References
to
Deadline 3 Submissions

for the
Royal Society for the Protection of Birds
and Suffolk Wildlife Trust

Submitted for Deadline 3
24 June 2021

Planning Act 2008 (as amended)

In the matter of:

Application by NNB Generation Company (SZC) Limited for an Order Granting Development Consent for

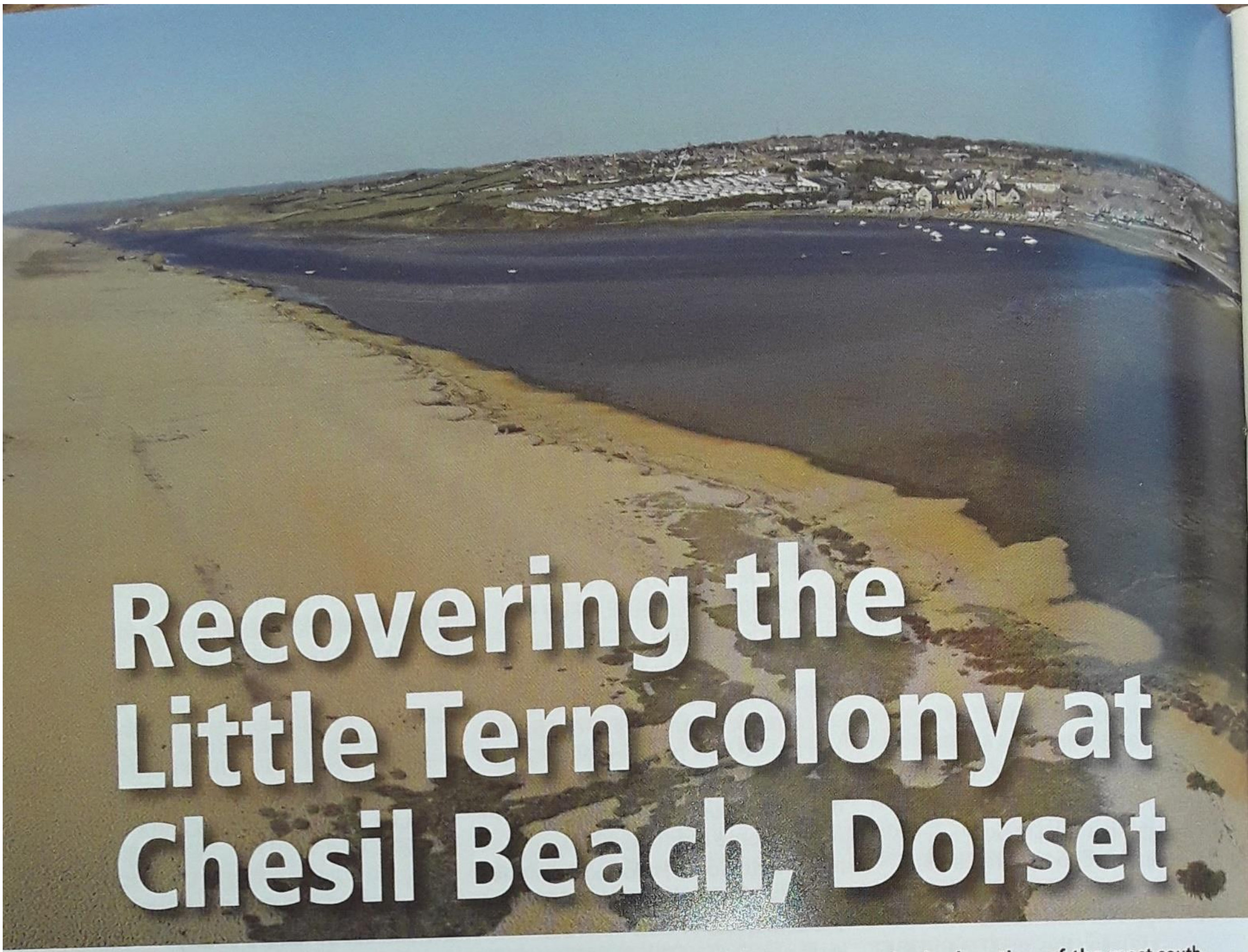
The Sizewell C Project

Planning Inspectorate Ref: EN010012
RSPB Registration Identification Ref: 20026628
Suffolk Wildlife Trust Registration Identification Ref: 20026359

References

Booker, H., & Moxom, D. (2019) Recovering the Little Tern colony at Chesil Beach, Dorset. *British Wildlife* 31: 96–103

Burt, L., Eastick, C. & Ferguson, P. (2018) Assessing the dynamics of vegetated shingle – Hurst Spit case study 2013 – 2017. New Forest District Council



Recovering the Little Tern colony at Chesil Beach, Dorset

Helen Booker and Don Moxom

Chesil Beach, Dorset is the location of the most south-westerly Little Tern colony in the UK. Matt Doggett

Little Terns *Sternula albifrons*, one of the UK's most threatened seabirds, arrive on our shores each spring to breed in colonies on low-lying sand or shingle at scattered sites around the coast. At the time of the last national seabird census numbers were in decline, with an estimated 1,900 breeding pairs in the UK (Mitchell *et al*. 2004); this decline has continued as a result of predation, especially by Foxes *Vulpes vulpes* and Kestrels *Falco tinnunculus*, summer storms, food shortages and human disturbance (Hayhow *et al*. 2017). The UK population is now estimated, from annual reporting and trends, at fewer than 1,600 breeding pairs, following a reduction in both the number of colonies and their size (Rendell-Read 2013–2018). In Essex, for example, Little Tern numbers have declined from 370 pairs at their peak in 1985–88 (Mitchell *et al*. 2004) to fewer than 50 pairs in recent years. Suffolk, too, has seen a substantial decline, although there is some possible interchange with Norfolk sites, while in Lincolnshire numbers have dropped from over 150 pairs to around 30. In Wales, the number of colonies has dwindled from eight to just one, at Gronant, in Denbighshire (Cook *et al*. 2017).

The Little Terns of Chesil Beach

The Little Tern colony at Chesil Beach, in Dorset, is the most south-westerly in the UK, being situated at the eastern end of the 28km bank of pebbles that stretches from West Bay, near Bridport, to the Isle of Portland. On the landward side from the village of Abbotsbury, the beach encloses the Fleet Lagoon, which flows into Portland Harbour. On the seaward side of Chesil Beach is Lyme Bay. The beach and lagoon are of international importance for nature, designated as a Special Area of Conservation (SAC) for the coastal lagoon, saltmarsh, driftline and stony bank vegetation, as a Special Protection Area (SPA) for wintering Wigeon *Mareca penelope* and breeding Little Terns, and as a Site of Special Scientific Interest (SSSI) for coastal geomorphology and its associated habitats and species.

The Fleet Lagoon and part of the beach are owned by the Ilchester Estate, which operates the Chesil Bank and the Fleet Nature Reserve

(CB&FNR). The remainder of the beach, including the location of the Little Tern colony, is owned by the Crown Estate and is designated common land.

Little Terns and over 1,000 pairs of Common Terns *Sterna hirundo* shared Chesil Beach in the early 1900s to 1950s, being spread out along its length. By the 1980s, the Common Terns had declined and abandoned the beach. This was thought to be a consequence of the rapid spread of myxomatosis in 1953, which wiped out Rabbits *Oryctolagus cuniculus* and therefore halted the control of Foxes *Vulpes vulpes* by Rabbit-hunters. This led to Foxes roaming the beach, and these predators began to breed in earths under the numerous derelict wartime concrete structures within easy access of nesting terns (Moxom & Burden 2004).

Around this time the Little Terns settled in their current location, a nesting area occupying 7ha of the lagoon-facing slope as it gently rises towards its steeper crest before dipping sharply down into Lyme Bay. The nesting substrate is pebbles, which are coarse in this part of the beach (approx. 15 × 25 × 35mm). In exceptional storms, waves over-wash the ridge of the beach and drain out of the lower part into the Fleet, which can also be flooded by exceptionally high tides entering from Portland Harbour; so far, flooding has never occurred during the terns' breeding season.

The colony is close to the coastal settlements of Weymouth and Portland, which have human populations of 52,000 and 12,400 respectively (2011 UK Census) and is within 400m of the large Chesil Beach Car Park, which receives some 200,000 visitors per year. Within the car park is a major visitor centre, the Chesil Beach Centre, which attracted 75,000 people in 2016 (Dorset Wildlife Trust staff pers. comm.).

Poor breeding success

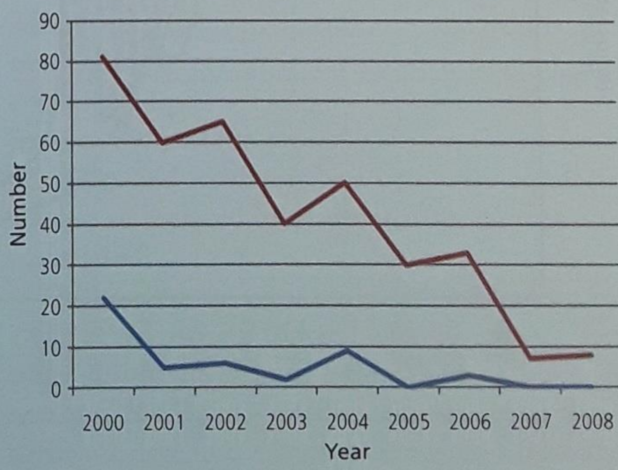
Chesil's Little Tern colony has been at its current location since 1985, when monitoring and protection by the CB&FNR warden began. Temporary hides situated just below the crest of the beach provided a disturbance-free vantage point from which to monitor incubating birds and enabled wardens to see approaching beach-users and potential predators. Daily checks confirmed the presence of known terns, the establishment of new incubations and the progress of chicks and fledglings. Visits to the colony were minimised, conducted only in order to place nest-markers (a few metres from each scrape) and to assess clutch size. Listed on Schedule 1 of the Wildlife and Countryside Act 1981 (as amended), Little Terns are afforded protection from disturbance while breeding, and consequently all visits to the colony for monitoring and other conservation purposes were undertaken under licence from English Nature (and its predecessor).

The fortunes of the colony up to 1999 are documented by Moxom & Burden (2004), who reported its size as growing from 40 pairs in 1985 to a peak of 100 pairs in 1997. Productivity over this period fluctuated but was often very low as a result of predation (Foxes, raptors and corvids, in order of concern), disturbance and low hatching rates.

Between 2000 and 2008, with support from English Nature (which became Natural England in 2006) and RSPB, the CB&FNR wardens made every effort to protect the colony with their limited resources, using seasonal fencing and working with beach-users to minimise disturbance. Despite these efforts, numbers of breeding pairs of Little Terns continued to decline (Figure 1). Of 502 clutches monitored in this period, 201 (40%) were preyed on. The vast majority of breeding attempts ended during incubation rather than during chick development; this was due largely to Fox predation, which over this period accounted for 173 lost clutches, with the remaining 28 lost to Carrion Crows *Corvus corone*.

Wardens trialled different fencing methods to keep Foxes at bay. In the early years, more than

Figure 1. **Numbers of Little Tern pairs (red) and fledged chicks (blue) between 2000 and 2008.**



half of the nesting pairs settled in stout, chicken-wire compounds constructed pre-season around known, favoured nesting areas. Although these proved Fox-proof, fledglings were nevertheless few in number and after two years the birds abandoned the enclosures. The second trial used 50m lengths of electrified flexi-netting, which could be shaped in relation to the natural undulations of the beach and quickly erected around groups of nests. Two or three of these compounds were installed annually from 2003 to 2008. Success was variable, excluding Foxes in some years but not in others. It proved difficult for the wardens to keep the netting stable in high winds and to prevent the electric current from 'shorting out', particularly where wet, wind-blown plastics lay across live and earth wires. In these conditions, Foxes found their way into the compounds. In total, just 40–45 chicks fledged over this eight-year period, Kestrels having preyed on six chicks before they were able to fly.

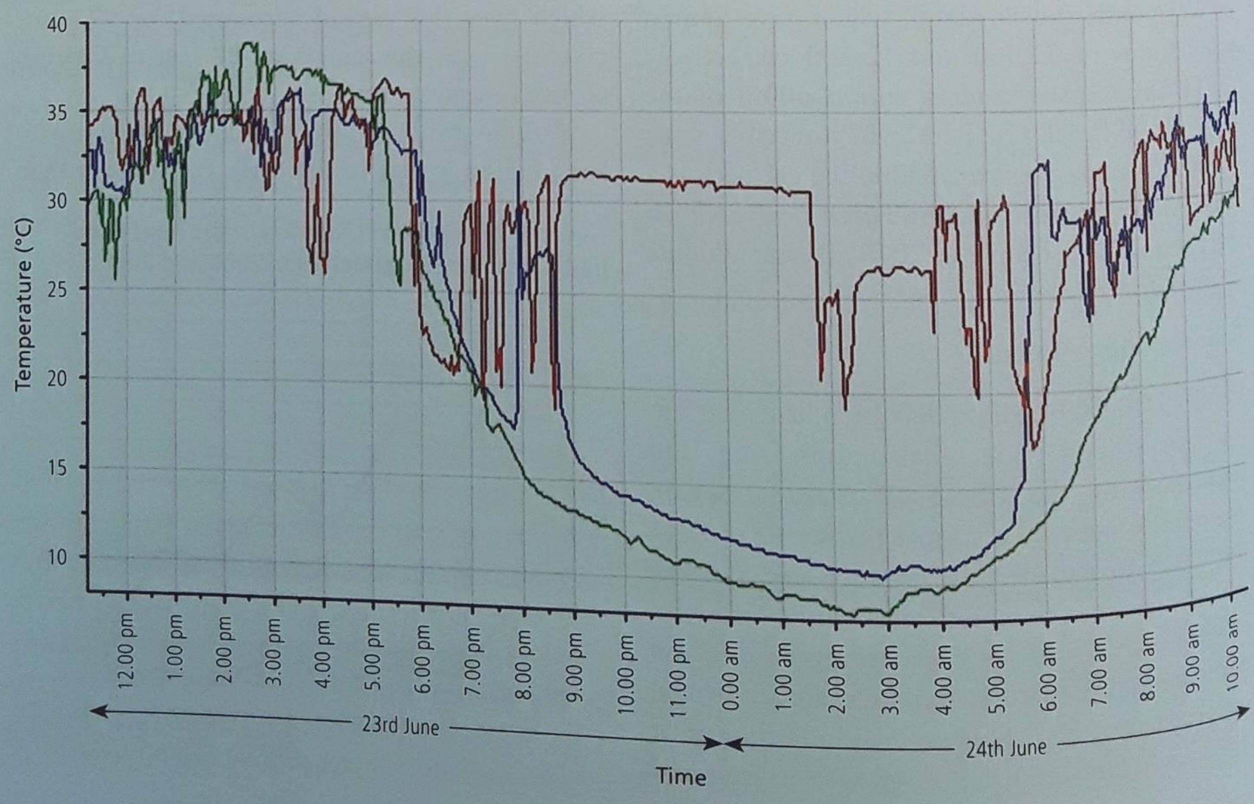
It became clear that, in order successfully to protect the colony, a more robust fence design, ideally coupled with 24-hour wardening, was required to keep nocturnal ground predators away and that, to achieve this, significantly greater resources would be required. Predators, however, were not the only problem.

Eggs fail to hatch

Earlier studies (1984–99) recorded that, of 1,061 monitored incubation attempts, 156 (14.7%) failed to produce hatchlings (Moxom & Burden 2004). It was thought that eggs might have been lethally chilled following absences of incubating adults at night. It also seemed possible that draughts flowing through the coarse pebbles were exacerbating thermal stress. To investigate these concerns, a licence was obtained in 2000 from English Nature permitting the introduction of data-loggers into a limited number of nests in order to record temperature levels and fluctuations.

Of all monitored incubation attempts by the Little Terns in nine seasons during 2000–2008, 149 (33% of the total) failed to hatch. Nearly 6,000 hours of temperature data-logging carried out on 26 incubation attempts from 2000 to 2004 showed that some terns were leaving their eggs at night, its being assumed that they were being disturbed by Foxes. On 71 occasions terns returned to their nests within the hour, but in 60 instances an incubating bird left at dusk and did not return until first light. With early-morning ambient temperatures (usually the coldest time) dipping to as low as 6°C, these absences were exposing the

Figure 2. Data-logger graph showing temperature traces of two nests (blue and red) against the ambient temperature (green) on the night of 23rd June and the morning of 24th June 2001.



Little Tern feeding its young in the Fleet Lagoon in 2017. Angela Thomas

eggs to hypothermic stress. During the same period (2000–2004), 80 eggs, abandoned after prolonged incubation, were retrieved and examined. Many had cracked shells and were dried out, but it was possible to see that various stages of embryonic development had occurred in most. Figure 2 shows how the temperature of two different nests fluctuated over approximately 23 hours between 23rd June and 24th June. Between 9.48pm and 2.37am, the red trace may be interpreted as an undisturbed incubation session and shows how incubating birds sit tight at night, maintaining a fairly constant temperature – in this instance of 31°C. During the day, the trace moves up and down erratically, reflecting a less settled incubation. This is typical daylight behaviour, with movement of the incubating tern on the nest or just off to feed or be relieved by its partner, and periodic long and short absences due to real or potential disturbances. The blue trace reflects an all-night and early-morning absence lasting 8 hours and 47 minutes.

With this evidence and the data recorded by the temperature-loggers, the wardens considered that the embryos either had perished on a specific occasion from prolonged exposure to too low a temperature or had succumbed after a series of sublethal exposures. Nonetheless, with ambient temperatures in the upper 30s and even 40°C occasionally being reached, and data showing that on hot days the terns were shading their nests, the possibility of eggs being subjected to hyperthermic stress should not be ruled out either.

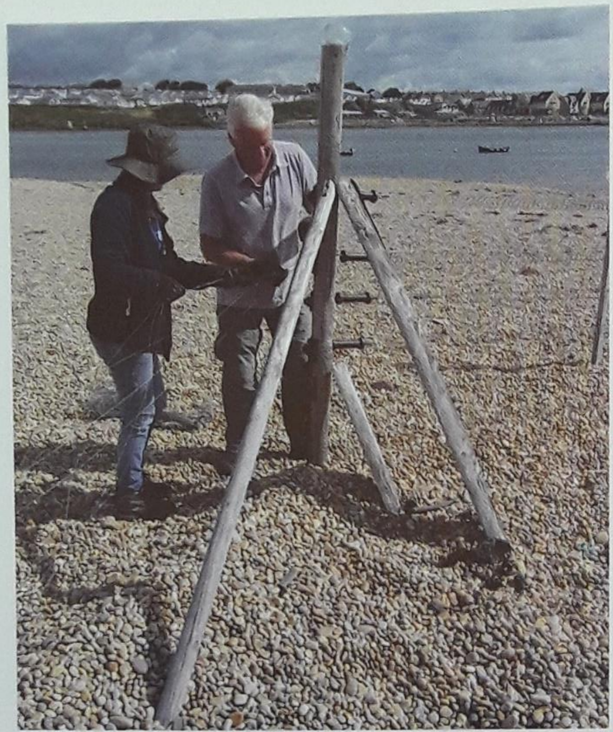
The Chesil Beach Little Tern recovery project: 2009 to date

By 2008, the combination of predation and poor hatching rates had reduced the colony to just eight pairs. In 2009, at least 37 Little Terns arrived but none attempted to breed. The threats were well known, but a major injection of resources was needed to give any chance of tackling them. In that year, a group of organisations joined forces in developing a fully resourced recovery plan to try to save the colony. The emerging partnership was led by RSPB, with the CB&FNR, Natural England, Portland Court Leet and the Crown Estate. The Dorset Wildlife Trust, managers of the newly opened, enlarged Chesil Beach Centre, joined the partnership in 2012. The plan involved a revamped fencing and wardening regime, with advice from overseers of the successful colony at North Denes, in Norfolk.

Keeping out the Foxes

Secretary of State permission was acquired under the Commons Act 2006 for new seasonal infrastructure and access restrictions. An outer single strand of rope was installed, with small interpretation signs, in order to reduce human disturbance around the colony. Within this, an electric-fence compound comprising nine strands of alternating live and earth wires was installed (prior to the birds' arrival) to prevent Fox incursion. Importantly, the wires could be adjusted in height to match the contours of the beach and form a much better 'seal' than flexi-netting, particularly at ground level where intrusions usually occurred. Permanent corner posts added vital stability to the enclosure and reduced the time taken every year on construction of the compound. Upturned sections of plastic bottles were fixed to the posts to prevent Carrion Crows from perching, and insulators and wire were regularly washed or replaced to ensure that the current was maintained.

This fencing set-up is still used, backed up by 24-hour wardening to keep away predators and other disturbances both by day and by night. A seasonal RSPB lead warden, supported by three night wardens and a team of volunteers from the



Volunteers putting up the fence in 2015. Corner posts are stoutly supported to enable them to bear the considerable strain of the wiring and to stay firm in the loose shingle. Thalassa McMurdo Hamilton

local community, provides around-the-clock cover, working to a carefully assessed protocol to ensure that avian predators, especially Carrion Crows, Kestrels and Herring Gulls *Larus argentatus*, are kept away from the colony throughout the season and to minimise human disturbance. Improvements to the hides and marking of nests have ensured that breeding progress can be accurately monitored and recorded. Guided walks and talks have raised awareness of and support for the Little Terns among beach-users.

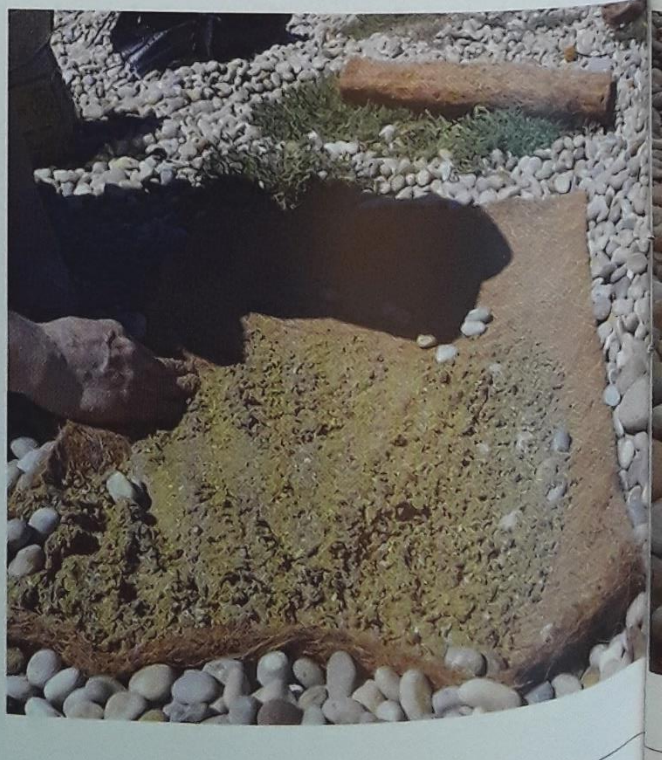
After the barren year in 2009, 12 pairs of terns returned to breed in 2010. The fencing and wardening successfully excluded Foxes, but over 30% of eggs failed to hatch (Dadds 2010). In 2011, this figure rose to nearly 50% (Dadds 2011), and in 2012, a particularly cool, wet summer, 60% of eggs failed to hatch (Dadds 2012). In the absence of predation, the full extent of clutch failures became apparent, adding weight to the argument that the physical nature of the beach, rather than simply the presence of Foxes keeping adults away, was causing the hatching failures, especially in cooler years.

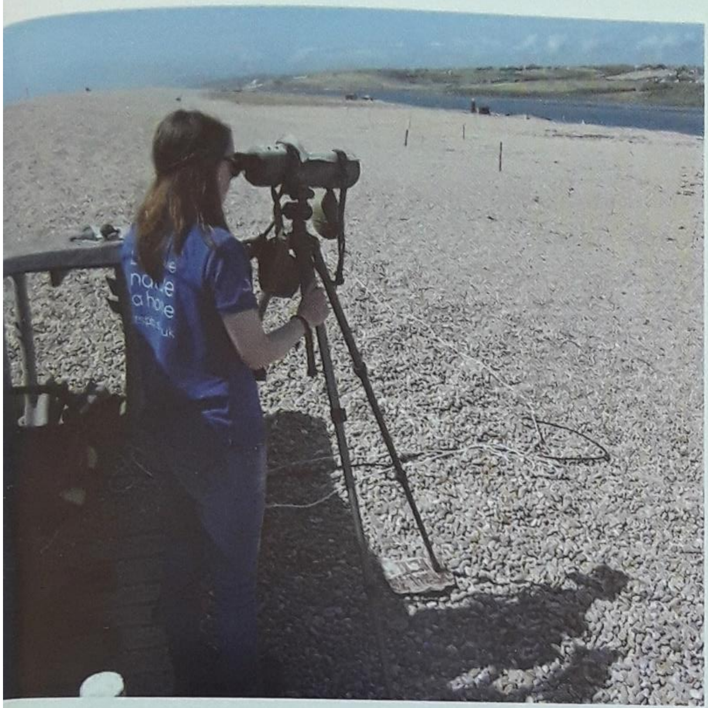
Insulating the nest scrapes

A 2009 audit of colonies on RSPB nature reserves across the UK found that Little Terns were selecting areas of mixed substrates, often preferring finer, sandy areas among the shingle for nest location (Graham White pers. comm.). Such a choice is not available at Chesil, where it was therefore considered whether the provision of patches of finer substrate would benefit the nesting terns. To test this, in 2013 the project trialled a reducing of the amount of cool air circulating around the eggs by introducing nest linings. These linings were made of a porous membrane (coconut matting, as used in hanging baskets) topped with fine sand. Patches of this lining (approximately 50 × 70cm) were placed across the colony site before nesting commenced, in the hope that the terns would select them for nesting. The results were quite spectacular. Twelve pairs chose to nest on the preplaced patches. In addition, under licence, linings were put under the clutches of a further eight pairs that nested on pebbles and these pairs had no problems in accepting their new homes. Nine pairs remained on pebbles. In that year, 90% of eggs on sand hatched, compared with 23% of those on pebbles, and there was evidence to show that the lining had enabled the night-time temperature of an incubated clutch to be maintained at a level approximately 3°C higher than at nests without a lining (Dadds 2013).

In 2014, the lining was modified with the use of plastic plant pots, 20–25cm in diameter, in which the sand and porous membrane rested on a pebble

Initial sand-patch design in 2013.
John Dadds





Monitoring the Little Tern colony.
Thalassa McMurdo Hamilton

base. In each year subsequently, more than 70 artificial scrapes have been positioned according to previously used nest sites before the terns' arrival, and new ones inserted under pebble nests as required during the season. All are then covered at the end of the season, ready for the following year (Vaughan 2014).

An additional advantage of the sand is that it enables the scrape to assume a cup shape, allowing eggs and incubating birds to remain in close contact, thereby giving a greater chance for the clutch to reach and maintain the required temperature. In 2017, a nest on pebbles outside the fence was successfully moved a total of 9m, on to sand within the fence, by six incremental moves over eight days (Hutchin 2017).

Since their trial at Chesil, sand patches have been used at Langstone Harbour, in Hampshire (Smith 2017), and tested at other sites, especially as a method to encourage nesting in newly restored areas.

An abundance of chicks!

The fencing and wardening at CB&FNR successfully prevented predation by Foxes, and the use of sand patches solved the problem of eggs failing to hatch. Between 2000 and 2008, of the 502 monitored nests, just 53 clutches hatched (11%). Since 2013, however, most clutches have hatched, equating to 351 eggs hatching from the 449 laid (78%).

This abundance of chicks attracted the attention of local breeding Kestrels, and Little Tern fledging rates have since been influenced primarily by the level of Kestrel activity, by the success of diversionary feeding (a conservation tool tested by Smart & Amar [2018] which involves providing predators with food in order to reduce their motivation to

Modified sand patch in 2016 with newly hatched chicks and showing nest scrapes. Ali Quinney

Sand patch with chicks and egg in 2016.
Ali Quinney

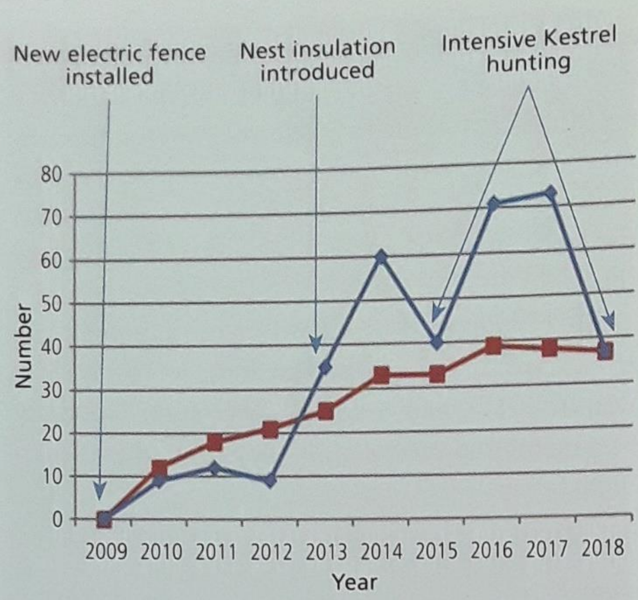


Figure 3. **The Chesil Beach Little Tern population 2009–2018, showing the increase in breeding pairs (red) and fledged chicks (blue) following interventions from 2009. The impact of intensive hunting by Kestrels is clear in 2015 and 2018.**

hunt), and by the ability of the wardens to deter these raptors as they approach the colony.

Two pairs of Kestrels are known to hunt to varying degrees over the colony. One pair nests on an MoD site in Wyke Regis, 1.8km away, and the other on cliffs at Portland, at a distance of approximately 4km. With kind support from the MoD, diversionary feeding of the Wyke Regis pair began in 2010 when the Kestrel chicks hatched. In that year just a single Little Tern chick and an adult were lost to Kestrel predation (Dadds 2010). Since then, diversionary feeding has continued during years in which Kestrels bred (they did not breed at this site in 2014) and, in general, this has successfully reduced the falcons' hunting effort at the tern colony.

Diversionary feeding of the Portland cliffs pair is more difficult, but a successful trial was conducted in 2018. This pair actively hunted at the colony in 2014, 2015 and 2018 (Vaughan 2014; McMurdo Hamilton 2015; Hutchin 2018). In 2014, diversionary feeding at the beach close to the colony proved effective, while in 2015 hunting was particularly intensive, with 468 visits by Kestrels between 3rd June and 23rd July. During this latter period, at least 21 (and possibly as many as 29) unfledged Little Tern chicks and one fledgling were lost to Kestrel predation. The persistence of the wardens in trying to deter the Kestrels, along with diversionary feeding near the colony, enabled an estimated 34 chicks to fledge from 35 pairs.

The situation was similar in 2018, with at least 27 (and up to 33) chicks preyed on by a persistent Kestrel over just six days. In contrast, 2016 and 2017 were quiet years in terms of Kestrel activity and this allowed tern productivity to peak in 2017, with up to 71 chicks fledged from 38 pairs (Figure 3) (Hutchin 2017).

Similarly, the sole surviving Welsh Little Tern colony, at Gronant, has experienced intensive Kestrel predation in 2012, 2015 and 2018, indicating a three-year cycle (Cook *et al.* 2017; Rendell-Read pers. comm.). At Chesil, in 2012, the hatching rate was very low and Kestrel hunting activity was also low (Dadds 2012). Further monitoring will determine if there is any pattern to the Kestrel hunting pressure at this colony.

Food availability

We have discussed the main factors that have limited breeding success at Chesil Beach, but we have not yet commented on why the terns failed to attempt to breed in 2009, despite the arrival of at least 37 adults (Dadds 2009). In that year, anecdotal evidence from local fishermen of a lack of small fish, coupled with the abandonment of the nearby Common Tern colony (Steve Groves, Abbotsbury Swannery, pers. comm.), suggested that food supply was the most probable explanation.

Little Terns have a small foraging range, with a mean maximum distance from the colony of 6.3km (Thaxter *et al.* 2012). Sufficient food has to be available within this area throughout the season. A year later, in 2010, all indications were that food was abundant, colony observations recording whitebait as being taken from Lyme Bay and an apparently plentiful supply of nourishment for tern chicks, which were often seen to refuse food. Towards the end of the 2010 season when the chicks began to fledge, most feeding took place in the Fleet and large numbers of small fish were observed. Food availability has remained good in subsequent years, with clupeids, sand eels *Ammodytes*, gobies and small crustaceans seen being fed to chicks (Dadds 2010). Timed watches during 2015, 2016 and 2017 revealed chicks being provisioned four to six times per hour (McMurdo Hamilton 2015; Quinney 2016; Hutchin 2018). On this basis, the conditions in 2009 were considered exceptional. The terns have Lyme Bay, the Fleet and Portland Harbour within their foraging range, providing them with alternative options should conditions in one of these areas be unfavourable. This is perhaps one reason why the birds have remained faithful to their breeding site through the years of repeated poor productivity.

The future

Chesil's Little Tern colony is now one of the most productive in the UK, as evidenced in the UK Little Tern annual newsletters (Rendell-Read 2013–2018). The Little Tern is, however, a conservation-dependent species; it remains vulnerable to predators, and our beaches are becoming increasingly crowded with human and dog visitors, in addition to the growing threats of sea-level rise and storms. We have learnt that without adequate resources to counter the range of pressures this colony cannot be productive. As a result of a strong partnership project and support from the local community, these threats can be brought under control, only the annual variation in Kestrel hunting activity now seeming to impact significantly on breeding outcomes.

Resourcing the project is an ongoing challenge and we strive to make it as sustainable as possible. We have reduced the annual costs by increasing the role of volunteers, most of whom are from the local community. We have also replaced paid night wardens with residential volunteers, and the whole team is led by an RSPB seasonal lead warden. The coming years will reveal if the high levels of productivity eventually result in an increase in colony size towards its former peak of 100 pairs.

Acknowledgements

Many people have contributed to the protection of Chesil's Little Terns over the years. We should like to thank the RSPB lead wardens John Dadds (2009–2013), Morgan Vaughan (2014), Thalassa McMurdo Hamilton (2015), Alice Quinney (2016) and Scarlett Hutchin (2017–2018), and also Angela Thomas, Simon Pinder, Simon Travis and Dan Bartlett, all of whom have been responsible for wardening at various points over the past two decades. Other RSPB staff who have contributed greatly to the project include Mark Smart, Jen Smart, Graham White, Damon Bridge, Claire Young, Sarah Alsbury, Nick Tomlinson and Kevin Rylands. We also thank the numerous volunteer day wardens, the RSPB night-shift staff and volunteers, the Dorset RSPB staff and local volunteers, MoD staff, and Ed Harland. We are grateful for the support of our project partners, including Angela Thomas (CB&FNR), Ruth Carpenter and Maxine Chavner (Natural England), Fiona Wynne and Gary Thompson (Crown Estate), Philip George and Jane White (Portland Court Leet), Emily Brown and Marc Kativu-Smith (Dorset Wildlife Trust), and also thank others who have provided funding, including Dorset Biodiversity Fund, Dorset AONB, PANACHE Interreg Project, Weymouth Sealife, ESG Robinson Charitable Trust and Sea Rangers Charitable Trust. Finally, we thank Paul Buckley, Susan Rendell-Read, Kevin Rylands, Graham White and Leigh Lock for comments on the draft.

References

Cook, H., Harrington, B., Taylor, R., & Slattery, J. 2017. Gronant Little Tern Report (*Sterna albifrons*) 2017. Denbighshire County Council (unpublished).

Dadds, J. 2009, 2010, 2011, 2012 & 2013. Chesil Bank Little Tern reports. RSPB report (unpublished).

Hayhow, D. B., *et al*. 2017. *The State of the UK's birds 2017*. RSPB, BTO, WWT, DAERA, JNCC, NE and NRW, Sandy, Bedfordshire.

Hutchin, S. 2017. Chesil Beach Little Tern recovery project report. RSPB report (unpublished).

Hutchin, S. 2018. Chesil Beach Little Tern recovery project report. RSPB report (unpublished).

McMurdo Hamilton, T. 2015. Chesil Beach Little Tern recovery project. RSPB report (unpublished).

Mitchell, P. I., Newton, S. F., Ratcliffe, N., & Dunn, T. E. (eds) 2004. *Seabird Populations of Britain and Ireland*. Poyser, London.

Moxom, D. J., & Burden, R. F. 2004. The recent history of monitoring and management of Little Tern (*Sterna albifrons*) and common tern (*Sterna hirundo*) on Chesil Bank, Dorset, 1974–1999. *Dorset Natural History and Archaeological Society Proceedings* 126: 63–84.

Quinney, A. 2016. Chesil Beach Little Tern recovery project. RSPB report (unpublished).

Rendell-Read, S. (ed.) 2013–2018. Little Tern Newsletters (unpublished).

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.

Smith, W. 2017. *Langstone Harbour Little Tern Colony Report 2017 (short report)*. RSPB report (unpublished).

Thaxter, C. B., Lascelles, B., Sugar, K., Cook, A. S. C. P., Roos, S., Bolton, M., Langston, R. H. W., & Burton, N. H. K. 2012. Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biological Conservation* 156: 53–61.

Vaughan, M. 2014. Chesil Beach Little Tern recovery project. RSPB report (unpublished).

Helen Booker is a Senior Conservation Officer at the RSPB working on conservation of a range of bird species and their habitats in south-west England. **Don Moxom** was the warden of Chesil Bank and the Fleet Nature Reserve for over 20 years, during which time he undertook detailed monitoring and trialling of protection measures for the tern colony.

Assessing the dynamics of vegetated shingle
Hurst Spit case study 2013-2017.

Project	Assessing the dynamics of vegetated shingle – Hurst Spit case study 2013-2017
Published By	New Forest District Council
Further Details	Funding Contributions by SCOPAC Independently reviewed by representatives from Natural England
Authors	Lauren Burt Catherine Eastick Peter Ferguson
Version	Final (May 2018)

Front Cover- Snapshot of Vegetated Shingle at Hurst Spit, 2017 UAV Aerial Photography courtesy of Geo-4D.

Contents

Assessing the dynamics of vegetated shingle – Hurst Spit case study 2013-2017.

1. Introduction

1.1 Background to this Study

Shingle beaches are natural wave barrier features that effectively dissipate wave energy, providing natural flood protection to areas of low lying land (Stripling *et al*., 2008). Where environmental conditions are favourable, vegetation communities may develop to form areas of vegetated shingle. Vegetated shingle is internationally recognised as an important coastal habitat in the UK, and as such these areas are often protected under environmental designation. A more detailed description of the geomorphology and ecology of coastal vegetated shingle is provided by Sneddon and Randall (1993), and a literature review is provided by Murdock *et al.,* (2010).

During extreme storms, the shingle barrier may respond dynamically through natural processes of erosion and recovery, leading to natural disruption of vegetated shingle species. A proportion of these coastal frontages are also subject to beach management activities (such as beach recycling, reprofiling and recharge) to ensure that the natural flood protection provided by the shingle beach is maintained either in response to, or in preparation for extreme storm events. These activities must consider the environmental sensitivities of the vegetated shingle. The impact of these extreme storm events and beach management activities on vegetated shingle communities has not been assessed.

In this first study, a simplistic methodology for assessing the response of vegetated shingle species to beach management activities and storm events will be presented, using Hurst Spit beach (Hampshire) as a case study.

This study focuses on the most recent significant storm events, that commenced in winter 2013/14. A series of severe storms impacted Hurst Spit, with wave heights of 4.5m measured at Milford-on-Sea generated during the highest magnitude event on the 14th February 2014 (Bradbury and Mason, 2014). Seven of the 15 highest storms (exceeding a 1 in 1 year return period) since 2003 at Milford-on-Sea were recorded between October 2013 and February 2014, with the 14th of February storm reaching a 1 in 50 year return period. At Hurst Spit, waves overwashed the beach crest, causing erosion, gullying and crest lowering along significant sections of the spit. In turn, this lead to extensive reworking of areas of vegetated shingle. Emergency beach management activities included beach recycling to reprofile the beach and reinstate the standard of flood protection provided by the spit (further disrupting the vegetated shingle communities along Hurst Spit).

Prior to 2013, there have been regular beach management activities at Hurst Spit. Beach management activities are restricted to the main section of spit between the rock breakwater at the proximal end along the spit to towards Hurst Castle. This is reflected in the study area which is restricted to the areas of shingle within this extent. Therefore, this study excludes areas of shingle adjacent to Hurst Castle, and extending along North Point towards the distal end of the spit. Whilst these areas are populated by vegetated shingle communities (including rare and protected species), they are not subject to anthropogenic beach management activities and are therefore beyond the scope of this project.

There have not been any other beach management activities for the remainder of the timescale covered by this study (to Summer 2017).

1.2 Aims and Objectives

The main aim of the study was to assess the dynamics of vegetated shingle at Hurst Spit between 2013 and 2017.

In order to achieve the study's aim, the following objectives were established:

- To develop and present suitable methodology for assessing recovery in vegetated shingle species extent and diversity over time using Regional Coastal Monitoring Programme Data and in-house field survey data.
- To assess the impact of extreme storms and beach management activities during winter 2013/14.
- To explore the spatial variation in recovery of vegetated shingle coverage and the potential reasons for this.
- To discuss the wider implications for coastal management at Hurst Spit, and make recommendations for the next study.

1.3 Location

Located within the New Forest National Park across the entrance to the Western Solent, Hurst Spit beach is included within a plethora of National, European and International nature conservation designations. The extent of the study site is limited to the main section of Hurst Spit which has been subject to modification due to regular beach management activities, as shown in Figure 1- below. The study site is shown in more detail in Appendix A.

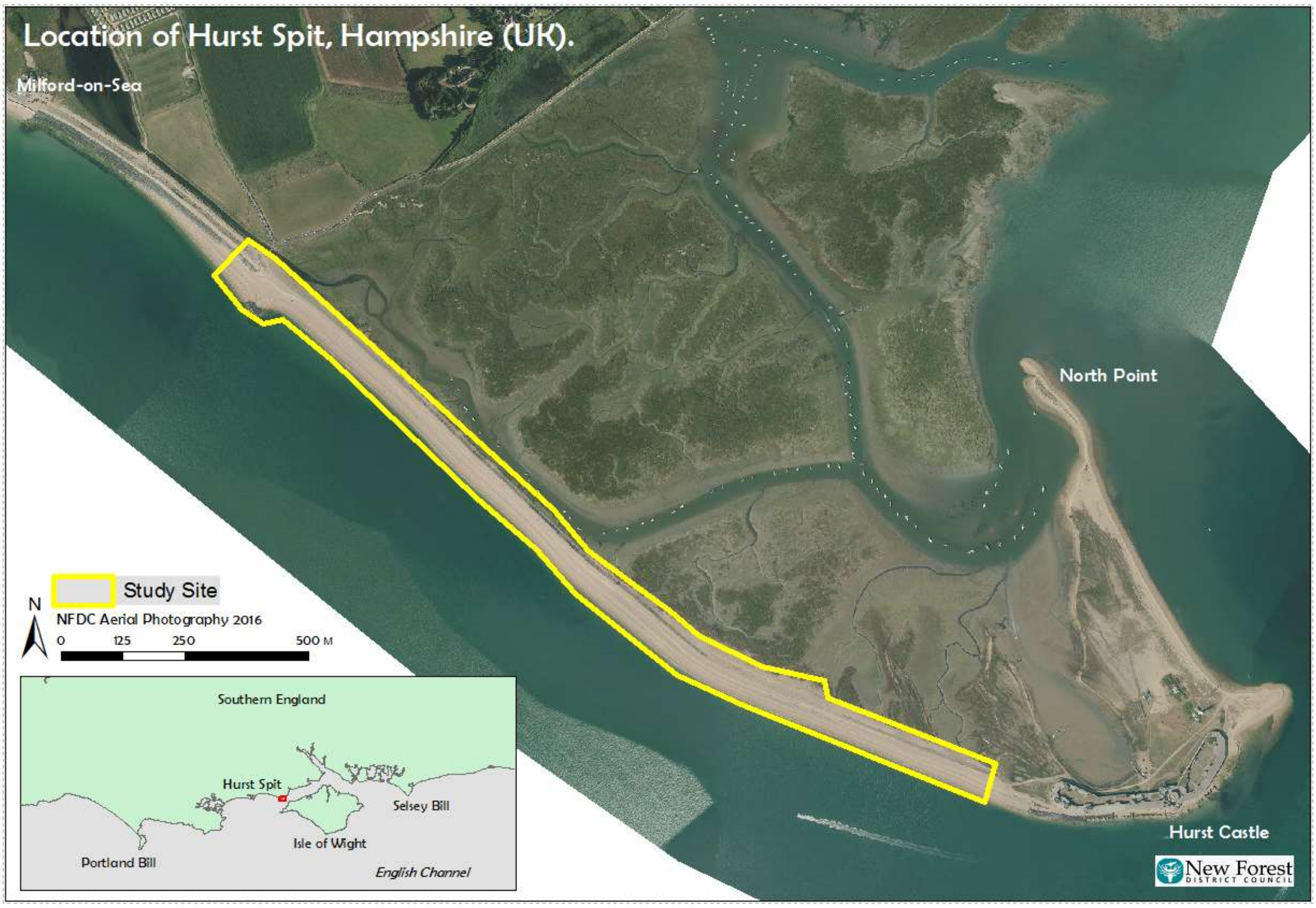


Figure 1- Location of Hurst Spit Study Site, including Study Site outlined in yellow.

Hurst Spit is highlighted as an important vegetated shingle area in England with Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC) designation (Houston *et al.,* 2008; Murdock *et al.,* 2010). The type and extent of the specialised vegetated shingle species recorded at Hurst Spit include strandline communities through to more stable open shingle habitats and areas of shingle saltmarsh (Murdock *et al*., 2010).

Whilst the National Vegetation Classification (NVC) System is available to enable classification of species found (with reference to Rodwell (ed.), British Plant Communities Volume 5 - Maritime Communities and Vegetation of Open Habitats (1992) and Volume 3 Grasslands and Montane Communities (2000)), it was agreed that the classification system provided by Sneddon and Randall (1993) is more suited to vegetated shingle communities. Recent field surveys conducted by the New Forest District Council Coastal Team (2014, 2015 and 2017) detail all species found within the study site, with particular focus on those located on the shingle.

Species found are typical of the grassland, pioneer and secondary pioneer coastal vegetated shingle communities as presented by Sneddon and Randall (1993). Communities within the study site are dominated by curled dock (*Rumex crispus*), sea beet (*Beta vulgaris maritima*) and sea campion (*Crambe maritima*). There are also transitional low marsh species influenced by saltmarsh such as sea blite (*Suaeda maritima*) and sea milkwort (*Lysimachia maritima*) (Figure 2).

Further surveys and studies that focus on the vegetated shingle of Hurst Spit are limited. Recent work appears to be limited to a study by Cox and Crowther (2001) which provides a brief introduction to the dominant species along the main section of spit, but focuses mainly on a species list for the terminal hook between Hurst Castle and North Point (beyond the scope of this study).

Murdock *et al.* (2010) also noted that the main section of Hurst Spit has not been the subject of previous vegetation surveys and as such it was included in Murdock *et al.'*s (2010) study, featuring as a study site. For the 2010 study, an alternative survey method was utilised to provide a general survey of the site with use of transects to a high ecological standard. Through further analysis of the 2010 data, it was found that the majority of study sites were again located along the distal recurve of Hurst Spit. Only one of the 2010 study sites (HT4a) was located within the current study area extent, located between HU19 and HU19a. As such there appears to be an absence of suitable and comparable pre-2013 baseline vegetation surveys which have been conducted within the current survey area.


Rear slope vegetation communities


Strandline of Grass Leaf Orache


Sea Campion


Sea Beet


Sea Milkwort


Sea Kale on beach crest

Figure 2- Images (NFDC Coastal Team) of vegetated shingle species at Hurst Spit (2017).

Hurst Spit is also a highly managed beach, with an approved programme of ongoing maintenance and beach recycling operations to continue to provide effective flood risk management for the western Solent (New Forest District Council, 1996). Beach recycling takes place using material from North Point which is deposited along spit (within the study area) on a triennial basis (with most recent recycling events taking place in 2004/07/10 and 2014). Further beach management activities include localised 'crest trimming' from areas of accumulation to eroded sections (2003/05/09/11/13/14), and also localised recycling from the beach in front of the breakwater (HU5-HU6) to top up beach levels where required (2005/09/11/13/14).

The severe storm events of winter 2013/14 caused significant natural disruption and damage to vegetated shingle communities at Hurst Spit much, so much that it can be assumed that the majority of vegetation was destroyed or damaged during this period within the study area by March 2014 (Figure 3). Wide spread (post-storm) emergency beach management and recycling operations were conducted to repair the crest, further impacting the vegetated shingle extent (Recycling from HU5-6 in front of the breakwater, North Point and crest trimming were all carried out as part of emergency works).

Figure 3- Image looking southeast along Hurst Spit showing damage caused during winter storms 2013/14 (NFDC).

2. Recommended Literature

The reader is invited to review the following sources of literature for further understanding of aspects in relation to this study (including gravel barrier geomorphology, vegetated shingle ecology and other studies and surveys):

Bradbury, A. P. Mason, T. E. (2014). Review of south coast beach response to wave conditions in the winter of 2013-2014. Technical Report SR01, Southeast Regional Coastal Monitoring Programme.

Cole, K. Tait, A. Yates, B. Younghusband, T. (2005). *Techniques for Assessing Shingle Communities*. http://www.sussex.ac.uk/geography/researchprojects/BAR/publish/biodiversity_report.pdf

Cox, J. Crowther, K. (2001) *Survey of Solent Strandline Vegetation: July –September 2000*. Jonathan Cox Associates.

Doody, P. Randall, R. (2003) *A Guide to the Management and Restoration of Coastal Vegetated Shingle.* Contract No. MAR 05-03-002 English Nature.

Houston, J. Rooney, P. Doody, P. (2008). *The Conservation and Management of Coastal Vegetated Shingle in England; Report of the meeting at Salthouse, North Norfolk on 18 September 2008 (organised by the Sand Dune and Shingle Network on behalf of Natural England*. Sand Dune and Shingle Network Occasional Paper No.1 Liverpool Hope University Press.

JNCC. (2004) *Common Standards Monitoring Guidance for Vegetated Coastal Shingle Habitats.* ISSN 1743-8160. http://jncc.defra.gov.uk/pdf/csm_coastal_shingle.pdf Accessed November 2017.

JNCC, Maddock, A (ed.) (2008) *UK Biodiversity Action Plan Priority Habitat Descriptions- Coastal Vegetated Shingle*. http://jncc.defra.gov.uk/page-5706 Accessed November 2017.

Murdock, A. Hill, A. Cox, J. Randall, R. (2010) *Development of an evidence base of the extent and quality of shingle habitats in England to improve targeting and delivery of the coastal vegetated shingle HAP*. Natural England Commissioned Reports, Number 54.

Natural England. (2009) Development of a Coastal Vegetated Shingle Inventory for England, Natural England Commissioned Report NECR015.

New Forest District Council (1996) Hurst Spit Beach Management Plan

Sneddon, P. & Randall, R. (1993) *Coastal vegetated shingle structures of Great Britain*

Stripling, S. Bradbury, A. P. Cope, S. N. Brampton, A. H. (2008). Understanding Barrier Beaches. R&D Technical Report, Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Web Pages:

http://coast.hope.ac.uk/ourprojects/shingle/

https://www.buglife.org.uk/advice-and-publications/advice-on-managing-bap-habitats/coastal-vegetated-shingle

https://eunis.eea.europa.eu/sites/UK0030059- Habitats Directive (Solent)

http://eunis.eea.europa.eu/habitats/10013- Perennial vegetation of stony banks- EUNIS European Environment Agency

3. Methodology

In this section, a new approach to assessing the extent and diversity of vegetated shingle species over time is presented. This methodology draws upon data from the Regional Coastal Monitoring Programme, so that the method can be repeated and adopted at other coastal locations where data is available. The method for field surveying is simplistic however can be adapted and improved over time, whilst still meeting the aims of this study.

The survey area extent is shown in more detail in Appendix A.

In order to meet the objectives and overarching aim of this study, the following methodology has been established:

3.1 Digitisation of vegetation area using Aerial Photography

The National Network of Regional Coastal Monitoring Programmes (RCMP) currently coordinates the collection of coastal monitoring data to meet the needs of coastal management and engineering projects. The English coastline is divided into a number of distinct coastal cells and subcells. Within each subcell the coastline is monitored using a series of 'profile lines' at set intervals, perpendicular to the coastline. Further information on the RCMP can be found here: https://www.channelcoast.org/

Aerial photography is one of the data outputs of the programme. Available aerial photography datasets were analysed using GIS to identify and digitise (1:50) areas of vegetated shingle along Hurst Spit. The output was the total area (m^2), and area between profile lines or 'survey area' (m^2). Through comparison of total area of vegetation per survey area, an idea of spatial distribution over time can be understood. Furthermore, beach management activities are recorded by survey area between beach profiles, making it easier to discuss impacts of beach management activities on area of vegetation per survey area (as some survey areas are targeted more for beach management activities).

The methodology is as follows:

1. Download Aerial Photography for required years and import into ArcGIS.
2. Import RCMP profile line shapefile into GIS and use to create polygon 'survey area' shapefile. Add column in attribute table to name each survey area according to profiles (Figure 4a). Note that the 'old' (HU) survey name has been used for this report; however any suitable naming convention can be used.
3. Digitise areas of vegetated shingle at 1:50 scale to create shapefile for each aerial photography year (Figure 4b).
4. Use 'Clip' tool to trim the digitised vegetated shingle shapefile to each 'survey area' within the study site.
5. Calculate area of vegetated shingle within each survey area for each year and total area (m^2).
6. Repeat for each year of aerial photography available.

The following datasets were digitised using GIS for vegetation extent:

20130822	Aerial Photography	New Forest District Council	Pre-Storm/ Works
20160824	Aerial Photography	New Forest District Council	Post Storm/Works recovery
20170613	UAV Aerial Photography	Geo-4D	Post Storm/Works recovery

Appendix B shows the digitised shapefile of vegetation extent for each year.

Figure 4a- Polygon of survey areas based on Regional Coastal Monitoring Programme profile lines- a snapshot.

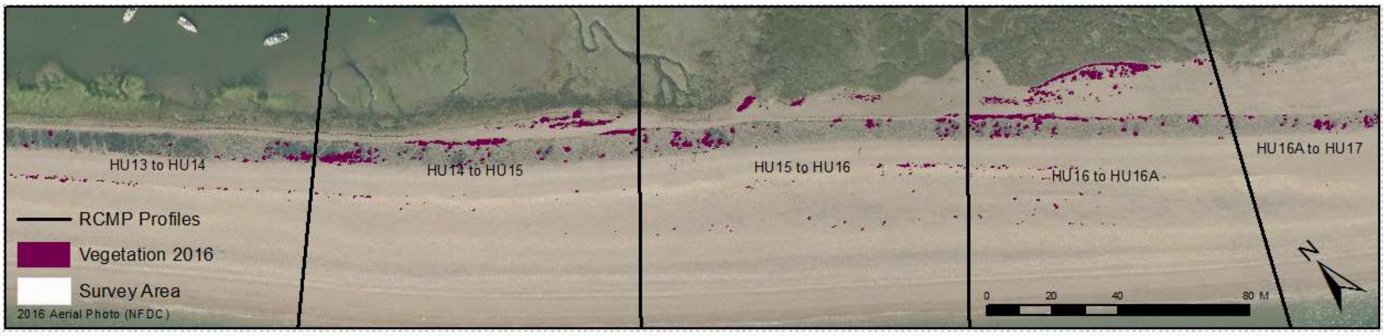


Figure 4b- Digitised extent of vegetated shingle- a snapshot.

3.2 Field Surveys

At present, three field surveys have been completed at Hurst Spit (in 2014, 2015 and 2017). Field surveys were conducted in late summer/ early autumn to ensure that later growth of vegetation is covered by the survey.

Surveys focused on all species of vascular plants (bryophytes and lichens excluded). The field survey methodology is as follows:

1. Use RCMP profile lines to set up required survey areas and plan survey.
2. Conduct visual inspection/site walk through of each survey area along the rear of beach slope (RoB), crest of beach (CoB) and seaward face of beach (SoB)to identify all species within that area.
3. Record all discrete species (including grassland, pioneer and secondary pioneer coastal vegetated shingle communities) within the area to provide information on species richness. Species richness refers to the number of different species within an area.
4. Take photographs for each survey area.
5. Note any further observations.

Field surveys were conducted as follows:

20140903	Vegetated Shingle Survey	New Forest District Council	Post Storm/Works recovery
20150623	Vegetated Shingle Survey	New Forest District Council	Post Storm/Works recovery
20170717	Vegetated Shingle Survey	New Forest District Council	Post Storm/Works recovery

Appendix C shows the spreadsheet of species found per year, with data split between discrete "vegetated shingle" species and "other" species. "Other" species could include saltmarsh and non-native species recorded.

6. Results

6.1 Total Area of Vegetated shingle per year

The total area of vegetated shingle per year within the survey area is shown in Table 1 and Figure 5 below.

Year	2013	2016	2017
Total Area (m^2)	4,299	2,134	3,686

Table 1- Total area of vegetated shingle per year within the survey area.

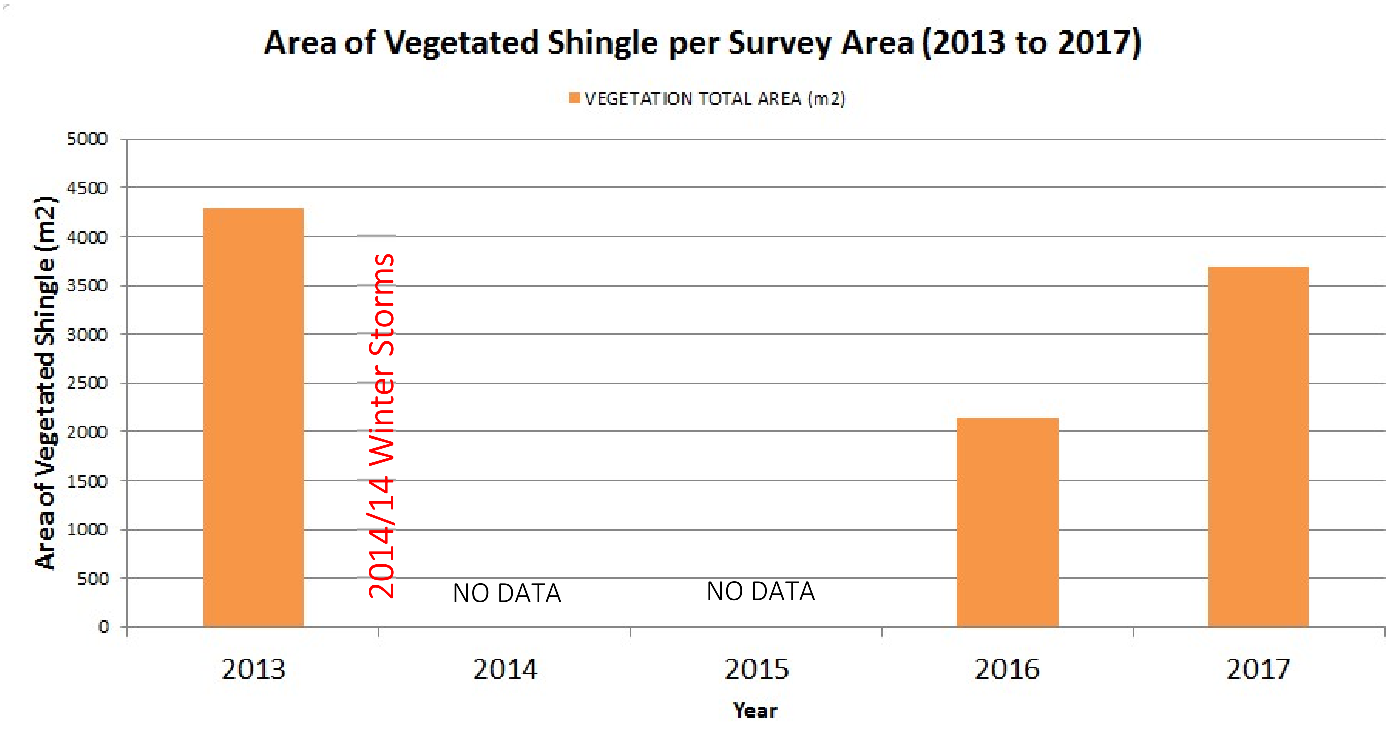


Figure 5- Total area of vegetated shingle per year within the survey area.

Prior to the extreme 2013/14 winter storms, the total area of vegetated shingle was 4,299m^2 in 2013. Photographic records show that that a major proportion of this vegetation area was disrupted during the extreme winter storms (2013/14) and consequent emergency beach management activities.

By 2016, the area of vegetation had recovered to half of the 2013 extent within the study site (2,134m^2 totals). During the year 2016-2017 the area had increased by 1,552m^2 to 3,686m^2.

The 2017 total area has not yet reached the pre-storm (2013) area, however is anticipated to have recovered if the 2016/17 rate of area increase has continued into 2017/18.

6.2 Total Area of Vegetated shingle per survey area per year

The total area of vegetated shingle per survey area per year is shown in Figure 6 below.

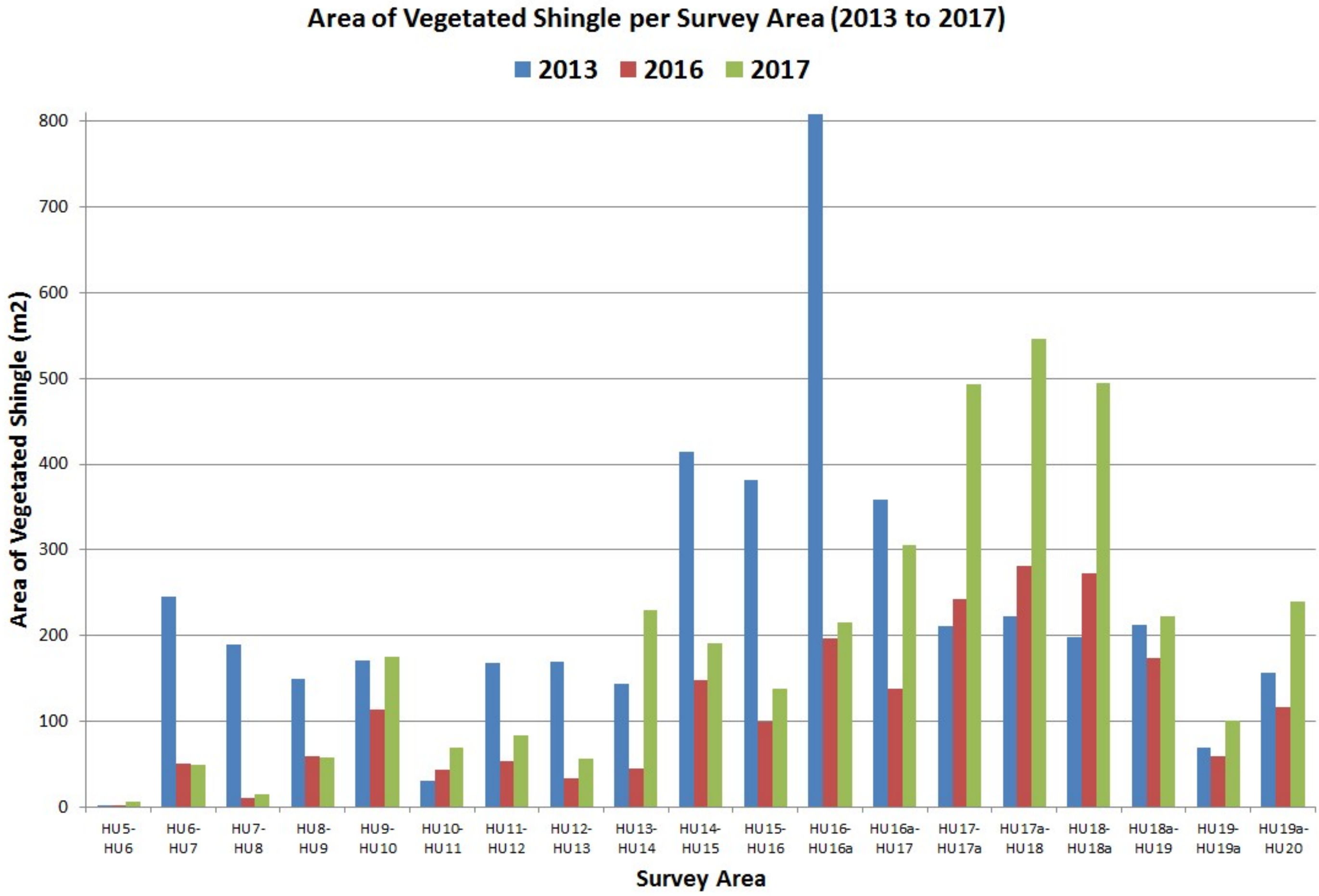


Figure 6- Area of Vegetated Shingle per Survey Area (2013 to 2017).

In 2013, the greatest areas of vegetated shingle were located between HU14 and HU17 reaching 800m^2 in HU16-HU16a. Along other survey areas, there was a similar area of vegetated shingle per area of about 100-200m^2.

The 2013/14 storm events caused widespread reduction in vegetated shingle area across the majority of survey areas. There are however several areas which have seen a small increase in vegetated shingle area 2013-2016 (HU10-11 and HU17-18a) of between +10-75m^2.

When focusing of recovery of vegetated shingle area between 2016 and 2017, there has been some recovery for the western section of the survey area (HU5-HU13). The recovery improves further east between HU13 and HU16a, with the most recovery occurring between HU16a and HU18a (+265m^2 recovery at HU17a to HU18).

When looking at the years in isolation, there has been a shift in the greatest areas of vegetated shingle since 2013, from HU14-HU17 (2013) to HU17-HU18a (2017).

For all years, there is a notable lack of vegetation in HU5-HU6 (<10m^2).

6.3 Number of Species found per survey area

The total number of discrete vegetated shingle species found per survey area is presented in Figure 7.

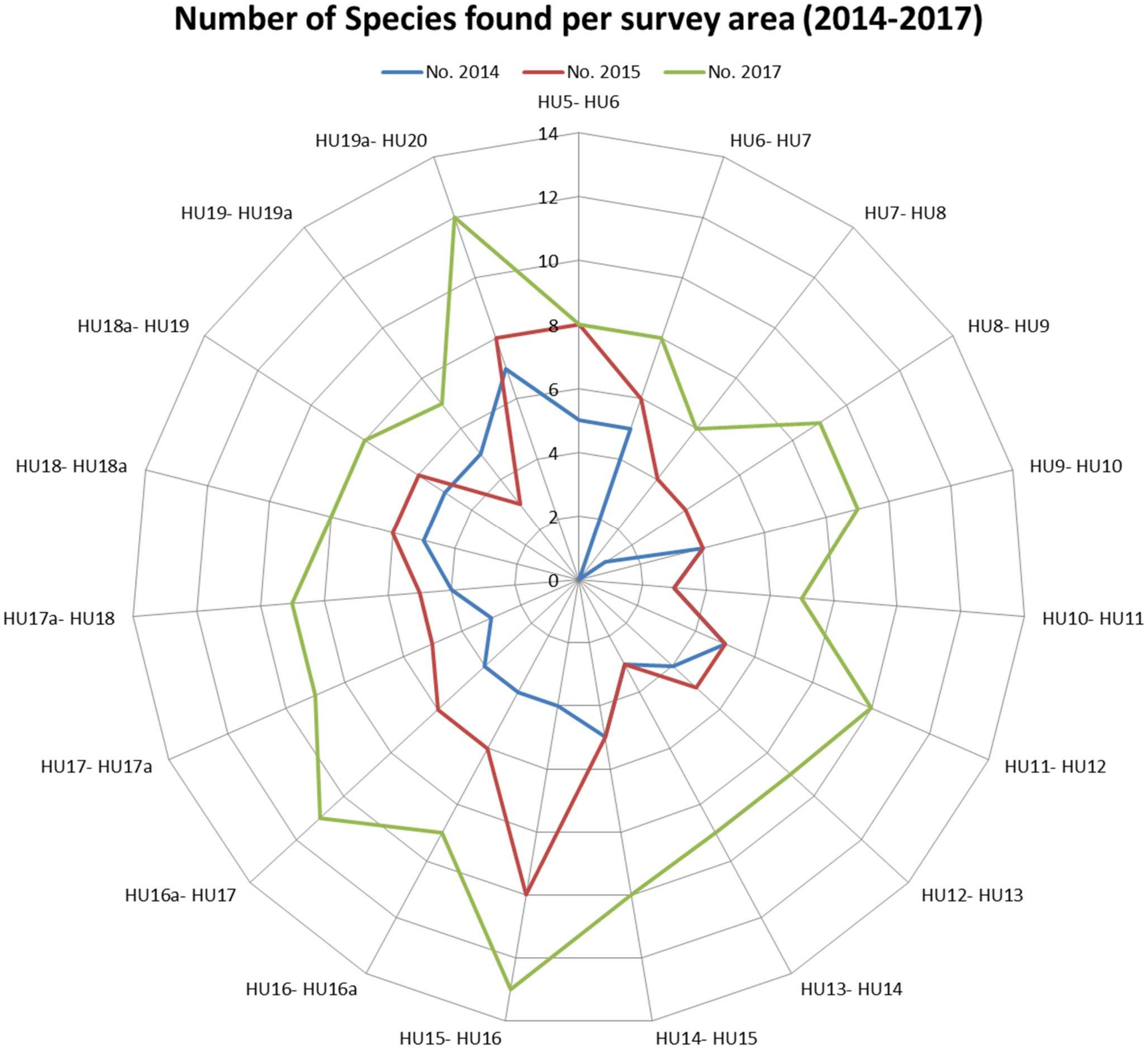


Figure 7- Number of discrete vegetated shingle species found per survey area (2014-2017).

Figure 7 captures the recovery of species after the 2013/14 winter storms and consequent emergency works which saw major disruption to vegetated shingle communities along Hurst Spit. At HU8-HU9, no vegetated shingle species were found in the 2014 survey.

For the majority of survey areas, the number of species recorded increases 2014-2015, with a reduction in number of species found between HU19 and HU19A. Appendix C shows that the actual species found between years is subject to variation, and this is seen in HU19-HU19a (2014-2015). Furthermore, where the number is constant between years, this may not be true for the species recorded as seen in HU9-HU10 and HU10-HU11.

For the period 2015 to 2017 there is a noticeable increase in number of species at all sites (apart from HU5-HU6) where there is no change. The maximum number of species found is 13 at HU15-HU16, followed by 12 at HU19a-HU20 (2017).

6.4 Species found per survey area

A spreadsheet of the species found per year can be found in Appendix C.

Through analysis of Appendix C, there are certain species which are common to all survey dates such as Curled Dock, Yellow Horned Poppy, Sea Beet, and Sea Kale with coverage increasing over time (2014-17).

In 2014, the most frequently occurring species are Yellow Horned Poppy, Spear Leaved Orache and Sea Kale. By 2015, there are no occurrences of Spear Leaved Orache recorded across the site, with the most frequently occurring species identified as Yellow Horned Poppy, Sea Kale and increasing distribution and dominance of Sea Beet and Curled Dock.

By 2017, there is a clear dominance of Curled Dock, Yellow Horned Poppy, Sea Beet, Sea Kale and Spear Leafed Orache across the majority of survey areas. Sea Campion increases in distribution alongside Couch Grass, Sea Mayweed and Rock Samphire. There are a number of species recorded in 2017 not previously recorded (2014/15) such as Sea Thrift, Sea Milkwort, Haresfoot Clover, Low Hop Clover, Coltsfoot, Spear Thistle.

At HU13-14, the number of discrete species is constant 2014 to 2015 at 3 species recorded, and this jumps to 9 species identified in 2017 (this is the greatest difference recorded). This unit provides an interesting example of shifting species, where it cannot be assumed that the same three species are found in each year. In 2014, the three species recorded are Yellow Horned Poppy, Sea Blite and Grass Leaf Orache. In 2015 this is Curled Dock, Yellow Horned Poppy and Sea Beet. By 2017, these 5 different species are accompanied by Couch Grass, Spear Leaved Orache, Sea Campion and Sea Mayweed.

7. Discussion

The impact of the 2013/14 winter storms and consequent emergency beach management activities is highlighted by the distinct reduction in total area of vegetated shingle along the main section of Hurst Spit between 2013 and 2016. Since these storms, there has been a notable recovery in vegetated shingle extent throughout the survey area. It is inferred that the absence of extreme storms and beach management activities in the period since the 2014 emergency works to the end of 2017 has resulted in a period which has encouraged this recovery of vegetated shingle.

There are indications that whilst the 2017 total extent had not yet reached the pre-storm (2013) area, it is anticipated to have recovered if the 2016/17 rate of area increase has continued into 2017/18. It is therefore estimated that recovery of vegetated shingle coverage could take up to 4 years if there is no significant disruption from storm events or beach management activities within this period.

It is interesting to note the shift in survey areas where vegetation area is the greatest from HU14-HU17 (2013) to HU17-HU18a (2017). This suggests that the survey areas between HU17 and HU18a were relatively more sheltered from storm impacts and as such were not subject to such intense emergency beach management activities as sections further west (HU6-HU17). HU17 to HU18a show a continued increase in vegetation extent over time, despite the 2013/14 storm events, further confirming that this area is well sheltered.

Further analysis of beach profile data suggests that profiles between HU17 and HU18a are generally stable, with material accretion on the foreshore (formation of a secondary berm) and at the toe during the period of this study.

Through annotation of **Figure 6** (now **Figure 8**) with details of the spatial distribution of the 2014 emergency beach management activities (provided by NFDC), this provides confirmation that the section between HU17-HU18a experienced minimal damage in relation to the section between HU13 and HU17 which experienced the most significant storm damage and beach reprofiling. Survey areas between HU6 and HU13 also have a southwesterly facing aspect and as such were also subject to storm wave impact and damage, and emergency beach management activities.

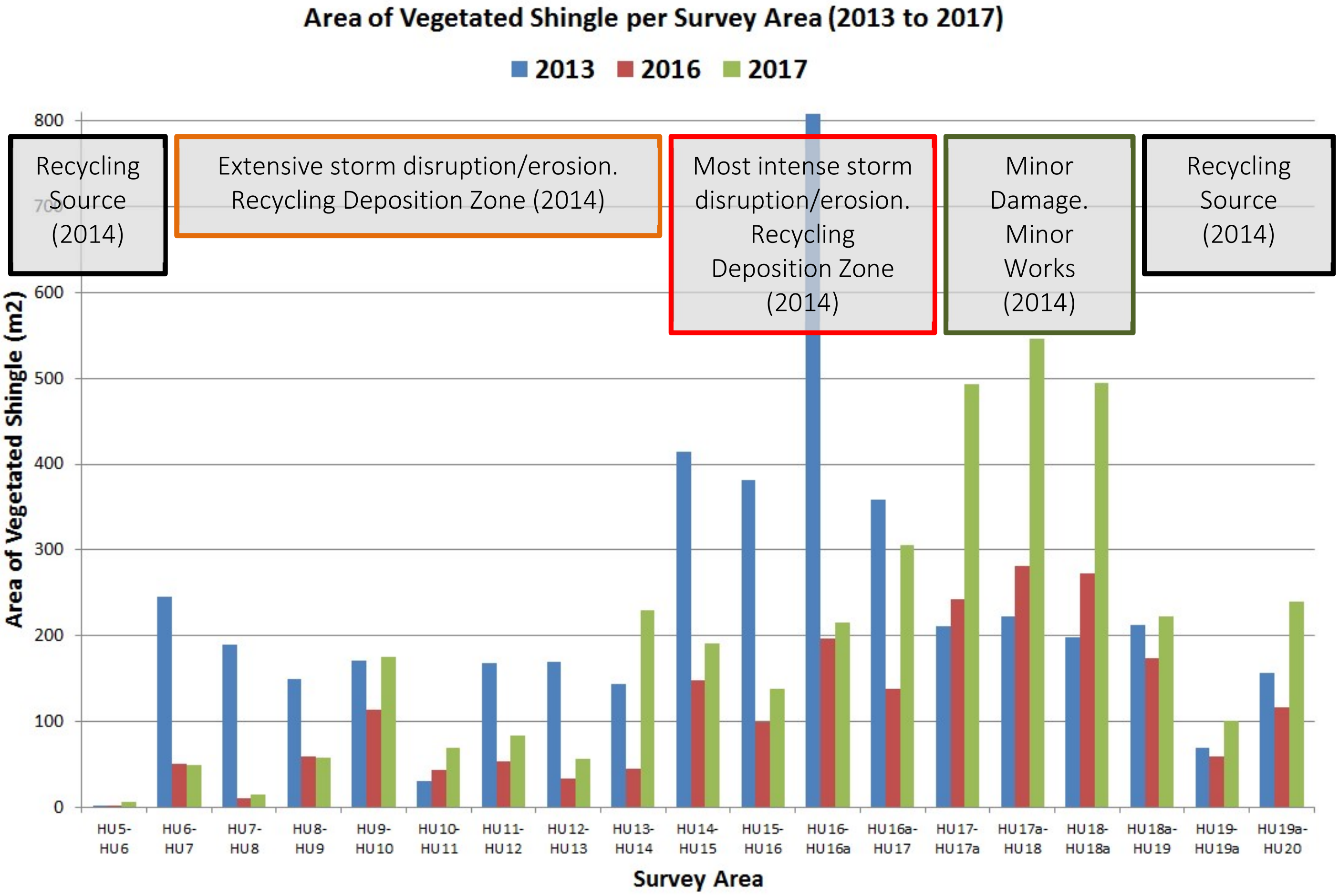


Figure 8- Area of Vegetated Shingle per Survey Area (2013 to 2017) with annotation of location and extent of storm disruption and reprofiling (2014).

The lack of vegetation area at HU5-HU6 is attributed to presence of the rock revetment, and trampling by visitors and vehicles which use this area as the main access point up onto and along the crest of Hurst Spit.

Further observations include the potential impact of beach slope and sediment matrix on vegetated shingle area. Although these aspects have not yet been included in the methodology, they are likely to be included in future surveys. It was observed that slope angle along the rear beach slope (RoB) changes with distance along the spit. In general, the slope angle is the steepest HU8-HU16 due to the artificially higher crest height, with slope angle reducing between HU16 and HU17, to a more gradual (natural) slope HU17 to HU20 (lower crest height). As such, slope angle and crest height could impact vegetation extent.

Superimposed upon these changes in slope angle and crest height, are changes in sediment matrix, more specifically the proportion of fine sediment within the matrix. It was observed that the sediment matrix between HU6 and HU9 had a lack of fine (sandy) proportion. This fine proportion increased further east, linking with an increase in vegetation area at this location 2013-17. This is attributed to source of beach material used during the emergency beach management activities in 2014. It was observed that rounded cobbles of relatively large, uniform size were used between HU6 and HU9 to restore the beach profile, and that these were sourced from the seaward face of Hurst Spit just west of the survey area at HU5. The material used to restore the beach profile between HU9 and HU20 was mostly sourced from North Point material recycling and contained a mixture of shingle and sand, of a smaller size.

The recovery of vegetated shingle between 2013 and 2017 is established through analysis of vegetated shingle area, however this does not account for the changes in species richness. A recovery in vegetated shingle extent after major storm and beach management activities is desirable, however further evidence which documents the recovery in species richness is required to understand the true recovery of vegetated shingle.

In the first instance, the number of discrete species has been used to provide information on species recovery. If the number of different species is able to recover, this is desirable. In the absence of pre-storm baseline data, this study is only able to capture the post-storm recovery of species number. The data suggests that the number of species showed minor increases between 2014 and 2015, with a marked increase between 2015 and 2017 (longer duration). The overall species richness has therefore increased between 2014 and 2017 within the survey area.

When taking a closer look at the discrete species behind the numbers, there are clear dominant species that have established over time. The species found are all typical of shifting or colonising vegetated shingle within the Solent. There are no occurrences within the survey area of species that are uncommon or rare in England within the survey area.

Whilst the number of species continues to increase within the study site, it does not meet the species richness found along the recurve towards North Point as recorded by Cox and Crowther (2001). Whilst there are similarities in species and communities at both sites, the terminal recurve towards North Point hosts a variety of other species not found within the study site, such as little robin (*Geranium purpureum)*. When comparing the two sites, there are other clear differences that may also impact the occurrence of rare species such as slope angle, crest height, aspect, exposure, and accessibility.

The majority of species are found on the rear slope, potentially due to sheltering from prevailing winds and wave action. Very few species are recorded on the beach crest, and this is potentially due to disturbance by vehicles and trampling as the crest is used as an access point.

It is noted that the surveys (aerial flights and field surveys) take place during different months of the year, however as these are within summer months, this is not thought to impact the results. A spring/summer seasonal variation in species identified and vegetation extent is expected.

Emergency beach management activities are required as a result of extreme storm events to ensure that the beach profile is re-established and that the standard of protection is maintained. These extreme storm events have the potential to disrupt extensive areas of vegetated shingle, as observed during the 2013/14 winter period (natural disruption is expected). Post-storm emergency works may indirectly impact the vegetation through movement of sediment, beach re-profiling (slope angle and crest height), beach recharge (input of new material), and compression of beach material (by vehicles). Natural fluctuations in the extent and distribution of vegetated shingle is expected, however the 2013/14 winter season appears to have had a significant impact.

Where beach management activities are conducted as part of regular maintenance works (as part of an agreed Beach Management Plan) for example at Hurst where sediment is recycled from within the sediment cell to areas along Hurst Spit, these works may disrupt the vegetation through reprofiling and loading of beach material. Within the study period, these works had not taken place (due March 2018) and as such it is difficult to assess the impact on vegetated shingle extent and species richness. Again, where beach management activities are conducted as part of a new capital scheme, the impact of these works will need to be assessed.

8. Conclusions and Recommendations

One of the original objectives of this study was to develop and present suitable methodology for assessing recovery in vegetated shingle species extent and diversity over time using Regional Coastal Monitoring Programme data and in-house field survey data. The study has been successful in developing a simplistic method for Coastal Practitioners to monitor and assess vegetated shingle extent and species richness over time. Through this monitoring, any impacts of major storms and beach management activities can also be captured. This study has made use of Regional Coastal Monitoring Programme data freely available for the study site.

The benefits of the simplistic method include the ability to repeat the field survey at regular (annual) intervals at low cost (two officers over 1 day to cover the survey area). The methodology presented could be adopted by other Coastal Practitioners with similar aims and objectives to this study, and repeated where data and resources are available.

The limitations of the simplistic field survey methodology include the lack of quantitative field data. The methodology is designed to be basic in nature; however data analysis revealed that the percentage cover of each species within the survey area would be beneficial, in addition to quantitative data about other environmental variables to allow a more detailed analysis of results.

It is also accepted that there are limitations of the digitisation method utilised to monitor changes in vegetated shingle coverage. In the first instance the process of digitisation is subjective, and reliant on the resolution of the data. There were also issues of shadowing in some areas of the beach slope (due aspect of sunlight) which made it difficult to digitise the photography without manipulation of the image brightness and contrast. It is also accepted that it would be difficult to identify some individual species strands due to scale however the method moves to obtain a suitable estimation of coverage per year so that a comparison is possible.

The methodology adopted enabled an assessment of the recovery of vegetated shingle species in response to extreme storms and beach management activities between 2013 and 2017. The extreme storm period and resultant emergency beach management activities in winter 2013/14 resulted in extensive losses of vegetated shingle extent, and disruption to species. Despite this widespread damage within the study area, it is encouraging to see that there has been a recovery in vegetated shingle, which is likely to have reached pre-storm extent by the end of 2017. Early indications suggest a 4 year period for this response.

The methodology also included monitoring of the individual species found and it is also encouraging to see that the number of different species increases over time resulting in an increase in species richness.

It is clear from the species list that there is a distinct absence of rare species within the study area, despite a number of rare species being recorded at an adjacent site. There are clear differences between the two sites which are not limited to the presence or absence of beach management activities such as aspect, crest elevation, slope and accessibility.

The methodology, whilst simplistic, enables a more detailed understanding of the spatial variation in recovery of vegetated shingle. It was found that spatial variation was likely to be due to a combination of factors including history of beach management, degree of exposure to extreme wave impacts, sediment transport, slope angle, crest height, trampling, sediment matrix and source of material used for beach recharge. Through improvement of the field survey methodology, these factors could be investigated further, with findings incorporated into future scheme design.

When considering the wider implications for coastal management at Hurst Spit, it is clear that the study site provides an insightful case study into the impacts of extreme storms and beach management activities on vegetated coastal shingle. Within the timescales covered by this study, the only beach management activities were conducted in 2014 (emergency scenario in response to the extreme storms of winter 2013/14). These storms had essentially naturally disrupted extensive areas of vegetated shingle, with consequent emergency works attempting to re-establish the beach profile. There are some areas which escaped major storm damage and were therefore not subject to extensive emergency works (HU17-18a) and it is recommended that where possible (and if this area remains stable) that this area is essentially protected from future beach management activities to ensure that anthropogenic disruption is minimal. It is expected that this area will continue to recover into the future in the absence of any extreme storms of similar magnitude to the 2014 storms.

If beach management activities did not continue, it is likely that Hurst Spit will not be able to maintain its current beach profile naturally, due to a natural decline in beach volume. In the absence of beach management activities, the beach will be more vulnerable to extreme storm events. The potential for storm damage could then become more likely in any given year, resulting in more frequent and prolonged disruption to the vegetated shingle communities. It is also accepted that some species are more suited to mobile shingle, so stabilisation of the beach does not necessarily benefit all vegetated shingle species.

Further work will build on this report, to include data where it becomes available either through the Regional Coastal Monitoring Programme or through in-house field surveys. The impacts of future extreme storm events and beach management activities will also be investigated.

The following recommendations are presented in conclusion to this study:

- There is potential for the methodology to be adopted by other Coastal Practitioners with similar aims and objectives to this study, where suitable data and resources are available. It is recommended that if adopted, that a baseline field survey is conducted at the earliest convenience (in anticipation for future storms and beach management activities).
- There is potential to improve the field survey methodology to include the following:
  - Sediment samples for particle size and/or soil characteristics analysis (to investigate spatial variation and impacts on vegetation)
  - Use of Regional Coastal Monitoring Programme profiles to investigate impacts of beach slope, aspect, crest height
  - Detailed photographic survey
  - Use of transects/quadrats/ SACFOR abundance scale
  - Record of percentage cover of each species within survey area (such as Domin values, to allow understanding of species diversity within each survey area).

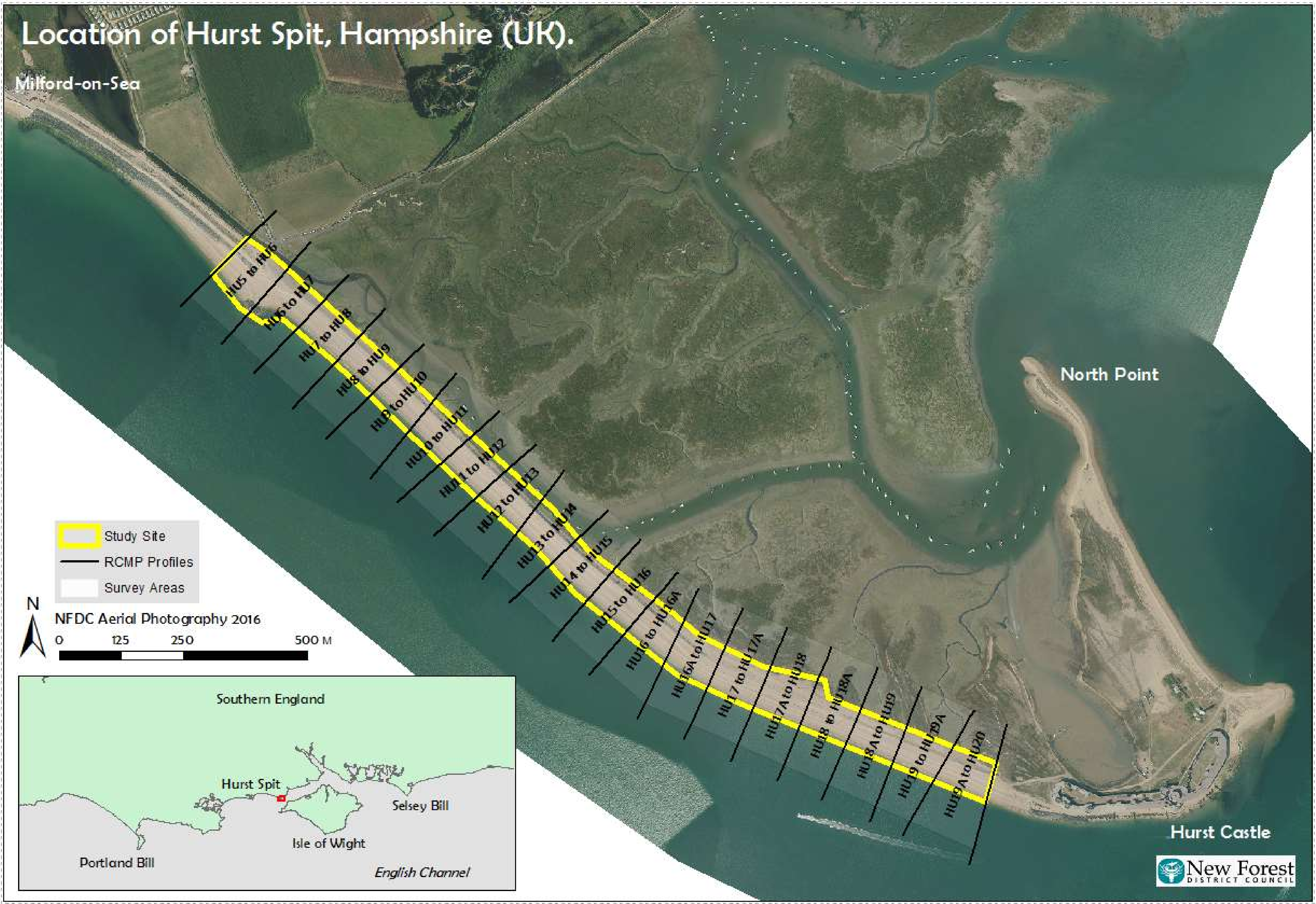
  It is envisaged that these will be considered and incorporated into any future studies.

- New Forest District Council intend to continue to update this study on an annual basis where data and resources are available so that future impacts of extreme storms and beach management activities can be monitored.

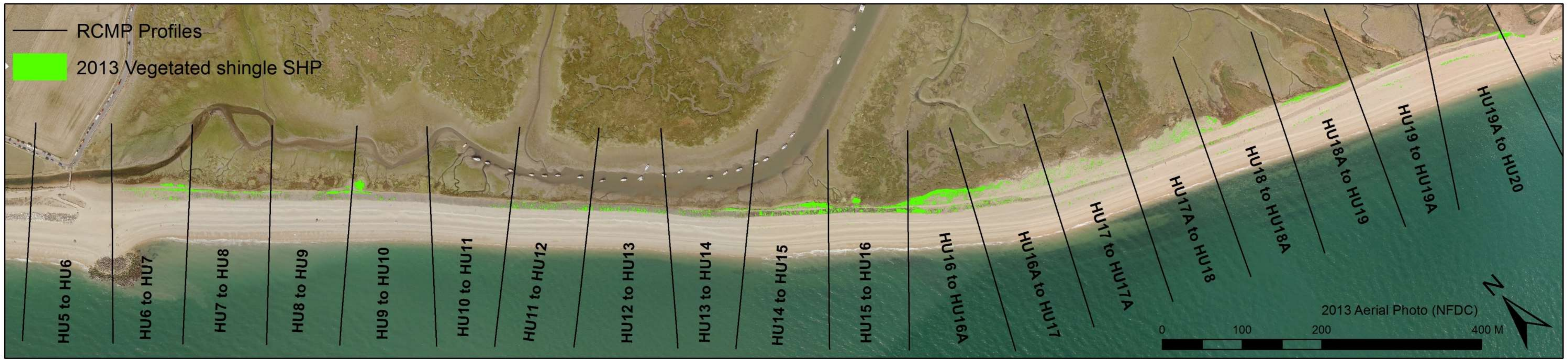
The main aim of the study was to establish the response of vegetated shingle species to beach management activities at Hurst Spit. It is concluded that the study was successful in meeting the overarching aim, and underlying objectives.

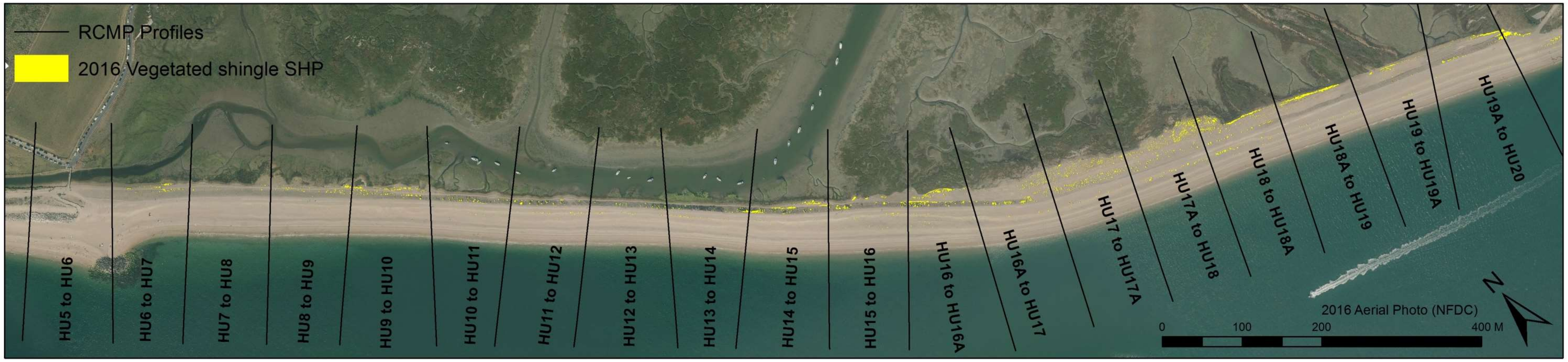
9. Appendices

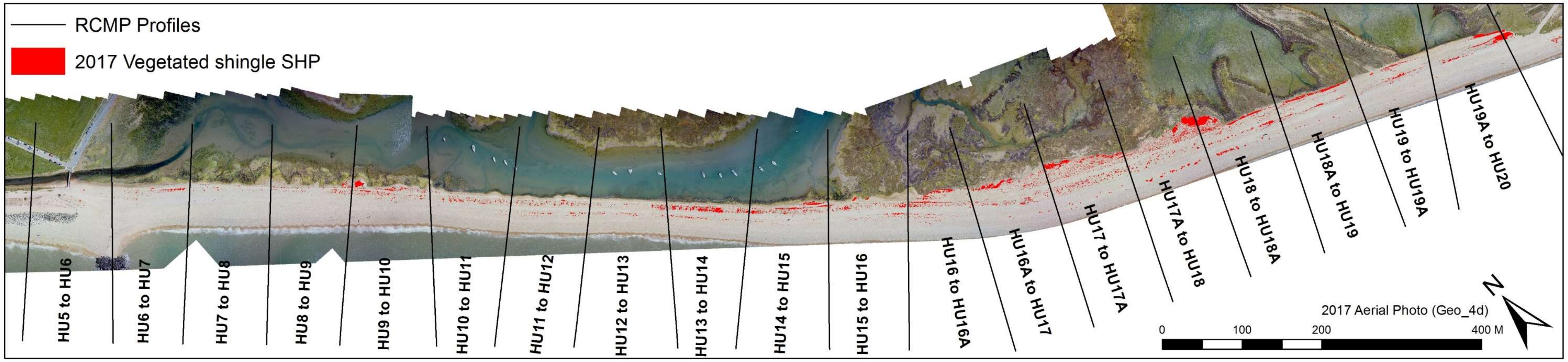
Appendix A- Map of profile/ survey area location



Appendix B- Maps of digitised vegetated shingle extent for each year (2013, 2016 & 2017).







Appendix C- Spreadsheet of Species (2014, 2015 & 2017).

VEGETATED SHINGLE (Discrete Species) — (NUMBER OF SPECIES)

2014

		Curled Dock (Rumex crispus)	Yellow Horned Poppy (Glaucium flavum)	Sea Beet (Beta vulgaris maritima)	Corn Sow Thistle (Sonchus arvensis)	Sea Plantain (Plantago maritima)	Couch Grass (Elymus pycnanthus)	Sea Blite (Suaeda maritima)	Sea Aster (Aster tripoleum)	Spear Leaved Orache (Atriplex prostrata)	Sea Kale (Crambe maritima)	Sea Campion (Crambe maritima)	Grass Leaf Orache (Atriplex littoralis)	Greater Sea Spurrey (Spergularia media)	Sea Mayweed (Maticaria maritima)	Rock Samphire (Crithmum maritima)	Pineapple Weed (Matricaria discoidea)	Sea Carrot (Daucus carota)	Spear Thistle (Cirsium vulgare)	Coltsfoot (Tussilago farfara)	Common Kidneyvetch (Anthyllis Vulneraria)	Ribwort Plantain (Plantago lanceolata)	Autumn Hawkbit (Scorzoneroides autumnalis)	Low Hop Clover (Trifolium campestre)	Haresfoot Clover (Trifolium arvense)	Sea Milkwort (Lysimachia maritima)	Ragwort (Jacobaea vulgaris)	Sea Thrift (Armeria maritima)	VEGETATED SHINGLE DISCRETE SPECIES (2014)	VEGETATED SHINGLE DISCRETE SPECIES (2015)	VEGETATED SHINGLE DISCRETE SPECIES (2017)	VEGETATED SHINGLE DISCRETE SPECIES (2018)
HU5- HU6	Rear	1	1	1	1	1																						5			
	Crest																														
	Seaward																														
HU6- HU7	Rear	1	1				1	1	1																				5			
	Crest																														
	Seaward																														
HU7- HU8	Rear																											0			
	Crest																														
	Seaward																														
HU8- HU9	Rear							1																					1			
	Crest																														
	Seaward																														
HU9- HU10	Rear	1	1	1			1																						4			
	Crest																														
	Seaward																														
HU10- HU11	Rear		1	1						1																				3			
	Crest																														
	Seaward																														
HU11- HU12	Rear	1		1						1	1	1																		5			
	Crest																														
	Seaward																														
HU12- HU13	Rear		1	1						1			1																	4			
	Crest																														
	Seaward																														
HU13- HU14	Rear		1					1					1																	3			
	Crest																														
	Seaward																														
HU14- HU15	Rear		1			1		1																					5			
	Crest			1									1																				
	Seaward																														
HU15- HU16	Rear		1										1																	4			
	Crest		1	1																											
	Seaward									1																					
HU16- HU16A	Rear										1																			4			
	Crest		1									1		1																		
	Seaward		1																												
HU16A- HU17	Rear										1	1			1														4			
	Crest																														
	Seaward		1																												
HU17- HU17A	Rear										1	1			1														3			
	Crest																														
	Seaward																														
HU17A- HU18	Rear									1	1	1																	4			
	Crest									1	1		1																		
	Seaward									1																					
HU18- HU18A	Rear						1					1				1												5			
	Crest										1																				
	Seaward									1																					
HU18A- HU19	Rear	1										1																4			
	Crest										1																				
	Seaward									1																					
HU19- HU19A	Rear	1		1			1																						5			
	Crest									1				1																	
	Seaward																														
HU19A- HU20	Rear		1		1		1				1	1			1														7			
	Crest									1																					
	Seaward									1																					

OTHER SPECIES

		Mature vegetation - Holm Oak - (Quercus ilex)	Red Fescue (Festuca rubra)	Yorkshire Fog (Holcus lanatus)	False Oat Grass (Arrhenatherum elatius)	Sea Purslane (Atriplex portulacoides)	Glasswort (Salicornia)	Spiral Wrack (Fucus spiralis) at MLW	Sea Lettuce (Ulva lactuca)	Green Algae (Cladophora sp) at MLW	Golden Samphire (Inula crithmoides)	Common Cordgrass (Spartina anglica) at MLW	Sea Lavender (Limonium cf L vulgare)	Shrubby Sea Blite (Suaeda vera)	Gutweed (Ulva intestinalis) at MLW	Notes
HU5- HU6	Rear	1														
	Crest															
	Seaward															
HU6- HU7	Rear					1	1	1	1								
	Crest															
	Seaward															
HU7- HU8	Rear							1	1							No vegetation on slope
	Crest															
	Seaward															
HU8- HU9	Rear					1		1	1							No vegetation on slope
	Crest															
	Seaward															
HU9- HU10	Rear							1	1							
	Crest															
	Seaward															
HU10- HU11	Rear															
	Crest															
	Seaward															
HU11- HU12	Rear									1					
	Crest															
	Seaward															
HU12- HU13	Rear									1					
	Crest															
	Seaward															
HU13- HU14	Rear															
	Crest															
	Seaward															
HU14- HU15	Rear					1					1	1			
	Crest															
	Seaward															
HU15- HU16	Rear															
	Crest															
	Seaward															
HU16- HU16A	Rear															
	Crest															
	Seaward															
HU16A- HU17	Rear										1				
	Crest															
	Seaward															
HU17- HU17A	Rear										1				
	Crest															
	Seaward															
HU17A- HU18	Rear															
	Crest															
	Seaward															
HU18- HU18A	Rear					1					1		1		
	Crest															
	Seaward															
HU18A- HU19	Rear					1		1		1	1			1	
	Crest															
	Seaward															
HU19- HU19A	Rear					1					1			1	
	Crest															
	Seaward															
HU19A- HU20	Rear					1					1			1	
	Crest															
	Seaward															

		VEGETATED SHINGLE (Discrete Species)																											(NUMBER OF SPECIES)				OTHER SPECIES														
		Curled Dock (Rumex crispus)	Yellow Horned Poppy (Glaucium flavum)	Sea Beet (Beta vulgaris maritima)	Corn Sow Thistle (Sonchus arvensis)	Sea Plantain (Plantago maritima)	Couch Grass (Elymus pycnanthus)	Sea Blite (Suaeda maritima)	Sea Aster (Aster tripoleum)	Spear Leaved Orache (Atriplex prostrata)	Sea Kale (Crambe maritima)	Sea Campion (Crambe maritima)	Grass Leaf Orache (Atriplex littoralis)	Greater Sea Spurrey (Spergularia media)	Sea Mayweed (Matricaria maritima)	Rock Samphire (Crithmum maritima)	Pineapple Weed (Matricaria discoidea)	Sea Carrot (Daucus carota)	Spear Thistle (Cirsium vulgare)	Coltsfoot (Tussilago farfara)	Common Kidneyvetch (Anthyllis Vulneraria)	Ribwort Plantain (Plantago lanceolata)	Autumn Hawkbit (Scorzoneroides autumnalis)	Low Hop Clover (Trifolium campestre)	Haresfoot Clover (Trifolium arvense)	Sea Milkwort (Lysimachia maritima)	Ragwort (Jacobaea vulgaris)	Sea Thrift (Armeria maritima)	VEGETATED SHINGLE DISCRETE SPECIES (2014)	VEGETATED SHINGLE DISCRETE SPECIES (2015)	VEGETATED SHINGLE DISCRETE SPECIES (2017)	VEGETATED SHINGLE DISCRETE SPECIES (2018)	Mature vegetation - Holm Oak - (Quercus ilex)	Red Fescue (Festuca rubra)	Yorkshire Fog (Holcus lanatus)	False Oat Grass (Arrhenatherum elatius)	Sea Purslane (Atriplex portulacoides)	Glasswort (Salicornia)	Spiral Wrack (Fucus spiralis) at MLW	Sea Lettuce (Ulva lactuca)	Green Algae (Cladophora sp) at MLW	Golden Samphire (Inula crithmoides)	Common Cordgrass (Spartina anglica) at MLW	Sea Lavender (Limonium cf L vulgare)	Shrubby Sea Blite (Suaeda vera)	Gutweed (Ulva intestinalis) at MLW	Notes
2015																																															
HU5- HU6	Rear	1	1	1	1	1	1										1	1											5	8			1				1		1							1	
	Crest																																														
	Seaward																																														
HU6- HU7	Rear	1	1	1	1		1	1																					5	6							1		1							1	
	Crest																																														
	Seaward																																														
HU7- HU8	Rear	1	1	1							1																		0	4																	Vegetation generally sparse
	Crest																																														
	Seaward																																														
HU8- HU9	Rear	1	1					1							1														1	4							1		1							1	
	Crest																																														
	Seaward																																														
HU9- HU10	Rear	1	1	1								1																	4	4									1							1	
	Crest																																														
	Seaward																																														
HU10- HU11	Rear	1	1	1																									3	3									1							1	
	Crest																																														
	Seaward																																														
HU11- HU12	Rear		1	1	1						1	1																	5	5																1	
	Crest																																														
	Seaward		1	1																																											
HU12- HU13	Rear		1	1						1	1	1																	4	5																1	
	Crest			1								1																																			
	Seaward		1								1																																				
HU13- HU14	Rear	1	1																										3	3																1	
	Crest		1	1																																											
	Seaward																																														
HU14- HU15	Rear	1	1	1			1																						5	5									1							1	
	Crest			1								1																																			
	Seaward	1																																													
HU15- HU16	Rear	1	1				1	1			1		1		1														4	10							1		1							1	
	Crest		1	1	1						1	1																																			
	Seaward																																														
HU16- HU16A	Rear	1	1	1									1																4	6							1										
	Crest									1																																					
	Seaward			1							1																																				
HU16A- HU17	Rear	1	1	1							1	1																	4	6							1	1				1	1	1			
	Crest									1																																					
	Seaward			1							1																																				
HU17- HU17A	Rear		1								1	1																	3	5							1										
	Crest									1																																					
	Seaward			1							1																																				
HU17A- HU18	Rear		1								1	1																	4	5							1										
	Crest									1																																					
	Seaward			1							1																																				
HU18- HU18A	Rear	1	1								1	1																	5	6							1										
	Crest									1																																					
	Seaward			1							1																																				
HU18A- HU19	Rear	1	1	1				1				1																	4	7							1										Slope sparsely vegetated
	Crest									1																																					
	Seaward			1							1																																				
HU19- HU19A	Rear		1	1																									5	3							1							1			
	Crest									1																																					
	Seaward			1																																											
HU19A- HU20	Rear	1	1					1			1		1					1											7	8					1	1											Much detritis causing enrichment of shingle in this location
	Crest									1																																					
	Seaward			1																																											

VEGETATED SHINGLE (Discrete Species)

2017

		Curled Dock (Rumex crispus)	Yellow Horned Poppy (Glaucium flavum)	Sea Beet (Beta vulgaris maritima)	Corn Sow Thistle (Sonchus arvensis)	Sea Plantain (Plantago maritima)	Couch Grass (Elymus pycnanthus)	Sea Blite (Suaeda maritima)	Sea Aster (Aster tripoleum)	Spear Leaved Orache (Atriplex prostrata)	Sea Kale (Crambe maritima)	Sea Campion (Crambe maritima)	Grass Leaf Orache (Atriplex littoralis)	Greater Sea Spurrey (Spergularia media)	Sea Mayweed (Maticaria maritima)	Rock Samphire (Crithmum maritima)	Pineapple Weed (Maticaria discoidea)	Sea Carrot (Daucus carota)	Spear Thistle (Cirsium vulgare)	Coltsfoot (Tussilago farfara)	Common Kidneyvetch (Anthyllis Vulneraria)	Ribwort Plantain (Plantago lanceolata)	Autumn Hawkbit (Scorzoneroides autumnalis)	Low Hop Clover (Trifolium campestre)	Haresfoot Clover (Trifolium arvense)	Sea Milkwort (Lysimachia maritima)	Ragwort (Jacobaea vulgaris)	Sea Thrift (Armeria maritima)
HU5- HU6	Rear	1	1		1	1						1			1			1	1									
HU5- HU6	Crest																											
HU5- HU6	Seaward																											
HU6- HU7	Rear	1	1	1				1			1		1		1					1								
HU6- HU7	Crest																											
HU6- HU7	Seaward																											
HU7- HU8	Rear	1	1	1				1		1		1																
HU7- HU8	Crest																											
HU7- HU8	Seaward																											
HU8- HU9	Rear	1	1	1				1		1		1	1		1					1								
HU8- HU9	Crest																											
HU8- HU9	Seaward																											
HU9- HU10	Rear	1	1	1				1		1	1	1	1						1									
HU9- HU10	Crest																											
HU9- HU10	Seaward			1						1	1																	
HU10- HU11	Rear	1	1	1			1				1		1															
HU10- HU11	Crest																											
HU10- HU11	Seaward			1						1	1																	
HU11- HU12	Rear	1	1	1	1		1			1	1	1				1												
HU11- HU12	Crest																											
HU11- HU12	Seaward		1	1							1										1							
HU12- HU13	Rear	1	1	1	1		1			1		1			1							1						
HU12- HU13	Crest																											
HU12- HU13	Seaward	1	1	1								1																
HU13- HU14	Rear	1	1	1			1			1	1	1	1		1													
HU13- HU14	Crest																											
HU13- HU14	Seaward		1	1								1																
HU14- HU15	Rear	1	1	1			1				1	1	1		1												1	
HU14- HU15	Crest	1	1	1						1	1																	
HU14- HU15	Seaward																											
HU15- HU16	Rear	1	1	1			1				1	1	1					1	1	1			1					
HU15- HU16	Crest																											
HU15- HU16	Seaward	1	1	1						1	1	1				1												
HU16- HU16A	Rear	1	1	1							1	1				1				1				1				
HU16- HU16A	Crest																											
HU16- HU16A	Seaward	1	1	1						1		1								1								
HU16A- HU17	Rear		1	1							1	1	1		1	1				1	1				1	1		
HU16A- HU17	Crest																											
HU16A- HU17	Seaward			1							1																	
HU17- HU17A	Rear	1	1	1							1	1			1	1			1	1								
HU17- HU17A	Crest																											
HU17- HU17A	Seaward																											
HU17A- HU18	Rear		1	1			1				1	1				1								1				
HU17A- HU18	Crest																											
HU17A- HU18	Seaward	1		1						1	1	1																
HU18- HU18A	Rear	1	1	1							1	1			1	1												
HU18- HU18A	Crest																											
HU18- HU18A	Seaward	1	1	1						1	1																	
HU18A- HU19	Rear	1	1				1				1				1							1			1			
HU18A- HU19	Crest																											
HU18A- HU19	Seaward			1						1	1																	
HU19- HU19A	Rear	1	1	1			1								1													
HU19- HU19A	Crest			1																								
HU19- HU19A	Seaward			1						1	1																	
HU19A- HU20	Rear	1	1	1			1			1	1	1	1		1			1	1									1
HU19A- HU20	Crest	1																										
HU19A- HU20	Seaward			1						1	1																	

(NUMBER OF SPECIES) / OTHER SPECIES

		VEGETATED SHINGLE DISCRETE SPECIES (2014)	VEGETATED SHINGLE DISCRETE SPECIES (2015)	VEGETATED SHINGLE DISCRETE SPECIES (2017)	VEGETATED SHINGLE DISCRETE SPECIES (2018)	Mature vegetation - Holm Oak - (Quercus ilex)	Red Fescue (Festuca rubra)	Yorkshire Fog (Holcus lanatus)	False Oat Grass (Arrhenatherum elatius)	Sea Purslane (Atriplex portulacoides)	Glasswort (Salicornia)	Spiral Wrack (Fucus spiralis) at MLW	Sea Lettuce (Ulva lactuca)	Green Algae (Cladophora sp) at MLW	Golden Samphire (Inula crithmoides)	Common Cordgrass (Spartina anglica) at MLW	Sea Lavender (Limonium cf L vulgare)	Shrubby Sea Blite (Suaeda vera)	Gutweed (Ulva intestinalis) at MLW	Notes
HU5- HU6	Rear	5	8	8		1	1					1			1				1	
HU5- HU6	Crest																			
HU5- HU6	Seaward																			
HU6- HU7	Rear	5	6	8						1	1	1	1				1			
HU6- HU7	Crest																			
HU6- HU7	Seaward																			
HU7- HU8	Rear	0	4	6							1	1	1						1	
HU7- HU8	Crest																			
HU7- HU8	Seaward																			
HU8- HU9	Rear	1	4	9						1	1	1	1			1	1		1	
HU8- HU9	Crest																			
HU8- HU9	Seaward																			
HU9- HU10	Rear	4	4	9						1	1	1	1			1				
HU9- HU10	Crest																			
HU9- HU10	Seaward																			
HU10- HU11	Rear	3	3	7						1		1	1						1	
HU10- HU11	Crest																			
HU10- HU11	Seaward																			
HU11- HU12	Rear	5	5	10								1							1	
HU11- HU12	Crest																			
HU11- HU12	Seaward																			
HU12- HU13	Rear	4	5	9								1							1	
HU12- HU13	Crest																			
HU12- HU13	Seaward																			
HU13- HU14	Rear	3	3	9								1							1	
HU13- HU14	Crest																			
HU13- HU14	Seaward																			
HU14- HU15	Rear	5	5	10						1	1	1			1	1	1	1	1	
HU14- HU15	Crest																			
HU14- HU15	Seaward																			
HU15- HU16	Rear	4	10	13						1	1	1				1	1	1	1	
HU15- HU16	Crest																			
HU15- HU16	Seaward																			
HU16- HU16A	Rear	4	6	9						1	1	1			1	1	1	1		
HU16- HU16A	Crest																			
HU16- HU16A	Seaward																			
HU16A- HU17	Rear	4	6	11							1				1		1	1		
HU16A- HU17	Crest																			
HU16A- HU17	Seaward																			
HU17- HU17A	Rear	3	5	9						1					1		1	1		
HU17- HU17A	Crest																			
HU17- HU17A	Seaward																			
HU17A- HU18	Rear	4	5	9		1				1	1				1	1	1			
HU17A- HU18	Crest																			
HU17A- HU18	Seaward																			
HU18- HU18A	Rear	5	6	8						1		1			1	1	1	1		
HU18- HU18A	Crest																			
HU18- HU18A	Seaward																			
HU18A- HU19	Rear	4	7	9						1					1	1	1	1	1	
HU18A- HU19	Crest																			
HU18A- HU19	Seaward																			
HU19- HU19A	Rear	5	3	7						1		1	1		1		1	1		
HU19- HU19A	Crest																			
HU19- HU19A	Seaward																			
HU19A- HU20	Rear	7	8	12			1			1		1			1		1	1		
HU19A- HU20	Crest																			
HU19A- HU20	Seaward																			