulloch, N., Szekely, T., Bolton, M., 2013. No overall benefit of predator exclosure cages for the endangered St. Helena Plover Charadrius sanctaehelenae. Ibis 155, 397–401. https://doi.org/10.1111/ibi.12021

Cohen, J.B., Houghton, L.M., Fraser, J.D., 2009. Nesting Density and Reproductive Success of Piping Plovers in Response to Storm- and Human-Created Habitat Changes. Wildlife Monographs 173, 1–24. https://doi.org/10.2193/2007-553

Colwell, M., 2019. Predation and Predator Management, in: The Population Ecology and Conservation of Charadrius Plovers, Studies in Avian Biology. CRC Press, pp. 127–147.

Comber, C.A., Dayer, A.A., 2021. Understanding attitudes and norms of dog walkers to reduce disturbances to shorebirds. Human Dimensions of Wildlife 0, 1–15. https://doi.org/10.1080/10871209.2021.1915437

Conover, M.R., 1990. Reducing Mammalian Predation on Eggs by Using a Conditioned Taste Aversion to Deceive Predators. The Journal of Wildlife Management 54, 360–365. https://doi.org/10.2307/3809055

Conway, G.J., Austin, G.E., Handschuh, M., Drewitt, A.L., Burton, N.H.K., 2019. Breeding populations of Little Ringed Plover Charadrius dubius and Ringed Plover Charadrius hiaticula in the United Kingdom in 2007. Bird Study 66, 22–31. https://doi.org/10.1080/00063657.2018.1563045

Dinsmore, S.J., Lauten, D.J., Castelein, K.A., Gaines, E.P., Stern, M.A., 2014. Predator exclosures, predator removal, and habitat improvement increase nest success of Snowy Plovers in Oregon, USALa exclusión de depredadores, la remoción de depredadores y las mejoras del hábitat aumentan el éxito de anidación de Charadrius nivosus nivosusSnowy Plover nest survival in Oregon. Condor 116, 619–628. https://doi.org/10.1650/CONDOR-14-7.1

Eaton, M., Aebischer, N.J., Brown, A., Hearn, R., Lock, L., Musgrove, A., Noble, D., Stroud, D., Gregory, R., 2015. Birds of Conservation Concern 4: the population status of birds in the UK, Channel Islands and Isle of Man. British Birds 108, 708–746.

Edwards, V., Knight, S., 2006. Understanding the psychology of walkers with dogs: new approaches to better management. University of Portsmouth, Portsmouth.

Ehmke, G., Maguire, G.S., Bird, T., Ierodiaconou, D., Weston, M.A., 2016. An obligate beach bird selects sub-, inter- and supra-tidal habitat elements. Estuarine, Coastal and Shelf Science 181, 266–276. https://doi.org/10.1016/j.ecss.2016.08.050

Fraser, J.D., Caitlin, D.H., 2019. Habitat Ecology and Conservation of Charadrius Plovers, in: The Population Ecology and Conservation of Charadrius Plovers, Studies in Avian Biology. CRC Press, pp. 217–243.

Fraser, J.D., Catlin, D.H., 2019. Habitat Ecology and Conservation of Charadrius Plovers, in: The Population Ecology and Conservation of Charadrius Plovers, Studies in Avian Biology. CRC Press.

Gaines, E.P., Dinsmore, S.J., Murphy, M.T., 2020. Effects of management for productivity on adult survival of Snowy Plovers. Journal of Field Ornithology 91, 130–141. https://doi.org/10.1111/jofo.12330

Gómez-Serrano, M.Á., 2021. Four-legged foes: dogs disturb nesting plovers more than people do on tourist beaches. Ibis 163, 338–352. https://doi.org/10.1111/ibi.12879

Gómez-Serrano, M.Á., López-López, P., 2014. Nest Site Selection by Kentish Plover Suggests a Trade-Off between Nest-Crypsis and Predator Detection Strategies. PLOS ONE 9, e107121. https://doi.org/10.1371/journal.pone.0107121

Gratto-Trevor, C.L., Abbott, S., 2011. Conservation of Piping Plover (Charadrius melodus) in North America: science, successes, and challenges. Canadian Journal of Zoology. https://doi.org/10.1139/z11-024

Green, R.E., Hawell, J., Jounson, T.H., 1987. Identification of predators of wader eggs from egg remains. Bird Study 34, 87–91.

Gruas, L., Perrin-Malterre, C., Loison, A., 2020. Aware or not aware? A literature review reveals the dearth of evidence on recreationists awareness of wildlife disturbance. wbio 2020. https://doi.org/10.2981/wlb.00713

Ham, S.H., Brown, T.J., Curtis, J., Weiler, B., Hughes, M., Poll, M., 2009. Promoting persuasion in protected areas. A guide for managers who want to use strategic communication to influence visitor behaviour. Sustainable Tourism Pty Ltd.

Hardy, M.A., Colwell, M.A., 2012. Factors Influencing Snowy Plover Nest Survival on Ocean-Fronting Beaches in Coastal Northern California. cowa 35, 503–656. https://doi.org/10.1675/063.035.0401

ICF GHK, 2013. The economic impact of Natural England's National Nature Reserves (Natural England Commissioned Report No. NECR131).

ICRT, 2011. The Economic Potential of Nature Tourism in Eastern Yorkshire. Leeds.

Isaksson, D., Wallander, J., Larsson, M., 2007. Managing predation on ground-nesting birds: The effectiveness of nest exclosures. Biological Conservation, Special section: Coastal Sandplains 136, 136–142. https://doi.org/10.1016/j.biocon.2006.11.015

Jackson, D.B., Green, R.E., 2000. The importance of the introduced hedgehog (Erinaceus europaeus) as a predator of the eggs of waders (Charadrii) on machair in South Uist, Scotland. Biological Conservation 93, 333–348. https://doi.org/10.1016/S0006-3207(99)00135-4

Jenkinson, S., 2015. Managing walkers with dogs at Winterton and Great Yarmouth North Denes, Norfolk. Natural England.

Jenkinson, S., 2010. Understanding and influencing dog owner behaviour in parks and the countryside. Kennel Club.

Jorgensen, J.G., Brown, M.B., 2017. Evaluating Persuasive Messages to Influence Dog Leash Law Compliance at a Public Area in the Great Plains. Great Plains Research 27, 131–142.

Keniger, L.E., Gaston, K.J., Irvine, K.N., Fuller, R.A., 2013. What are the Benefits of Interacting with Nature? International Journal of Environmental Research and Public Health 10, 913–935. https://doi.org/10.3390/ijerph10030913

Koenen, M.T., Utych, R.B., Leslie, D.M., 1996. Methods Used to Improve Least Tern and Snowy Plover Nesting Success on Alkaline Flats (Métodos Usados para Mejorar el Éxito en Anidaje de Sterna antillarum y de Charadrius alexandrinus en Planicies Alcalinas). Journal of Field Ornithology 67, 281–291.

Kwon, E., Robinson, S., Weithman, C.E., Catlin, D.H., Karpanty, S.M., Altman, J., Simons, T.R., Fraser, J.D., 2021. Contrasting long-term population trends of beach-nesting shorebirds under shared environmental pressures. Biological Conservation 260, 109178. https://doi.org/10.1016/j.biocon.2021.109178

Lafferty, K.D., Goodman, D., Sandoval, C.P., 2006. Restoration of Breeding by Snowy Plovers Following Protection from Disturbance. Biodivers Conserv 15, 2217–2230. https://doi.org/10.1007/s10531-004-7180-5

Laidlaw, R.A., 2013. Managing wet grassland landscapes: impacts on predators and wader nest predation (doctoral). University of East Anglia.

Larivière, S., 1999. Reasons Why Predators Cannot Be Inferred from Nest Remains. The Condor 101, 718–721. https://doi.org/10.2307/1370209

Larson, M.A., Ryan, M.R., Murphy, R.K., 2002. Population Viability of Piping Plovers: Effects of Predator Exclusion. The Journal of Wildlife Management 66, 361–371. https://doi.org/10.2307/3803169

Lee, A.C.K., Maheswaran, R., 2011. The health benefits of urban green spaces: a review of the evidence. J Public Health 33, 212–222. https://doi.org/10.1093/pubmed/fdq068

Leung, Y.-F., Speceley, A., Hvenegaard, G., Buckley, R., 2018. Tourism and visitor management in protected areas: guidelines for sustainability (Best Practice Protected Area Guidelines Series). IUCN, Gland.

Liley, D., 1999. Predicting the consequences of human disturbance, predation and sea-level rise for Ringed Plover population size. University of East Anglia, School of Biological Sciences, Norwich.

Liley, D., Lock, L., Brown, A., Scott, J., Legg, W., 2021. Beach-nesting Ringed Plovers and their conservation in England. British Wildlife 33, 157–165.

Liley, D., Panter, C., 2017. First year results of monitoring bird disturbance in the presence/absence of rangers on the Solent. Unpublished report by Footprint Ecology for for Bird Aware Solent.

Lord, A., Waas, J., Innes, J., Whittingham, M., 2001. Effects of human approaches to nests of northern New Zealand dotterels. Biological Conservation 98, 233–240.

Macdonald, M.A., Bolton, M., 2008. Predation on wader nests in Europe. Ibis 150, 54–73. https://doi.org/10.1111/j.1474-919X.2008.00869.x

Maguire, G.S., Duivenvoorden, A.K., Weston, M.A., Adams, R., 2011. Provision of artificial shelter on beaches is associated with improved shorebird fledging success. Bird Conservation International 21, 172–185. https://doi.org/10.1017/S0959270910000420

Maguire, G.S., Stojanovic, D., Weston, M.A., 2009. Conditioned taste aversion reduces fox depredation on model eggs on beaches. Wildl. Res. 36, 702. https://doi.org/10.1071/WR09123

Mahon, H., 1994. A visitor management handbook. A directory for AONB site managers. Norfolk Coast Project.

Maslo, B., Lockwood, J.L., 2009. Evidence-based decisions on the use of predator exclosures in shorebird conservation. Biological Conservation 142, 3213–3218. https://doi.org/10.1016/j.biocon.2009.07.034

Mason, L.R., Smart, J., Drewitt, A.L., 2018. Tracking day and night provides insights into the relative importance of different wader chick predators. Ibis 160, 71–88. https://doi.org/10.1111/ibi.12523

Mayer, P.M., Ryan., M.R., 1991. Electric fences reduce mammalian predation on piping plover nests and chicks. Wildlife Society Bull. 19, 59–62.

Medeiros, R., Ramosa, J.A., Paivaa, V.H., Almeidac, A., Pedroa, P., Antunes, S., 2007. Signage reduces the impact of human disturbance on little tern nesting success in Portugal. Biological Conservation 135, 99–106.

Mengak, L., Dayer, A., Longenecker, B., Spiegel, C., 2019. Guidance and best practices for evaluating and managing human disturbances to migrating shorebirds on coastal lands in the Northeastern United States. Atlantic Flyway Shorebird Initiative.

Michel, N.L., Saunders, S.P., Meehan, T.D., Wilsey, C.B., 2021. Effects of stewardship on protected area effectiveness for coastal birds. Conservation Biology 35, 1484–1495. https://doi.org/10.1111/cobi.13698

Murphy, Robert K., Greenwood, R.J., Ivan, J.S., Smith, K.A., 2003. Predator Exclusion Methods for Managing Endangered Shorebirds: Are Two Barriers Better than One? Waterbirds: The International Journal of Waterbird Biology 26, 156–159.

Murphy, R. K., Michaud, I.M.D., Prescott, D.R.C., Ivan, J.S., Anderson, B.J., French-Pombier, M.L., 2003. Predation on adult piping plovers at predator exclosure cages. Waterbirds 26, 150–155.

Neuman, K.K., Page, G.W., Stenzel, L.E., Warriner, J.C., Warriner, J.S., 2004. Effect of mammalian predator management on snowy plover breeding success. Waterbirds 27, 257–263.
Norbury, G.L., Price, C.J., Latham, M.C., Brown, S.J., Latham, A.D.M., Brownstein, G.E., Ricardo, H.C., McArthur, N.J., Banks, P.B., 2021. Misinformation tactics protect rare birds from problem predators. Science Advances 7, eabe4164. https://doi.org/10.1126/sciadv.abe4164
O'Connell, D., Power, A., Doyle, S., Newton, S., 2014. Nest movement by Little Terns Sternula albifrons and Ringed Plovers Charadrius hiaticula in response to inundation by high tides. Irish Birds 10, 19–22.
Ogden, J., Dowding, J.E., 2013. Population estimates and conservation of the New Zealand Dotterel Charadrius obscurus on Great Barrier Island, New Zealand. Notornis 60, 210–223.
O'Neill, R., 2019. Monitor of Engagement with the Natural Environment – The national survey on people and the natural environment. Headline report 2019 (NECR No. 275). Natural England and the Office for National Statistics.
Panter, C., Liley, D., 2016. Visitor observation surveys at Winterton Dunes NNR, Norfolk. Unpublished report by Footprint Ecology for Natural England.
Panter, C., Liley, D., Lowen, S., 2017. Visitor surveys at European Protected Sites across Norfolk in 2015 and 2016. Unpublished report by Footprint Ecology for Norfolk County Council.
Patrick, A.M., Colwell, M.A., 2014. Snowy Plovers select wide beaches for nesting. Wader Study Group Bulletin 121, 17–20.
Peterson, S.A., Colwell, M.A., 2014. Experimental Evidence That Scare Tactics and Effigies Reduce Corvid Occurrence. nwnt 95, 103–112. https://doi.org/10.1898/NWN13-18.1
Pienkowski, M.J., 1984. Breeding biology and population dynamics of Ringed Plovers Charadrius hiaticula in Britain and Greenland: nest predation as a possible factor limiting distribution and time of breeding. Journal of the Zoological society of London 202, 83–114.
Pienkowski, M.W., Pienkowski, A.E., 1989. Limitation by nesting habitat of the density of breeding Ringed Plovers Charadrius hiaticula: a natual experiment. Wildfowl 40, 115–126.
Powell, A.N., Collier, C.L., 2000. Habitat Use and Reproductive Success of Western Snowy Plovers at New Nesting Areas Created for California Least Terns. The Journal of Wildlife Management 64, 24–33. https://doi.org/10.2307/3802971
Prellwitz, D.M., Erickson, K.M., Osborne, L.M., 1995. Translocation of Piping Plover nests to prevent nest flooding. Wildlife Society Bulletin 103–106.
Pretty, J., Griffin, M., Peacock, J., Hine, R., Selens, M., South, N., 2005. A countryside for health and well-being: the physical and mental health benefits of green exercise. Countryside Recreation 13, 2–7.
Rare and the Behavioural Insights Team, 2019. Behaviour change for nature: A behavioural science toolkit for practioners. Arlington.
Rees, J.D., Webb, J.K., Crowther, M.S., Letnic, M., 2015. Carrion subsidies provided by fishermen increase predation of beach-nesting bird nests by facultative scavengers. Animal Conservation 18, 44–49. https://doi.org/10.1111/acv.12133
Richardson, M., Cormack, A., McRobert, L., Underhill, R., 2016. 30 Days Wild: Development and Evaluation of a Large-Scale Nature Engagement Campaign to Improve Well-Being. PLOS ONE 11, e0149777. https://doi.org/10.1371/journal.pone.0149777

Rimmer, J.M., Maguire, G.S., Weston, M.A., 2013. Perceptions of effectiveness and preferences for design and position of signage on Victorian beaches for the management of hooded plovers “thinornis rubricollis.” Victorian Naturalist, The 130, 75.
Robinson, S.G., 2020. Piping plover habitat and demography following storm-induced and engineered landscape change.
Saunders, P., Liley, D., 2021. Exe Estuary Wildlife Refuge Monitoring Programme - Final Report (Unpub. Report No. 459). Footprint Ecology / East Devon DC.
Schneider, T.J., Maguire, G.S., Whisson, D.A., Weston, M.A., 2020. Regulations fail to constrain dog space use in threatened species beach habitats. Journal of Environmental Planning and Management 63, 1022–1036. https://doi.org/10.1080/09640568.2019.1628012
Smart, J., Amar, A., 2018. Diversionary feeding as a means of reducing raptor predation at seabird breeding colonies. Journal for Nature Conservation 46, 48–55. https://doi.org/10.1016/j.jnc.2018.09.003
Smith, R.K., Pullin, A.S., Stewart, G.B., Sutherland, W.J., 2011. Is nest predator exclusion an effective strategy for enhancing bird populations? Biological Conservation 144, 1–10. https://doi.org/10.1016/j.biocon.2010.05.008
Stantial, M., Cohen, J., Darrah, A., Farrell, S., Maslo, B., 2021. The effect of top predator removal on the distribution of a mesocarnivore and nest survival of an endangered shorebird. Avian Conservation and Ecology 16. https://doi.org/10.5751/ACE-01806-160108
Stantial, M.L., Avery, M.L., Cohen, J.B., Darrah, A.J., Farrell, S., Maslo, B., 2021. Habitat-specific behavior, growth rate, and survival of piping plover chicks in New Jersey, USA. Ecosphere 12, e03782. https://doi.org/10.1002/ecs2.3782
Teunissen, W., Schekkerman, H., Willems, F., Majoor, F., 2008. Identifying predators of eggs and chicks of Lapwing Vanellus vanellus and Black-tailed Godwit Limosa limosa in the Netherlands and the importance of predation on wader reproductive output. Ibis 150, 74–85. https://doi.org/10.1111/j.1474-919X.2008.00861.x
The Land Trust, 2018. The Economic Value of Greenspaces. The Land Trust.
Vaske, J.J., Rimmer, D.W., Deblinger, R.D., 1994. The impact of different predator exclosures on piping plover nest abandonment. Journal of Field Ornithology 65, 201–209.
Wallander, J., Andersson, M., 2003. Reproductive tactics of the ringed plover Charadrius hiaticula. Journal of Avian Biology 34, 259–266.
Webber, A.F., Heath, J.A., Fischer, R.A., 2013. Human disturbance and stage-specific habitat requirements influence snowy plover site occupancy during the breeding season. Ecology and Evolution 3, 853–863. https://doi.org/10.1002/ece3.511
Weitowitz, D.C., Panter, C., Hoskin, R., Liley, D., 2019. Parking provision at nature conservation sites and its implications for visitor use. Landscape and Urban Planning 190, 103597. https://doi.org/10.1016/j.landurbplan.2019.103597
Weston, M.A., Dodge, F., Bunce, A., Nimmo, D.G., Miller, K.K., 2012. Do temporary beach closures assist in the conservation of breeding shorebirds on recreational beaches? Pac. Conserv. Biol. 18, 47–55. https://doi.org/10.1071/pc120047
White, G., Hirons, G., 2019. The predator exclusion fence manual. Guidance on the use of predator exclusion fences to reduce mammalian predation on grouind-nesting birds on RSPB reserves. RSPB.
Williams, K.J.H., Weston, M.A., Henry, S., Maguire, G.S., 2009. Birds and Beaches, Dogs and Leashes: Dog Owners’ Sense of Obligation to Leash Dogs on Beaches in Victoria,

Australia. Human Dimensions of Wildlife 14, 89–101. https://doi.org/10.1080/10871200802649799
Wiltermuth, M.T., Anteau, M.J., Sherfy, M.H., Shaffer, T.L., 2009. Nest Movement by Piping Plovers in Response to Changing Habitat Conditions. The Condor 111, 550–555. https://doi.org/10.1525/cond.2009.080106
Witton, K., 2018. Are bird exclusion areas effective as part of visitor management strateies in reducing human disturbance on ground nesting beach birds? A case study on the North Norfolk Coast (MSc). Birkbeck College, University of London.
Wu, Y., Xie, L., Huang, S.-L., Li, P., Yuan, Z., Liu, W., 2018. Using social media to strengthen public awareness of wildlife conservation. Ocean & Coastal Management 153, 76–83. https://doi.org/10.1016/j.ocecoaman.2017.12.010
Zeigler, S.L., Gutierrez, B.T., Hecht, A., Plant, N.G., Sturdivant, E.J., 2021. Piping plovers demonstrate regional differences in nesting habitat selection patterns along the U.S. Atlantic coast. Ecosphere 12, e03418. https://doi.org/10.1002/ecs2.3418

Appendix 1: Sample forms for nest recording and checking

NEST RECORDING FORM FOR FIELD USE: DETAILS OF NESTS WHEN FIRST FOUND

Nest ID	Date found	Grid ref	No. eggs when found	Finder initial	Distance (m) from MHWM	Distance (m) to path edge or top of seawall	Substrate (Sand, shingle or mix)	NOTES (inc notes as to how to re-find)

Nest ID = unique identifier, distances from MHWM and path/top of seawall are approximate and intended to help with relocation and on a linear section of beach would be estimated at 90 degrees to water's edge. Substrate relates to the actual nest cup and the material under the cup. It may be useful in the notes to record distinctive features on the beach which will help with relocating the nest

NEST RECORDING FORM FOR FIELD USE: LOG OF NEST CHECKS

Nest ID	Date checked	Time checked	No. eggs present	No. chicks present	Cause of any failure	NOTES (behaviour of adults if nest not approached, further details of any causes of failure)

This form supplements the nest recording form and provides a means to record outcomes for each nest. Nest ID = unique identifier, cross-references to the nest recording sheet. For failure, record details using following categories: PREDATED (1 or more eggs predated (shell fragments present)); MISSING (1 or more eggs missing); TRAMPLED (nest trampled/eggs crushed); FLOOD (nest flooded); ADDLED (1 or more eggs addled or failed to hatch); OTHER.