Use of Foraging Habitats and Disturbance of Ringed Plover (*Charadrius Hiaticula*)

Thesis Report




USE OF FORAGING HABITATS AND DISTURBANCE OF RINGED PLOVER (*CHARADRIUS HIATICULA*)

Comparing use of- and disturbance on three key foraging habitats of Ringed Plover on Dutch sandy beaches during early breeding season

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Summary

The natural value of Dutch sandy beaches has been declining for decades. These relatively unstable, low nutritious, wave-washed environments lack the primary producers that represent the base of the food web. Thus, the sandy beach food web relies almost entirely on nutrient influx of other systems. Beside phytoplankton that supply nutrients to the lower beach suspension feeders, organic beach wreck deposits provide one of the two major foundations of food supply for the successive trophic levels in sandy beach ecosystems. The combination of the unpleasant odours caused by the natural decomposition and the plastic and other human litter poses a problem for tourism and beach-users. To rid tourists and beach-users from unpleasantries, beach management often resolves to "clean" the beach from organic wreck and plastic. This practice, however, represents a problem for the natural value of Dutch beaches, as one of the major food sources enhancing the biodiversity and abundance of life along the coastline is compromised. One of the key species groups that inhabit sandy beach ecosystems in the Netherlands are beach-nesting birds. Ringed Plovers (Charadrius hiaticula) are vulnerable migratory beach-nesting birds that, without interference, may be unable to successfully breed in the Netherlands. The province of Zeeland has a specific responsibility to protect Ringed Plover, as around 30 percent of the total Dutch population breed in the area. To facilitate presence of breeding pairs with nests, and ultimately increase breeding success, it is necessary to adjust beach management to complement essential habitat requirements. While the breeding success, presence and migration patterns of Ringed Plover in the Netherlands are well-studied topics, there seems to be relatively little known about the importance and usage of food resources. For the identification of important foraging habitats, it is essential to gain insight on what important food sources on sandy beaches in the province of Zeeland are, what types of prey are available, and in what microhabitat or zones disturbance may limit foraging time or opportunities.

This study investigated foraging activity and disturbance of present breeding pairs of Ringed Plover on the beach of Oranjezon and the Veerse Gatdam / Banjaardstrand, the Netherlands. The main objectives are: (I) To determine the relative importance of key foraging habitats, (II) To identify major disturbance factors associated with the habitats, (III) To find correlations between the foraging activity and disturbance on the foraging habitats with e.g. time-based parameters. Three key foraging habitats were investigated in this study: the intertidal area, fresh wash-up (depositions by prior high tide) and the winter flood-mark (older depositions of spring or storm tides). Foraging activity, presence of potential disturbance factors and disturbances was monitored in defined plots, during roughly 300 5-minute blocks, from a stationary lookout during a 5-week period (March – May 2020). Prey types were sampled in by estimating abundance in 0.5m2 quadrants on the tidal deposition habitats, and counting *polychaete* holes in quadrants, and sediment samples of 50cm top layer on the intertidal area.

Results showed that foraging activity was highest on the intertidal area, but also evident on both tidal deposition habitats. General presence was highest on the winter flood-mark, indicating it is primarily used for other purposes than foraging. Foraging on the winter flood-mark may be a more opportunistic and sporadic feeding behaviour, as Ringed Plover may pick-up prey when they notice it nearby. Prey types were abundant on both tidal deposition habitats, with the highest abundance of *Diptera*, *Amphipoda* and *Coleoptera*. High abundance of *Amphipoda* were seen during night-time. Although the sample size was small, results indicate that foraging activity during the night was high on the fresh wash-up. These results therefore indicate that Ringed Plover may utilize the high *Amphipoda* activity during the night. It is stressed that the importance of both tidal deposition habitats may be of greater

importance to chicks than results of this study have shown, as the proportion of insects is higher in the diet of chicks. Prey type abundance was extremely low on the intertidal area. Possibly the sampling method missed small *Polychaetes* (mesh size 0.5mm), or coarse sand and a dynamic intertidal area resulted in low densities. Ringed Plover were observed foraging on the banks of tideways present on the beach, where washed-up prey, or small *Polychaetes* may accumulate. Moreover, no significant relation was found between foraging activity and tidal phase on the tidal deposition habitats, but there seemed to be a slight preference for foraging on the intertidal area during a ebbing tide, which could be explained by the high macrozoobenthic activity during a retrieving tide. However, foraging activity was also evident during a rising tide. It is suggested that tideways increase the foraging time on the intertidal area and may also offer different prey types not traditionally associated with the intertidal area e.g. *Diptera*. Ringed Plover seemed to prefer foraging during the evening, which was also the period most disturbances occurred. Disturbance was induced most frequently by pedestrians, dogs on a leash and stationary beach-visitors. Disturbances were notably low (28 cases out of roughly 300 records). Disturbances were not significantly higher during higher tides, which was surprising since the beach is narrower during high tide, and RP may not have as much opportunity to avoid potential disturbance factors. This study took place during the worldwide corona-virus pandemic under extensive measures taken by the government and, as a result, (foreign) tourist and other big crowds were completely absent from the study area. Recreational intensity was likely too low to significantly dictate foraging activity and habitat use in the study area.

It is suggested that halting cleaning the beach of organic wash-up may improve breeding success and regulating access around tidal deposition habitats near or in breeding territories may increase foraging opportunities and ultimately increase breeding success. It is suggested that limiting or halting cleaning the beach of tidal depositions near present breeding territories or potential breeding habitat will increase food availability, and likely for chicks in particular. It is advised to leave both tidal depositions, the fresh wash-up and winter flood-mark, where occurring naturally.

Abstract

To facilitate breeding succes of Ringed Plover (*Charadriua Hiaticula*), it is necessary to adjust the beach-management to complement essential habitat requirements. While the breeding success, presence and migration patterns of Ringed Plover in the Netherlands are well-studied topics, there seems to be a gap in knowledge about the relative importance of food resources. It is hypothesised that Ringed Plover feed on insects and other prey on tidal depositions, aside from *Polychaetes* on the intertidal area. This study investigated foraging activity and disturbance of present breeding pairs of Ringed Plover on the beach of Oranjezon and the Veerse Gatdam / Banjaardstrand, the Netherlands. Three key foraging habitats were investigated in this study: the intertidal area, fresh wash-up, and the winter flood-mark. Foraging activity, presence of potential disturbance factors and disturbances was monitored in defined plots, and abundance of prey types on the three habitats was sampled and estimated during a 5-week period (March – May 2020). Results showed that foraging activity was highest on the intertidal area, but also evident on both tidal deposition habitats. General presence was highest on the winter flood-mark, indicating it is primarily used for other purposes than foraging. Prey types were abundant on both tidal deposition habitats, with the highest abundance of *Diptera*, *Amphipoda* and *Coleoptera*. High abundance of *Amphipoda* were seen during night-time. Although the sample size was small, results indicate that foraging activity during the night was high on the fresh wash-up. These results therefore hint that Ringed Plover may utilize the high *Amphipoda* activity during the night. Prey type abundance was extremely low on the intertidal area. Possibly the sampling method missed small *Polychaetes* (mesh size 0.5mm), or coarse sand and a dynamic intertidal area resulted in low densities. Ringed Plover were observed foraging on the banks of tideways present on the beach, where washed-up prey, or small *Polychaetes* may accumulate. No relation was found between foraging activity and tidal phase on the tidal deposition habitats, but there seemed to be a slight preference for foraging on the intertidal area during a ebbing tide, which could be explained by the high macrozoobenthic activity during a retrieving tide. However, foraging activity was also evident during a rising tide. It is suggested that tideways increase the foraging time on the intertidal area and may also offer different prey types not traditionally associated with the intertidal area e.g. *Diptera*. Ringed Plover seemed to prefer foraging during the evening, which was also the period most disturbances occurred. Disturbance was induced most frequently by pedestrians, dogs on a leash and stationary beach-visitors. Disturbances were notably low (28 cases out of roughly 300 records). Disturbances were not significantly higher during higher tides, which was surprising since the beach is narrower during high tide, and RP may not have as much opportunity to avoid potential disturbance factors. This study took place during the worldwide corona-virus pandemic under extensive measures taken by the government and, as a result, (foreign) tourist and other big crowds were completely absent from the study area. Recreational intensity was likely too low to significantly dictate foraging activity and habitat use in the study area. It is suggested that halting cleaning the beach of organic wash-up and regulating access around tidal deposition habitats near or in breeding territories may increase foraging opportunities and ultimately increase breeding success.

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1. Introduction

1.1 Background

The natural value of Dutch sandy beaches has been declining for decades. These relatively unstable, low nutritious, wave-washed environments lack the primary producers that represent the base of the food web. Thus, the sandy beach food web relies almost entirely on nutrient influx of other systems. Beside phytoplankton that supply nutrients to the lower beach suspension feeders, organic beach wreck deposits provide one of the two major foundations of food supply for the successive trophic levels in sandy beach ecosystems. (Cadée, 2014; Brown & McLachlan, 2010; Colombini & Chelazzi, 2003; Griffiths et al., 1983). Beach wrack consists largely of macrophytes, as well as marine animals washed ashore like jellyfish and molluscs, in addition to human litter. The combination of the unpleasant odours caused by the natural decomposition and the plastic and other human litter poses a problem for tourism and beach-users. To rid tourists and beach-users from unpleasantries, beach management often resolves to "clean" the beach from organic wreck and plastic. This practice, however, represents a problem for the natural value of Dutch beaches, as one of the major food sources enhancing the biodiversity and abundance of life along the coastline is compromised (Cadée, 2014; Colombini & Chelazzi, 2003; Ryan & Swanepoel, 1996).

1.2 This study

One of the key species groups that inhabit sandy beach ecosystems in the Netherlands are beach-nesting birds. Ringed Plovers (Charadrius hiaticula) are vulnerable migratory beach-nesting birds that, without interference, may be unable to successfully breed in the Netherlands (Boddeke et al., 2019). These Plovers are listed as a red-list species according to the Dutch and IUCN criteria (van Kleunen et al., 2016). The province of Zeeland has a specific responsibility to protect the Ringed Plover, as around 85 to 115 individuals are estimated to breed in the Zeeuwse Delta, which is around 30 percent of the total Dutch population (Boddeke et al., 2019). The presence of predators, the destruction of suitable habitat and the ability of these shorebirds and their chicks to find enough, or the appropriate kind, of food to sustain themselves seem to be important limiting factors (Boddeke et al., 2019). Moreover, beach-visitor induced Disruption may also confine foraging on the beach area to less suitable zones of the beach or limit foraging time. To facilitate habitation and presence of breeding pairs with nests, it is necessary to adjust the beach-management to complement essential habitat requirements. This requires enough foraging opportunities, in terms of potential foraging time and variety of available food resources. While the breeding success, presence and migration patterns of Ringed Plover in the Netherlands are well-studied topics, there seems to be relatively little known about the relative importance of food resources. Observations and experience in the field give the impression however, that Plovers forage at the intertidal area as well as around wash-up. In addition, I. Tulp (1997) observed that breeding Ringed Plovers predominantly foraged on the fresh flood mark (deposited by prior high tide) in a study done in the Dutch Wadden Sea. It is therefore hypothesised that halting cleaning the beach of organic wrack and protecting and regulating access to zones of importance may improve breeding success. For the designation of important foraging-zones, we need to know what important food sources are, what types of prey is available, and in what microhabitat-zones Disruption limits foraging time / opportunities.

Objective and research questions

This study will investigate foraging activity of present breeding pairs of Ringed Plover on the beach of Oranjezon up to the Banjaardstrand, the Netherlands. The study will be carried out during early breeding season from April - mid May 2020. The project is meant to provide advice on how to facilitate foraging opportunities and adapt beach management likely to allow for improved habitat requirements and in turn an increased breeding success of Ringed Plover in the study area. The main objectives are: (I) To determine the relative importance of three different microhabitat(s) for foraging, (II) To identify major Disruption factors associated with the key foraging habitats, (III) To find potential correlations between the foraging activity and active Disruption on three microhabitats with e.g. time-based parameters (time of the day or tidal stage).

Therefore, the main research question of this study is: "*How are key foraging habitats used by Ringed Plover during early breeding season (April – early May) and what are the major Disruption factors on the beach of Oranjezon up to Banjaardstrand, the Netherlands?"*

To answer the main question, it is therefore divided into the following sub-questions:

Foraging behaviour

- *In what foraging habitat in the study area do Ringed Plover display foraging behaviour most frequently?*
- *Is there a difference in the occurrence of foraging behaviour display in the foraging habitats during the morning, afternoon or evening, tidal phases, or days with relatively high recreational activities?*

Disruption*:*

- *In what foraging habitat in the study area are Ringed Plover disrupted most frequently?*
- *By what Disruption factors are Ringed Plover disturbed in the foraging habitats most frequently?*
- *Is there a difference in the frequency of Disruption in the foraging habitats during the morning, afternoon or evening, tidal phases, or days with relatively high recreational activities?*

Prey type availability:

- *What macrozoobenthic prey types are available in the foraging habitats for Ringed Plover to utilize?*

Hypotheses

It is hypostasised that results will demonstrate that foraging activity occurrence is higher on freshly deposited wash-up as opposed to the winter flood-mark higher on the beach. Freshly deposited macrophytes may contain a higher density of prey and result in a more favourable foraging habitat. However, since the winter flood-mark is either in, or near the breeding habitat of Ringed Plover, non-foraging activity or general presence may be observed to be lower than on the intertidal area and fresh wash-up. Since macrozoobenthic activity is higher during the night (mainly Amphipods), it is expected to observe foraging activity during the night on fresh wash-up. Since beach visitors often walk alongside the waterline, disturbance is hypothesised to be higher on relatively crowded days during low tide on the intertidal area especially. The beach is narrower during high tide thus disturbance occurrence may be generally higher on all foraging habitats versus lower tides. Furthermore, it is hypothesised that results will show dogs without a leash and pedestrians to be at least a significant disturbance factor on all foraging habitats.

2. Theoretical Framework

Relevant projects

In recent years, projects such as "Strandbroeders" and "Groene Stranden" have been initiated to undertake measures intended to push the conservation of beach-nesting birds and the natural value of beaches in the Netherlands forward. The ongoing project titled "Het Groene Strand", translated: "The Green Beach" of LandschappenNL is initiated to recover the natural value of a 200-kilometre length of beach. With the collective of provincial Landscape-organisations cooperating with Stichting Duinbehoud, IVN and Stichting Anemoon, Landschappen NL aims to change the current beach management and increase awareness for natural beaches by organising beach communities including local residents, municipalities and entrepreneurs. Areas will be designated for beach-nesting birds, and citizen scientists will monitor the development of key species associated with natural beaches. The project is expected to increase biodiversity on the green beaches.

Breeding and diet Ringed Plover

The Ringed Plover (Charadrius Hiaticula), aliased Common Ringed plover, is a small wader that typically breeds solitaire. However, several pairs may share a particularly suitable habitat. Ringed Plovers breed on the highest bear areas of a beach (rich with shells), saltmarsh, primary dunes, alongside dykes, sand supplements, and inland "karrevelden" – the dug-out clay area behind a dyke to construct it – and seldomly on farmland. One season may include two to three broods with an average of four eggs (Arts & Meininger, 1998). Ringed Plovers feed in a typical stop-run-peck manner like most species of Charadrius genus, rather than traditional strategies like probing the sediment by other wader species. They detect prey visually for several seconds while standing still. The time spent standing still varies with parameters such as respective site, weather conditions and prey type (Pienkowski, 1981, 1983), after which they run towards a new "searching position" or a location followed by a fast peck at prey. The eyes of Ringed Plover are set on the sides of the head and have good binocular vision, allowing view of a wide angle. This may be adaptations for specialization in visual foraging (Pienkowski, 1983). The diet of Ringed Plover consists primarily of (bristle) worms (Polychaetes). Pienkowski (1982) showed that the diet of Ringed Plover feeding on high flats of Lindisfarne, Great Britain consisted of on thin small worms like Scoloplos and Notomastus (44% of total energy intake) whole Areniaola (30%), and on low flats Scoloplos and Notomastus (75%), whole Areniaola (13%) and small prey (10%). Perez-Hurtado et. al. (1997) found that Ringed Plover foraged in dried up fishponds from which the water had just been removed, enabling Ringed Plover to access benthic resources. Although in small portions, droppings that were found included artifacts of *Crustaceans*, *Coleoptera* and *Diptera.* Thus, it is possible

Perez-Hurtado et. al. investigated the diet of a number of wader, including Ringed Plover. She found that the diet included *Diptera* and *Coleoptera* in moderate proportions, and *Crustaceans* in small proportions in dried up fishponds, and mudflats. Scientific reporting of the diet and habitat use of Ringed Plover is scarce and results of other studies may only be locally relevant, as circumstances may differ greatly from the situation on breeding pairs on sandy beaches in the Netherlands.

Ringed Plover are known to use foot-trembling behaviour while foraging (Astley 1923, Coleman 1960, Simmons 1961a, Redshaw 1980). B. C. Osborne (1982), investigated the effects of foot-trembling by Ringed Plover on prey behaviour and substrate characteristics. It was found that foot trembling was used on substrates where prey occur on the surface in a thin film of silt or clay. The trembling causes prey to move, so that it is detectable for Ringed Plover, and that it is unlikely used to stir up the substrate and prey in it.

Wash-up

Particularly during Autumn and winter storms, but also after regular high tide, detached algae deposit, sometimes great quantities, of algae on the Dutch coast. The algae often originate from nearby, e.g. (*Fucus*), *(Ascophyllum),* zeesla *(Ulva)* en darmwier *(Enteromorpha),* but also from water further away e.g. the occasionally high masses of *Himanthalia* growing in the Strait of Dover (Cadée, 2014). The decay of organic was-up by decomposers and withering caused by exposure to the atmosphere and weather starts immediately after deposition by the tides (Cadée, 2014). Beach hoppers (*Amphipoda*) and herbivore kelp flies (*Coelopidae*) consume the algae, and mites (*Acari*) and springtails (*Collembola*) consume the bacteria and fungi breaking down the organic material. In turn, these organisms provide food for higher trophic levels. In addition, the fertilization of the sand allows vegetation to grow and dunes to develop, transforming the ecological desert into a natural area housing habitat for a high biodiversity (Cadée, 2014; Lercari et al., 2010; Colombini & Chelazzi, 2003). The thick algae layer provides a unique microclimate with a higher temperatures and humidity than the surroundings (Dobson, 1976). Dobson measured temperatures of 40 degrees Celsius at a depth of 10 – 20 cm in wash-up covered by snow. An active population maggots and larvae of *Coelopa* sp., a wash-up fly. Animal carcasses washed ashore, especially after storms, include jellyfish, shellfish, starfish, seabirds and mammals. In the Netherlands, the latter two are collected for research purposes, and to prevent unpleasant odours on the highly recreational areas. The compacter heavy biomasses often mean deposition lower on the beach. Jellyfish, one of the major contributors of animal protein washed ashore with the wash-up, consist 98% of water, and are consumed by Isopoda until they are withered by the sun (Cadée, 2014). Shellfish wash ashore in great numbers when a mass death takes place, especially the invasive Atlantic jackknife clam *(Ensis directus)* from the North Sea. Shellfish provide food for European Herring Gull *(Larus argentatus)* and other birds (Cadée 2001). Animal material that washes ashore is often more temporal compared to the algae masses due to the large numbers of predators and scavengers attracted to it. The plant material washed ashore by the previous high tide is still moist and especially attracts *Amphipoda* (Cadée, 2014; Cowles, at al., 2009). At low tide, plant material quickly withers, a process more pronounced by the warmth of the sun. In thick algae masses only the exposed top layer wither, creating a protective crest that allows rotting processes to occur in underlaying algae. *Amphipoda* find food in the rotting masses during night-time and are dug into the sand below the wash-up during daytime to prevent dehydration. Every new high tide the algae masses are transported higher on the beach (in the case increasing tides – neap tide to spring tide). As time advances it is thus less reached by seawater, and it is mixed and buried with sand. At spring tide or extreme high water due to a North-western storm at the Dutch coast, the wash-up is transported to where it aggregates in sheltered patches. After such events, contact with seawater almost ceases and only precipitation keeps it moist, where mostly only terrestrial fauna components exist. These storm/spring tide marks provide fertile soil for pioneer vegetation e.g. *Atriplicetum littoralis*, including mainly annual vegetation e.g. *Atriplex littoralis* and *Atriplex prostrata* (Cadée, 2014; 2011).

Polychaetes on the intertidal area

A study by Omena & Amaral in 2003 investigated the morphodynamic and polychaete fauna on sandy beaches and found that sites with the greatest organic matter and silt-clay content had the highest diversity and abundance of polychaetes. Thus, density, diversity and evenness of polychaetes are affected by grain size, tidal range, slope profile and moister content. The coarse sand and the presence of deep tideways and gullies indicate a relatively dynamic intertidal area, which may explain low abundance of polychaetes that generally prefer finer sediments like clay or silt (Omena & Amaral, 2003.

Importance of beach-wash-up to shorebirds

Wader species are known to traditionally forage on the intertidal area, where macrozoobenthic prey is easier accessible during a retrieving tide (ebbing). Ringed Plovers, however, feed in a typical stop-run-peck manner like most species of Charadrius genus, rather than traditional strategies like probing the sediment by other wader species (Pienkowski, 1980). Because of this, use of foraging habitat by Plovers can expected to be different from most other wader species as well. A gap of knowledge exists on the importance of different foraging habitat of Plovers breeding in the Netherlands, and literature seems to lack scientific documenting of habitat use and prey type preferences. Moreover, because such studies may be only locally relevant, findings may be inappropriate for implementation in Dutch beach-management or beach-nesting bird conservation strategies. Deposited macrophytes supporting prey resources are commonly exploited by shorebirds and seems to be especially important to Plovers elsewhere in the world. Several studies have reported higher densities of Plovers or other shorebirds in areas with high quantities of macrophytes washed onto shores. Kirkman & Kendrik (1997), for example, found that the Hooded Plover (*Charadrius rubicollis*) was more abundant around high quantities of deposited macrophytes. Plovers were observed nesting close to the deposits in small depressions in the sand. Schulz & Bamford (1987) showed that Hooded Plover were actively feeding on *crustaceans, molluscs*, insects and *polychaetas* directly associated with the beach-wash-up. Shorebird species were observed to be more numerous at beaches with large amounts of kelp and supported a higher biomass (75%) of potential prey species compared to beaches without kelp deposits (Tarr et al. 1985). A relationship has been suggested between migratory shorebirds and wash-up-associated macrozoobenthos, especially Semipalmated Plover (*Charadrius semipalmatus*) that prefers *Amphipoda* prey species, in a study carried out in Baja, California by Lopez-Uriate et al. (1997). In addition, macrophytes washed onto shore by the retrieving waterline and deposited in the intertidal area were shown to be important for Brent Goose (*Branta bernicla)*. They showed a direct relationship between the distribution these geese and the density of macrophytes. Because food intake seemed to decline rapidly with a decreasing available food biomass through the season, the birds countered this with foraging at night. Even though geese feeding strategies and diet are fundamentally different from foraging ecology of Plovers, the study does show that there seem to be more ways higher densities of beach-wash-up may increase natural value on beach areas. It also shows how birds may adapt by foraging at night-time.

The literature review yielded little findings about the significance of beach-wash-up on Plovers breeding in the Netherlands seems to be lacking, except for an internal report of Vogelbescherming Nederland by I. Tulp in 1997. Tulp investigated the factors responsible for the low reproductive success of Kentish Plovers and Ringed Plover on Terschelling, Vlieland and het Griend (Dutch Waddensea area). Although no systematic measurements have been done in relation to food availability for chicks, the author noted hints of a high variation of food resources of the chicks per location were evident. No systematic methodology has been used to measure prey type abundance, but the author noted that abundance of insects on the fresh beach-wash-up which is still moist seemed to be highest. The older beach-wash-up, or the storm-tide mark higher on the beach being withered and dried up, appear less favourable for the chicks.

3. Methodology

3.1 Project area

The project area is located on the north-west coast of Walcheren (see figure 1). The project area is divided into two main areas: A series of 4 plots on the Veerse Gatdam – Banjaard (total of 110 Ha) and an additional series of 4 on the western side of Oranjezon (total of 48 Ha). Figure 2 below shows a map with exact the location of the plot series.

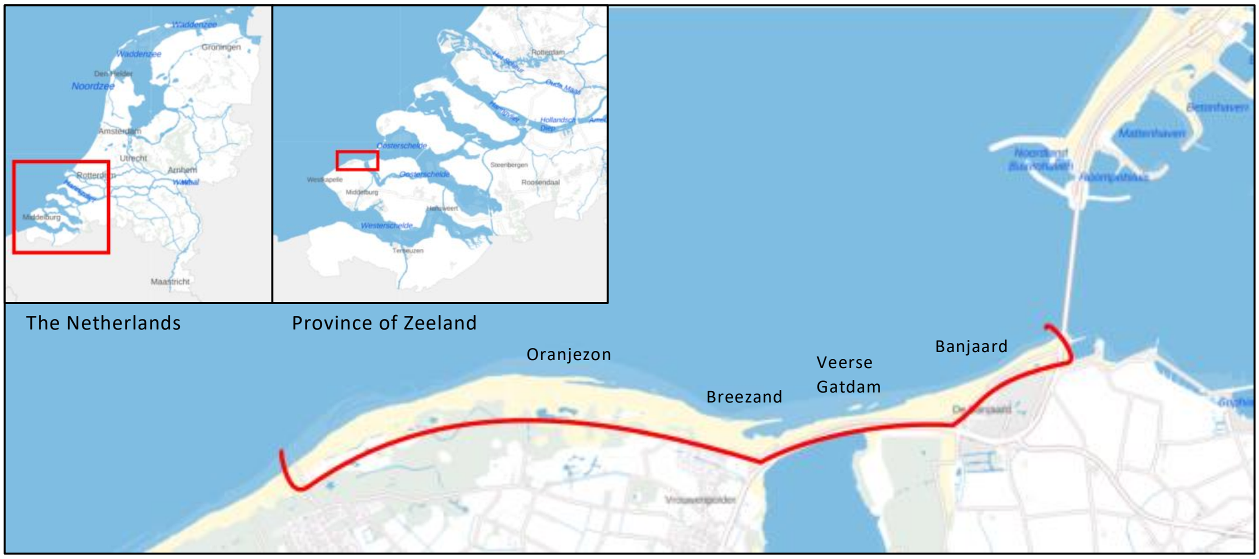

Fig 1: Map of project area and included beach areas

Figure 2: Map of two plot series locations

Veerse Gatdam - Banjaardstrand

All beach areas in the study area are sandy beaches with a recreational purpose publicly accessible. The Banjaardstrand is the most northerly beach and typed a tideway beach by the Province of Zeeland, which is characterised by a deep foreshore, shallow dunes as functional water barrage, and a hinterland with rural and recreational purpose (Provincie Zeeland, 2012). The beach is relatively narrow on the eastern side, a wider beach and tideways are present at the western side. No embryonic dunes are present, but a stretch of white dunes is present on the eastern side (see appendix 1, page 43). An area in the dunes near one of the two main entrances has been cleared and fenced to create quite area for breeding Little Terns with what seems to be potential breeding habitat for Ringed Plover (see figure 4). Recreational intensity, as shown in Appendix 2 on page 45, is moderate to high at the Banjaardstrand. There is a beach pavilion present at the main entrance, and four extra entrances. Arrays of beach huts are present during the main recreational season. The Veerse Gatdam is a dam that closed of the Veerse Gat in 1961, and thus typed a manmade structure (Provincie Zeeland, 2012). The beach in front of it is relatively wide with steep tideways. On the eastern a long stretch of white dunes, and a small patch of embryonic dunes (see appendix 1, page 43). There are five official beach entrances of which four have a beach pavilion. On the western side long arrays of beach huts are present during the main recreational season. The western side is commonly used for water sport activities e.g. windsurfing and kitesurfing.

Fig 3: Beach impression Banjaard 2020

Fig 4: Little Tern breeding area

Fig 5: Beach impression Veerse Gatdam 2020

Fig 6: White dunes at Veerse Gatdam 2020

Oranjezon is under management of Het Zeeuwse Landschap and is the peninsula headland of the Walcheren region. Island or peninsula headlands are characterised by a deep foreshore and broad dunes. The hinterland is a Natura 2000 area and included as a natural monument by the Society for preservation of nature monuments in the Netherlands (Natuurmonumenten). The beach includes three patches of white dunes and a stretch of embryonic dunes on the western side, a stretch of white dunes in the middle section and small patch of white dunes at the eastern side (Breezand) (see appendix 1, age 43). Recreational intensity, as shown in appendix 2, is moderate at the Eastern part of Oranjezon (Breezand), and relatively low on the Western part of Oranjezon (see appendix 1, page 44).

Figure 7: Impression beach Oranjezon

Figure 8: Potential breeding habitat Oranjezon

3.2 General research design

The design of this project involves a quantitative research method primarily based on observations. To determine the relative importance of key foraging habitats, the occurrence of foraging and Disruption is operationalised by systematised observations in the study area. Observation data will ultimately yield information such as l "when and how often birds are where doing what", which will be used to find potential correlations with e.g. time-based parameters and the general presence of Disruption factors. Gathering of data is therefore carried out on relatively crowded and quieter days (e.g. eastern from April 12 – 13); during several times of the day (morning, afternoon, evening); and during several phases of the tidal cycle. In addition, gathering observation data will also be planned at night. Although data gathering might be difficult or a different strategy may be adopted during night-time, this data may still be useful for supporting a broader sense of the data interpretation. Moreover, to assist explanation of foraging behaviour occurrence from observation data, the macrozoobenthic community of key foraging habitat will be sampled for potential prey types. The abundancy and type of prey available may help explain the occurrence of foraging behaviour on key habitats. Main activities are (I) observation of behaviour of breeding pairs with an established territory in the area, (II) monitoring Disruption factors and (III) sampling the three key foraging habitats for potential prey (macrozoobenthic communities). Fieldwork activities are carried out twice or three times a week from April to the first week of May 2020. Assistance with practical matters such as transportation of materials but also fieldwork activities may be granted by volunteers occasionally. The execution of the project will take place in the period of end of March until end of May 2020. If territories are established (likely during March), two sites will be selected considering distance to beach entrances, availability of suitable breeding habitat and general distribution over the three beaches. This will sign the start of the project as well. Three microhabitats are considered as key foraging habitats in this study: the storm tidemark (high on the beach, above the mean high-water line up to the embryonic dunes); the fresh hightide wash-up (just below most previous high-water line) and the intertidal area. These microhabitats are zones commonly used by Ringed Plover for foraging on beach areas during breeding season in other studies (Tulp, 1997; Pienkowski, 1982). Appendix 4 on page 47 gives an impression and description of the discussed foraging habitats.

3.3 FIELDWORK ACTIVITIES

General monitoring protocol

Observation data will be recorded using the application "Avimap" with the extension modified for this project but originally developed by Sovon for the project Oog voor het Wad. The app allows placement of an observation case on a map, within a pre-defined polygon during a time sample. Additional buttons and comment areas are used to fill in additional data with each observation. In addition to bird counts, the app also provides potential Disruptions as entries, for which additional buttons can be used to define whether a bird is actively disturbed and advanced information about the Disruption factor. The data will be collected using the app on location immediately after taking the time sample and will then be uploaded to a database administrated by Sovon and retrieved afterward for further processing and analysis. The application manual and the "Oog voor het Wad" project manual is referred to for specific instructions to use the application, as well as some guidelines for using it in the field. Monitoring behaviour and disturbance will be done in 5-minute time blocks, from a stationary outlook using a scope. The 5-minute time block will allow for reduced errors due to time limitations and therefore hasty, incorrect data entries, missing observations when entering data *during* the time block, as well as to counter for forgotten observations when entering data after a longer period. For each record, the following header data is filled out for monitoring behaviour and disruption: date; time; percentage wetted area; tidal phase and whether it is a holiday, work- or weekend -day.

Behaviour monitoring

Display of behaviour is operationalised as an observation entry on a map, along with additional information to specify the observation. The dynamic nature of the beach, especially the location of the fresh wash-up habitat, does not allow observation data to be linked to coordination data for the purpose of determining the use of foraging habitats. Therefore, it has been decided to label a habitat code on which a bird is present to an observation based on visual assessment instead. The following information is filled out in the application: number of birds; approximate location (coordinates); foraging habitat code and the prominent type of behaviour. The types of behaviour to be specified include: foraging (either stereotyped run-stop-search manner, or sandpiper-like); resting (if sitting, standing on one leg or with beak in feather visible); courtship (typical courtship behaviour or copulation); running (movement excluding foraging movement pattern) ; flying; grooming (including bathing in water); on nest (including on small depression in sand without eggs); other behaviour (when neither other types are applicable). The following foraging habitat types with respective codes are considered: spring tide mark = SM, fresh hightide wash-up = FW, Intertidal area = IA.

Disruption monitoring

Disruption and behaviour will be monitored simultaneously. Disruption factors are entered with the following additional information filled out in the application: amount and type of Disruption factor, approximate location (coordinates) and whether it causes Disruption behaviour of present birds (active Disruption). If the latter is applicable, it is specified whether Plovers are present on a foraging habitat, which foraging habitat as well as the effect of the Disruption. Disruption factors include all factors that are a potential Disruption for present Ringed Plover e.g. walking Dogs on leas, sun-bathing beach visitors, overflying drones, boats as well as foxes or birds of prey. A full list of the Disruption factors is shown in Appendix 3, but other factors may be added if observed. The effect of the Disruption is defined in the app as low (<1/3 of present birds react), moderate (1/3 – 2/3), strong (>2/3) or no effect. Because of the relatively low numbers of birds present (likely a maximum of 2 adults in territory + chicks), these categories are therefore translated as: low (some birds react) and strong (all birds react).

Prey type availability

This study will also investigate the macrozoobenthic potential prey types that are characteristic for the respective foraging habitats. Sediment and wash-up samples will be taken to provide insight on the available prey types in each habitat. Considered prey types are: *Polychaetes* (bristle worms), *Amphipoda*, *Caridea* (shrimp), *Caleoptera* (beetles) and *Diptera* (flies), differentiating between pupae, larvae and imago of *Caleoptera* and *Diptera*. These potential prey types are considered for their apparent significant portion in Ringed Plover diet (Perez-Hurtado, 1997; Pienkowski, 1982) and hypothesised availability in the project area. Relative abundance is categorised as 0, 0-3; 3-6; 6-10; 10-15; 15-25; 25-50; 50-100; 100-200 and >200 within prey species group. These abundance categories are chosen considering the abundance of samples taken during reconnaissance. The abundance categories allow differentiation between the significance of relatively low abundance (counted range 0 – 4) of some prey species groups compared to no abundance, and the relatively high numbers (counted range 84 - >220) resulting from the reconnaissance. To sample the fresh wash-up and storm/spring tide mark the abundance of each prey type is estimated in a 0.5m^2 quadrant placed on the sample location. Prey types will be looked for with the aid of tweezers, binoculars, sample treys, scrapers etc. Amphipoda as well as Diptera in Imago will be sampled separately. Amphipoda tend to be dug into substrate and because of practical reasons I is difficult to assess wash-up and the top sediment layer of 2 cm simultaneously. Some Diptera may fly out of the quadrant when disturbed thus flying Diptera abundance is estimated visually walking a 20m track along the habitat. Similar to the observation protocol, the location of habitat for determining sample locations will be visually assessed for all foraging habitats. A picture will be taken of the quadrant (or track) and it's surrounding with a label of the sample visible in the photo for each sample location. Sampling the intertidal area will be done as the tide goes out (between LW-3 and LW). Although Ringed Plover may forage on the intertidal area as the tide rises as well, a tide that goes out is generally considered the main foraging time of most waders foraging on sandy beaches. Sample locations are evenly distributed long three transects from the last highwater line to the current water line. Sediment will be sampled with a hand-made PVC sampling tube of 10 cm in diameter, up to a depth of 15 cm. The amount of visually observable worm holes in the quadrant will be counted and written down separately.

4. Results

Two breeding pairs in Oranjezon, and three breeding pairs in Veerse Gatdam / Banjaard occupied territories within the plots during the project. In both areas one breeding attempt has been registered. Observation activities generated roughly 300 records distributed over approximately 15 days during a period of five weeks (March 27th – May 3rd). The encounter rate of at least one Ringed Plover during a 5 min record was approximately 50%. The encounters ranged from 1 to 6 Ringed Plover with an overall average of 2 per record. Figure 9 below and figure 10 on the next page show the spatial distribution of Ringed Plovers in both areas. The overall density at the Oranjezon (2.8 RP/48 Ha) is twice as high as at Veerse Gatdam – Banjaard area (1.4 RP/110 Ha).

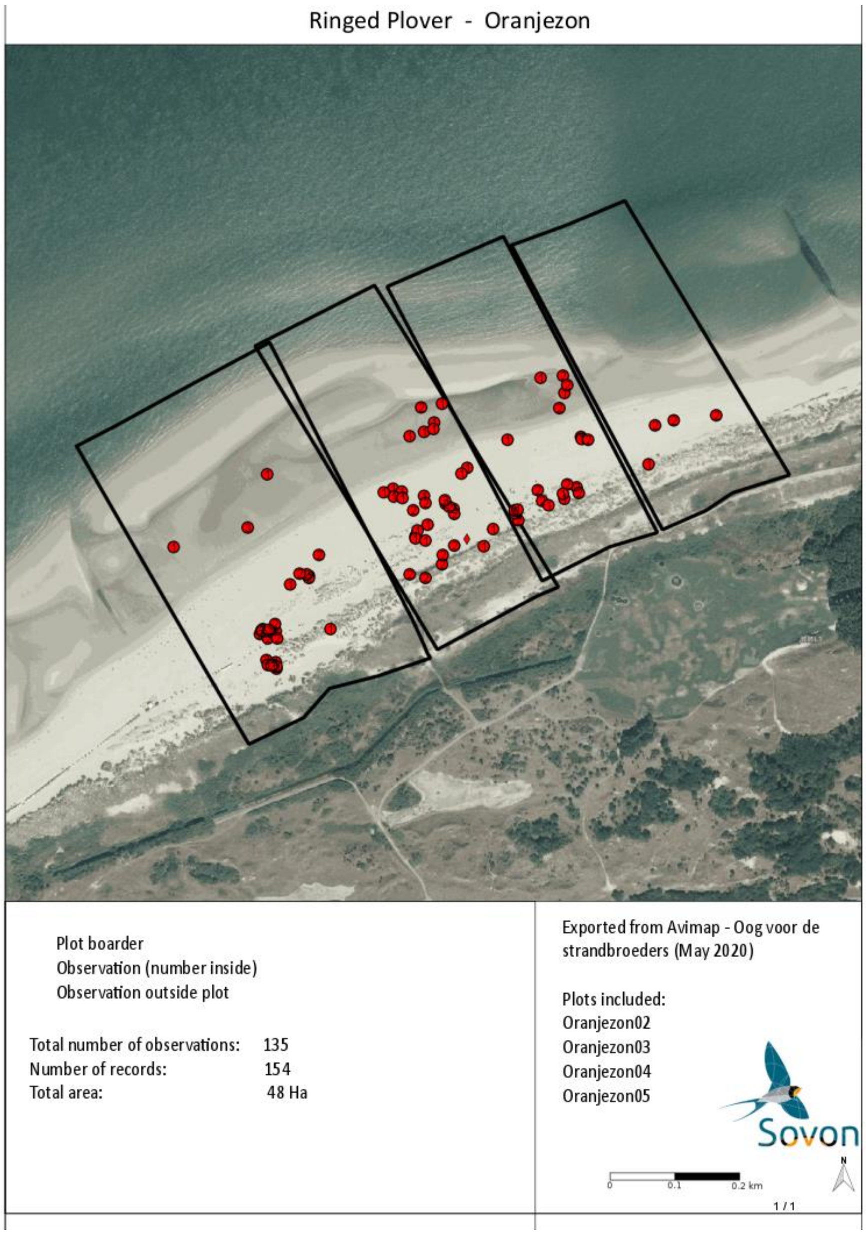

Figure 9: Map of Ringed Plover observations in Oranjezon area

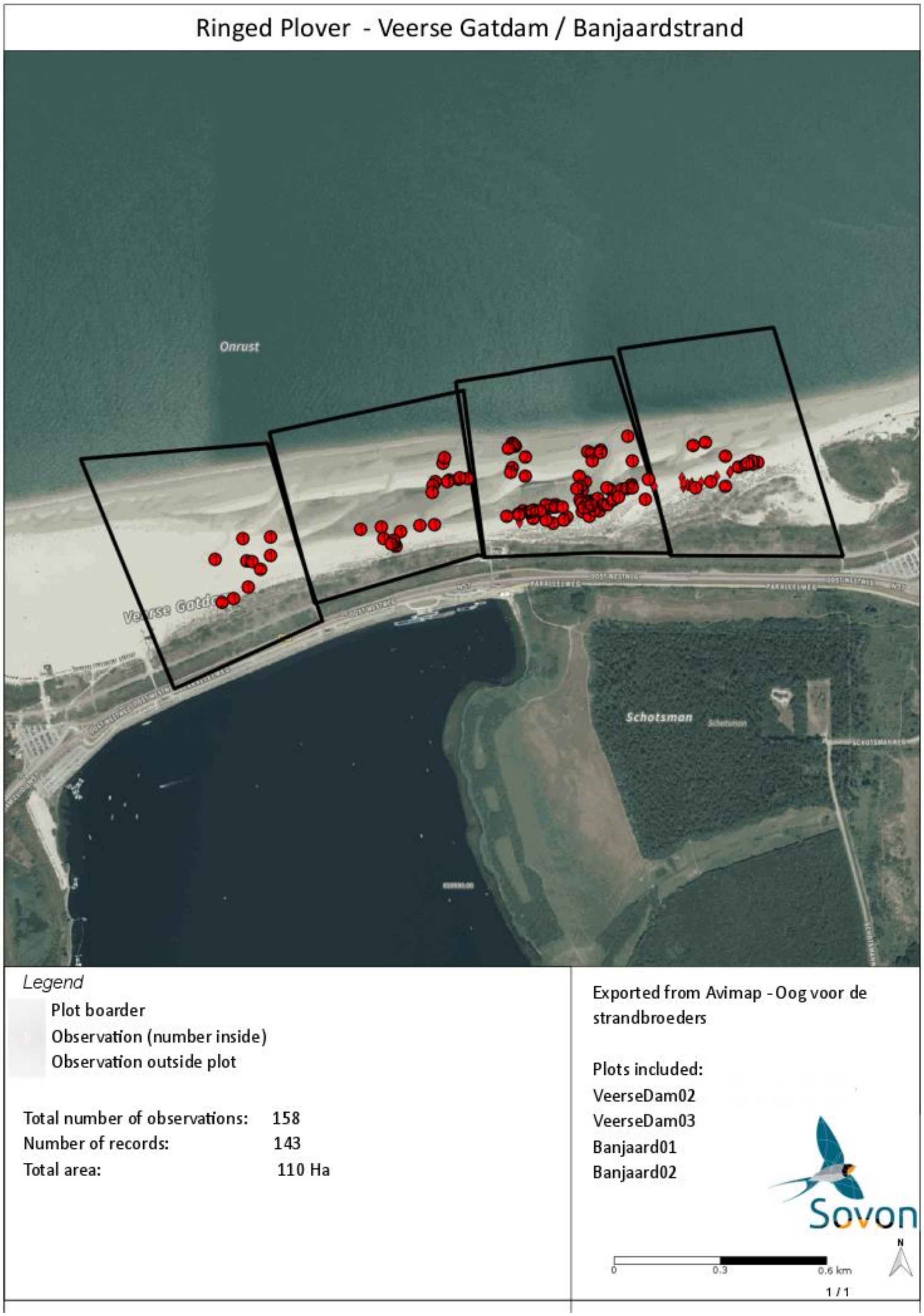

Figure 10: Map of Ringed Plover observations in Veerse Gatdam – Banjaardstrand area

4.1 FORAGING ACTIVITY AND HABITAT USE

Presence and activity in relation to key habitats

The general presence of Ringed Plover was highest in the winter flood-mark habitat (127), followed by the intertidal area (78), and lowest on the fresh wash-up (65), see figure 11 A below. The fraction of the sum of all observations per habitat is winter flood-mark = 41.3%, intertidal area = 25.4% and fresh wash-up = 21.2%. Plovers displayed foraging behaviour in 29.6 percent of all encounters. A Ringed Plover displaying foraging activity was observed most in the intertidal area (49), followed by the fresh wash-up (23) and lowest in the winter flood-mark (19), see figure 11. The fraction of the sum of all foraging activity observed during the study is intertidal area = 53.8%, Fresh Wash-up = 25.3%, Winter Flood-mark = 20.9%. Noticeable is the high frequency of overall presence of Ringed Plover compared to the lower frequency of foraging activity on the winter flood-mark habitat. Figure 12 shows the percentage of an activity observed on the respective habitat (presence on habitat = 100%). The fraction of foraging activity from all time spend on the respective habitat is highest on the intertidal area (80.3%), followed by the fresh wash-up (56.1%) and lowest on the winter flood-mark (21.8%). All habitats are primarily used for resting aside from foraging, the highest fraction of resting was observed on the fresh wash-up (77.8%) and the winter flood-mark (77.6%) and lowest on the intertidal area (58.3%) and miscellaneous habitat (55.6%). Noticeable is that running was not observed in the intertidal area, and highest on the fresh wash-up (11.1%). Habitat that is not considered in this study but is present in the study area (e.g. dunes or during flight) is represented by the miscellaneous habitat. These habitats are not known as foraging habitats, and for practical reasons it was impossible to record behaviour properly or considered inappropriate for the scope of this study. Therefore, foraging activity on these habitats is not recorded.

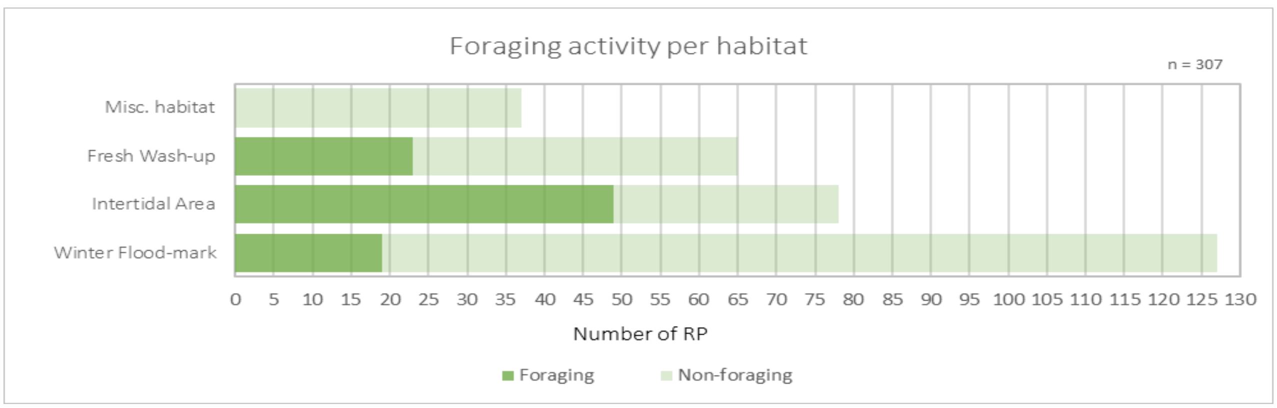

Figure 11: Graph showing the foraging activity distributed over the (foraging) habitats. X-axis represents number of Ringed Plover displaying foraging behaviour during a record.

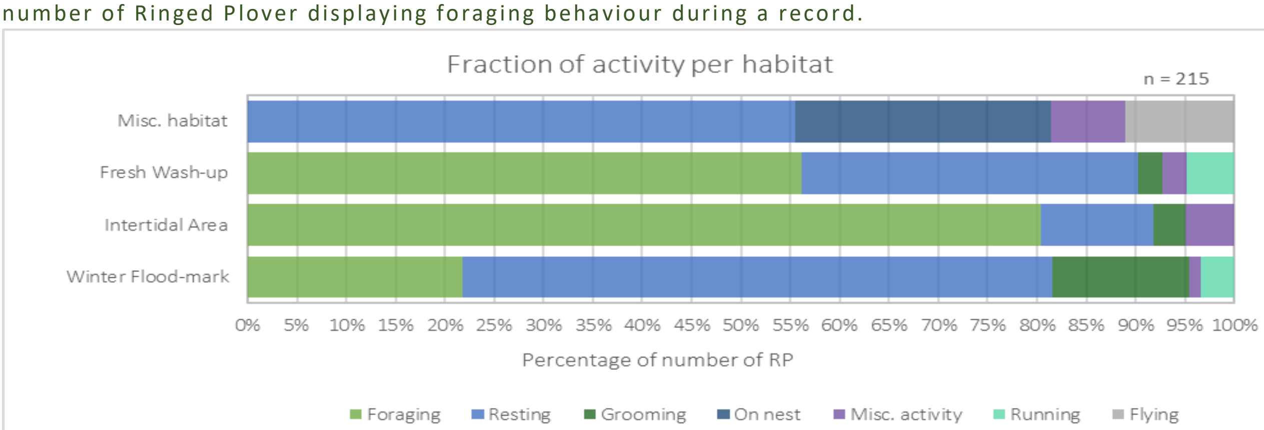

Figure 12: Graph showing the fraction of all activities per habitat. X-axis represents percentage of the number of Ringed Plover and the activity observed.

Foraging activity in relation to period of the day

Figure 13 shows that the percentage of foraging activity was highest during the night (54.5% of all observations during that period) followed by the evening (50.0%), the afternoon (26.5%) and lowest during the morning (19.8%). In figure 14 on the next page can be seen that the percentage of foraging activity from all records in the morning was highest in the intertidal area (69.0%), and lowest at the winter flood-mark (5.3%) and fresh wash-up (7.7%). In the afternoon, the percentage of foraging activity is highest at the fresh wash-up (80.0%), and lowest at the winter flood-mark (23.5%). In the evening, the percentage is highest on the intertidal area (66.75), followed by the fresh wash-up (44.0%) and winter flood-mark (0%). The percentage of foraging activity on the winter flood-mark was highest in the afternoon, and lowest in the evening. For the fresh wash-up, foraging activity is highest in the afternoon and lowest in the morning. For the intertidal area this is highest in the morning, and lowest in the afternoon. Observations during the night were gathered using a somewhat different strategy (described in Chapter 3, page 17). Results during the night can therefore only be compared with other results without regard to the different habitats and is thus not included in figure 14. Note that figure 14 does not show the percentage of foraging activity observed on a habitat from all records during that period. Nor does it show the percentage of foraging activity observed during a period from all observations on a certain habitat. The percentages per habitat or period do not add up to 100%.

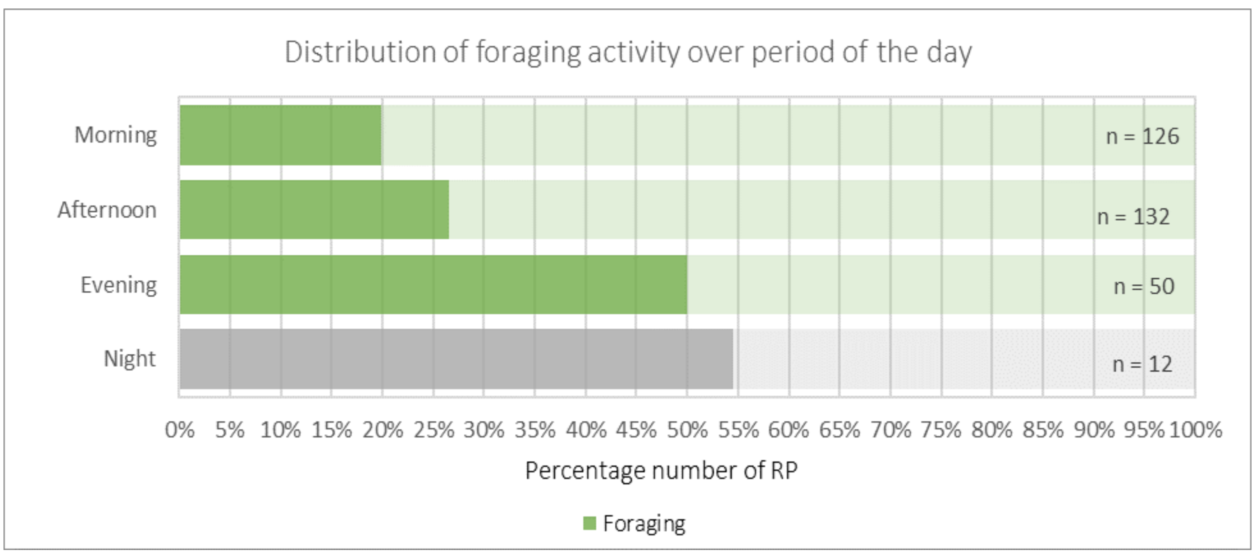

Figure 13: Graph showing the percentage of RP displaying foraging behaviour of the total number of RP observed during four periods of the day. The x-axis represents the percentage of number of Ringed Plover observed during that respective period. The n figure shown in the graph shows the total number of observations during each period.

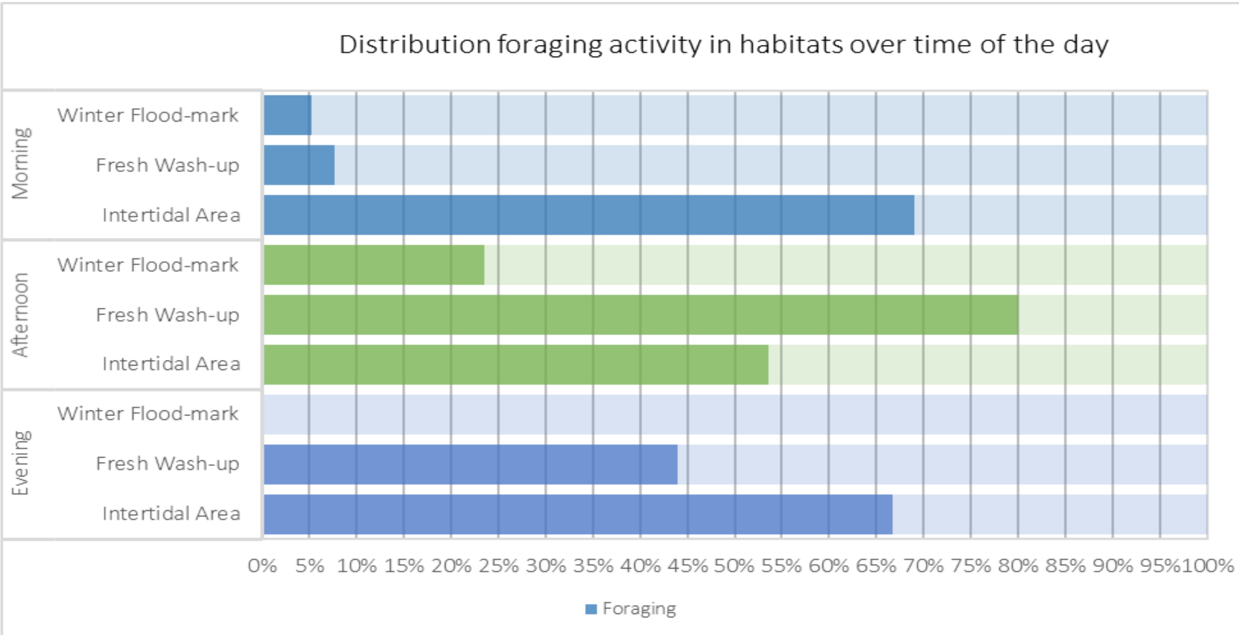

Figure 14: Graph showing the percentage of RP displaying foraging behaviour distributed over the habitats per periods: morning = 5:00 – 11:55, afternoon = 12:00 – 17:55 and Evening = 18:00 – 21:30. $N_{morning}$ = 112, $n_{afternoon}$ = 101 and $n_{evening}$ = 47.

Foraging activity in relation to the tidal cycle

In figure 15 on the next page can be seen that one hour after high water the percentage of the total number of Plover foraging during was highest (75.0%), and lowest during high water and two hours after low water. The percentage of foraging Ringed Plover observed during high water was relatively low, rises significantly after one hour (34.6%) and when the tide retracts (ebbing) and is almost five times as high during one hour before low water (50.0%). The percentage of foraging Ringed Plover is moderately high (39.5%) and fluctuates with a sudden peak at three hours after low tide (39.3%) and one hour before high tide (75.0%) and decreases again to high water. Figure 16 shows that foraging activity was somewhat higher during ebbing (HW – LW) compared to rising tide (LW - HW).

Figure 17 on the next page shows what habitat ringed plover were observed foraging on during the four main periods of the tidal cycle. Roughly the same pattern can be observed for the hight of percentage of foraging activity per habitat over the four tidal periods: Highest is the intertidal area, followed by fresh wash-up and lowest on the winter flood-mark. The percentage of foraging activity on the intertidal area is highest during the high and ebbing period (75.0%), followed by the rising water period (66.7%) and lowest during the low-water period (51.4). For the fresh wash-up, the percentage of foraging activity is highest during the rising period (62.5%), followed by high water period (50.0%), low water period (28.0%) and lowest during the ebbing period (25.0%). The highest percentage on the winter flood-mark is during the high-water period (19.4%), followed by the low-water period (16.7%) and the ebbing period (15.9%), and lowest during the rising water period (8.6%). Noticeably is that the hight of the percentage on the fresh wash-up is relatively high during the rising water period compared to the fresh wash-up during other periods as well as the other habitats during the rising water period. On the contrary, the percentages are lowest for both the winter flood-mark and intertidal area during the rising water period compared to other periods.

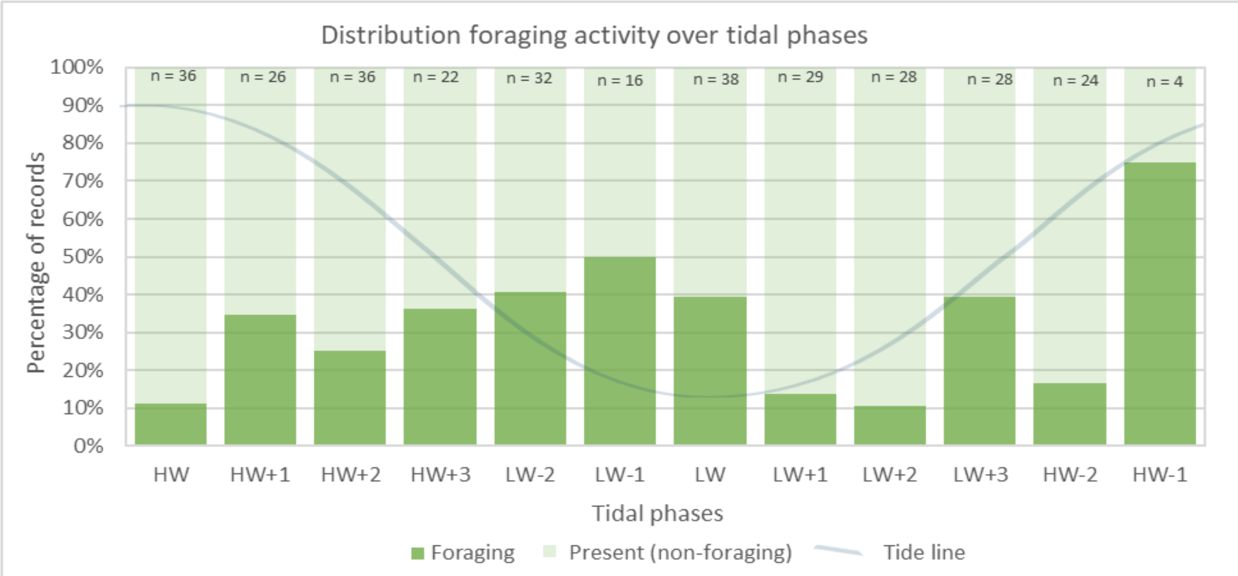

Figure 15: Graph showing the percentage of foraging activity observed on all habitats distributed over the 12 phases in the tidal cycle. HW = high water, LW = low water, -X and +X = number of hours prior to and after low of high water. The n figure shown in the graph shows the total number of observations during each tidal phase.

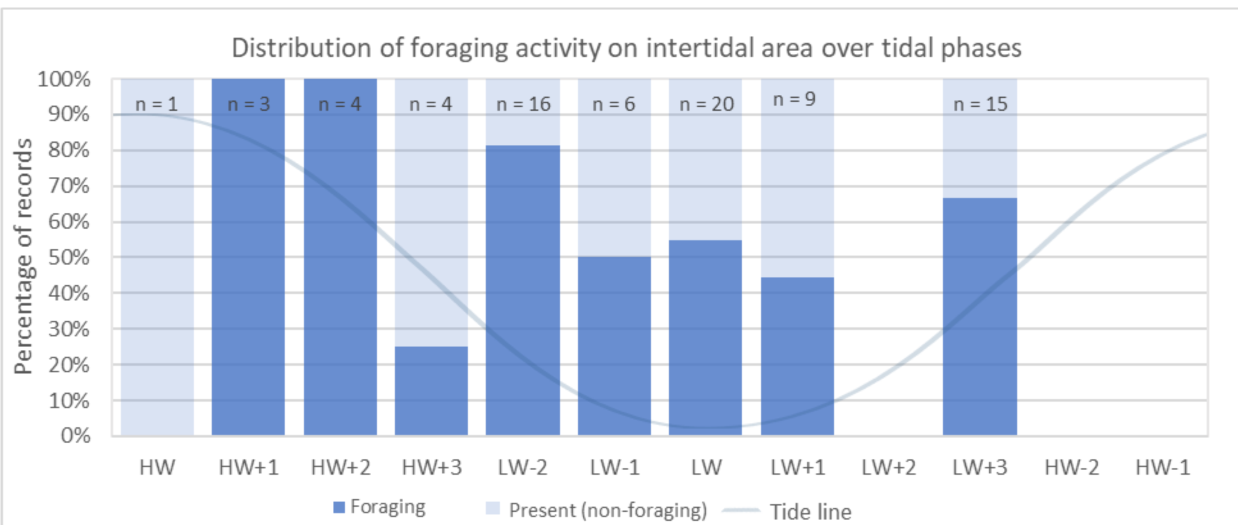

Figure 16: Graph showing the percentage of foraging activity observed on the intertidal area distributed over the 12 phases in the tidal cycle. HW = high water, LW = low water, -X and +X = number of hours prior to and after low of high water. The n figure shown in the graph shows the total number of observations on the intertidal area during each tidal phase.

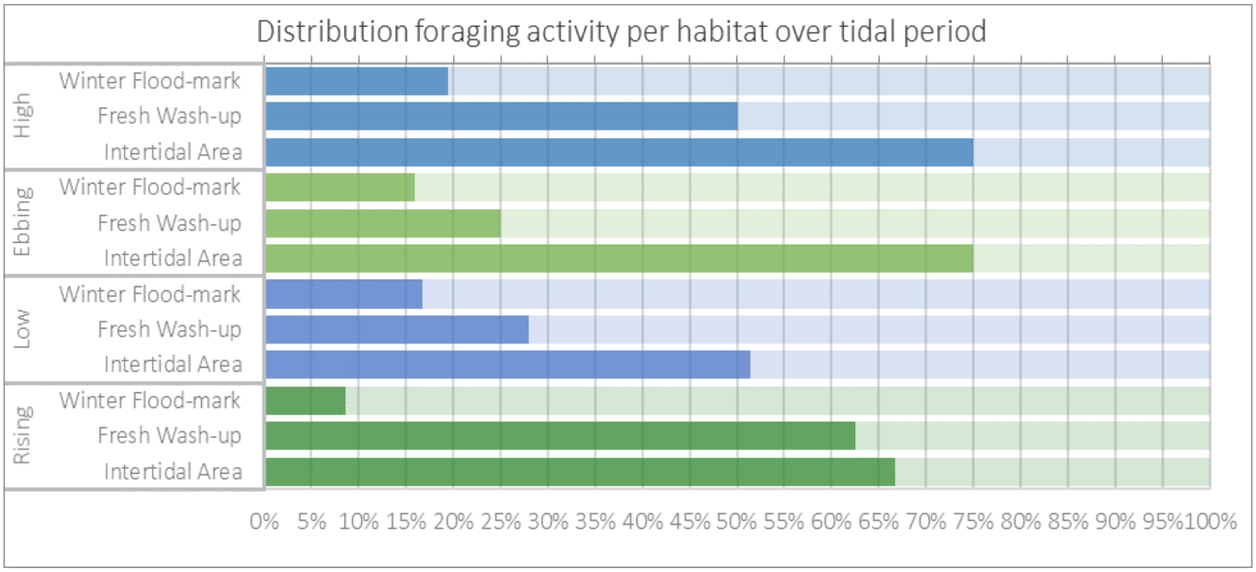

Figure 17: Graph showing the percentage of foraging activity observed during four periods in the tidal cycle, over the key foraging habitats. High = high tide one hour before until one hour after high water, Ebbing = retracting tide from one hour after high water until one hour before low water, Low = one hour before low water until one hour after low water, Rising = from one hour after low water until one hour before high water.

4.2 POTENTIAL DISTURBANCE FACTORS

Disruption factors

Disruption factors were present in 53.2% (185 records) of the total number of records. Figure 18 shows the sum of the number of potential disturbance factor present taken from all records on each habitat. Presence of potential disturbance factors is highest on the intertidal area (110), followed by the dune area, fresh wash-up and lowest at the winter flood-mark.

The top 5 most abundant potential disturbance factors in order are: Pedestrians, stationary beach-visitors, fisherman, dogs without a leash and horse-back riders (see figure 19). Notable is the low abundance in predatory disturbance factors. Pedestrians were present on all key habitats, most notably on the intertidal area and fresh wash-up. Stationary beach visitors were significantly abundant in the dune area. Fisherman were only present in the intertidal area and fresh wash-up, and dogs without a leash in all habitats, of which the intertidal area the highest presence.

Figure 20 shows that horse-back rides were most abundant in the intertidal area, and other than that only on the fresh wash-up. The most common potential disturbance factor on the winter flood-mark was pedestrians, followed by stationary beach-visitors and dogs without a leash. On the fresh wash-up, the most common is pedestrian and second stationary beach-visitor as well, followed by fishermen. On the intertidal area, the most common is pedestrians as well, followed by fisherman and horse-back riders. Notable is that the intertidal area is the only habitat where Red Fox was present.

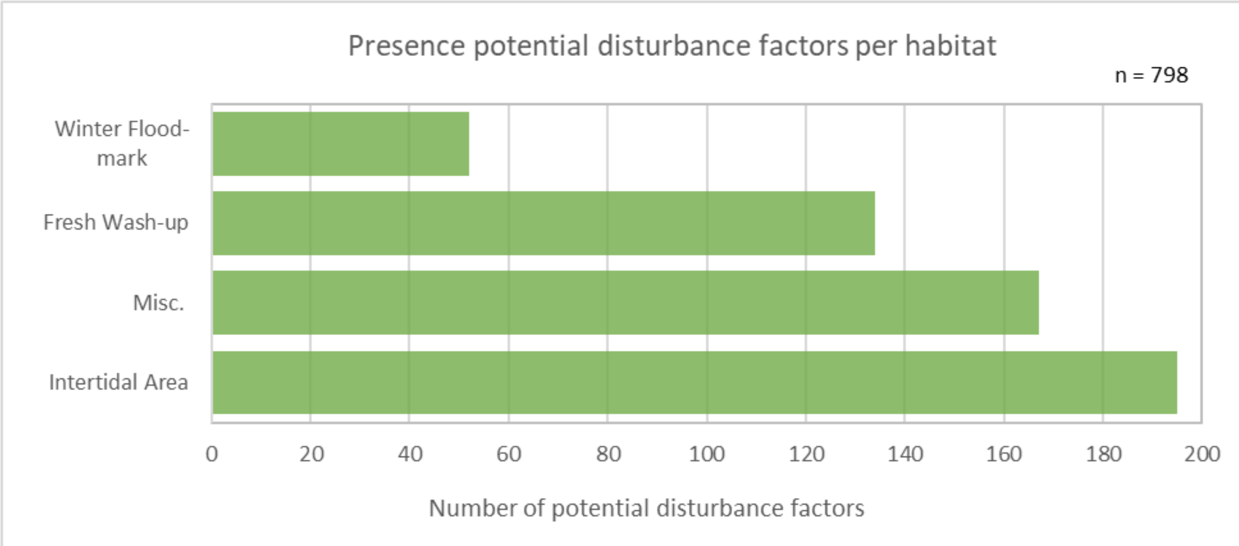

Figure 18: Graph showing the general presence of disturbance factors on key habitats, and the number of present disturbance factors active in disturbance of Ringed Plover.

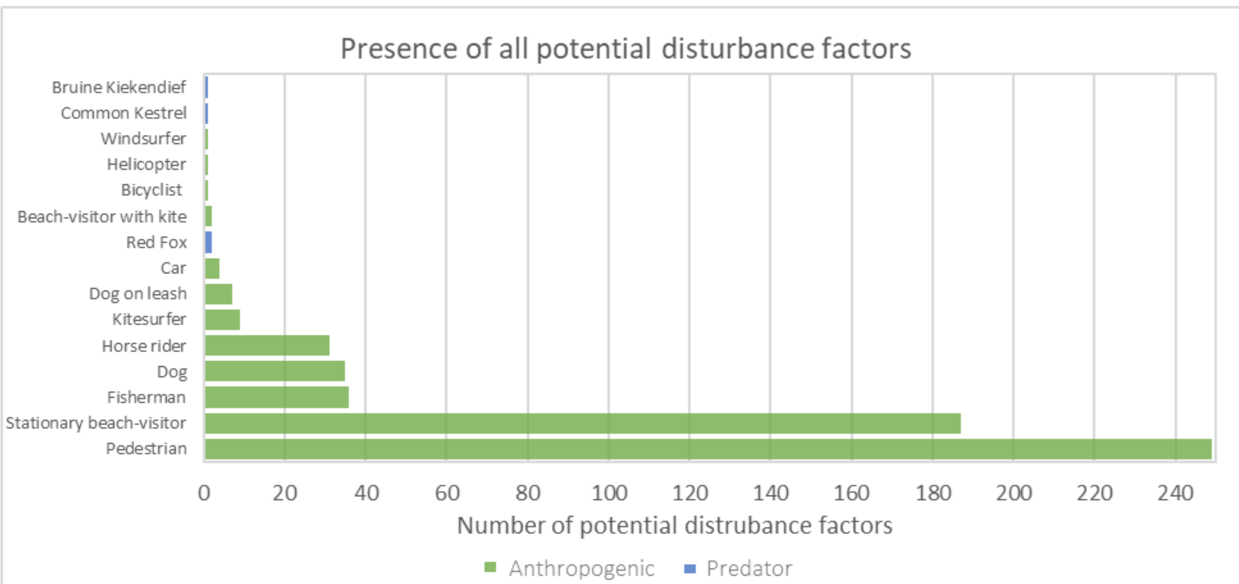

Figure 19: Graph showing the presence of the sum of potential disturbance factors. n = 798.

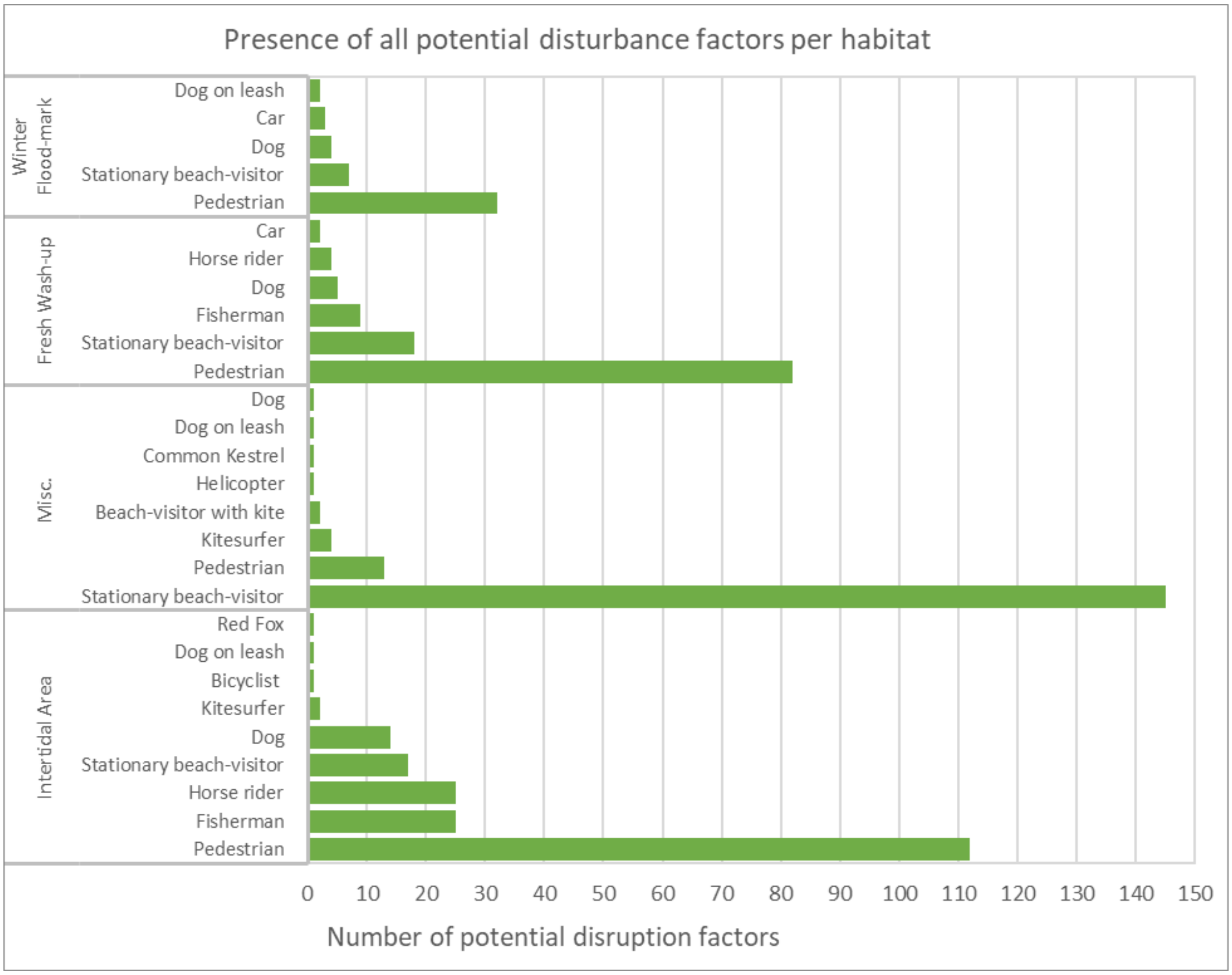

Figure 20: Graph showing the number of present potential disturbance factors distributed over the habitats. n = 798.

Disruption factors in relation to time-based parameters

Figure 21 shows the percentage of the number of records in which a potential disturbance factor was present of all records in the respective period. The highest percentage of records where a potential disturbance factor was present was during the evening, and lowest in the morning. In the evening, most disturbance factors were present on the fresh wash-up, or otherwise the winter flood-mark. In the afternoon, presence was somewhat distributed over all habitats, but highest in the dune area. In the morning, the percentage was highest on the intertidal area, followed by the fresh wash-up and dune area. Overall, presence on the fresh wash-up was highest during the evening, and almost equally during the morning and afternoon. The intertidal area was visited most frequently during the morning, followed by the afternoon, and never in the evening. The winter-flood mark was visited most frequently in the evening, but almost as high during the afternoon. In figure 22 can be seen that there is generally no relation between the total number of records where a potential disturbance factor was present and the tidal cycle. Presence on the beach was significantly higher on the intertidal area and lower for the habitats higher up the beach during lower tides.

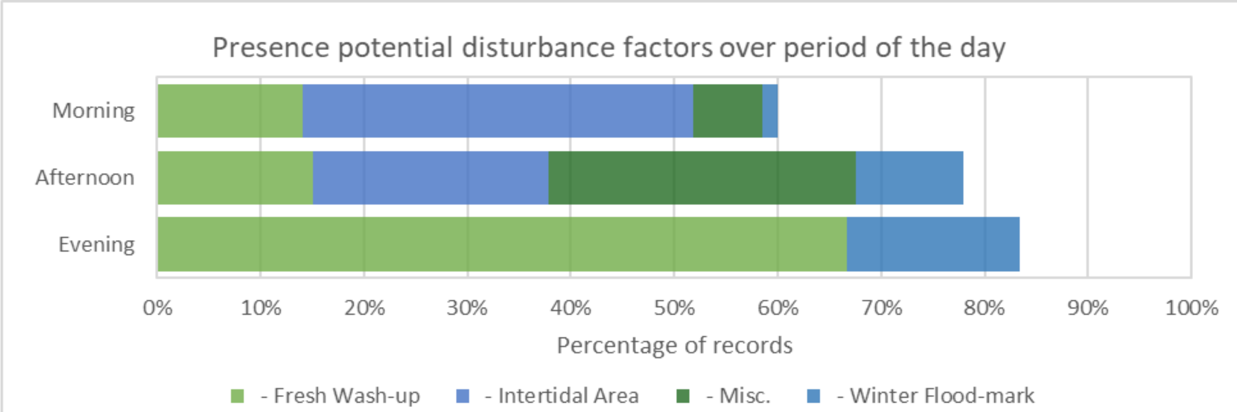

Figure 21: Graph showing the presence of potential disturbance factors distributed over the period of the day.n = 798.

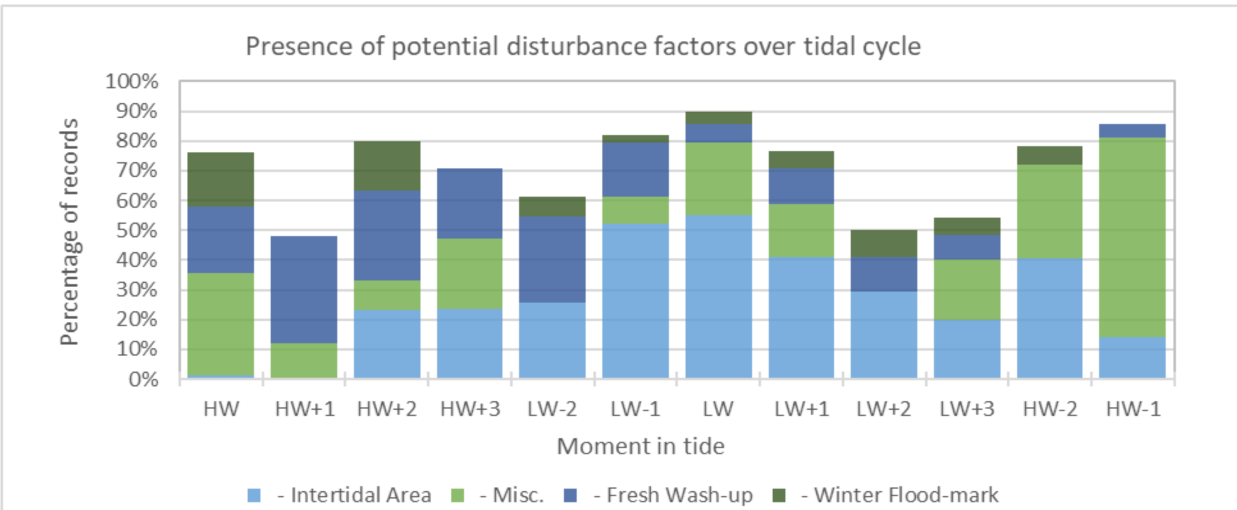

Figure 22: Graph showing the presence of potential disturbance factors distributed over the 12 phases in the tidal cycle. HW = high water, LW = low water, -X and +X = number of hours prior to and after low of high water. n = 798.

4.3 Disturbance

Disruption was observed in 9.4% (28 records) of the total number of records and 17.9% of records where a Ringed Plover was present. Most records with active disturbances occurred at the winter flood-mark and miscellaneous habitat (both 10 visible disturbances), and least at the intertidal area (once). Disturbances on the winter flood-mark were induced most frequently by dogs without a leash, followed by pedestrians and then stationary beach-visitors. It is the only habitat to include a record with active disturbance by stationary beach-visitors and a car. The fresh wash-up included the highest frequency of records with disturbances by pedestrians, together with the dune area (both 5 times). The only record with an active disturbance on the intertidal area was induced by a pedestrian. Figure 23 shows the measure of effect per disturbance factor. Most disturbances were caused by pedestrians (14 cases), with an overall strong effect, followed by dogs without a leash (9 cases) which had an equally distributed effect between low, moderate, and high. Other disturbances were induced by stationary beach-visitors (3 cases, with a generally strong affect, but also moderate and high, dogs on a leash 2 cases with strong effect), and finally one car with a moderate effect. Figure 24 shows that the measure of the effects of disturbances on the fresh wash-up was highest, followed by the dune area. And intertidal area. Disturbances on the winter flood-mark had the lowest effect.

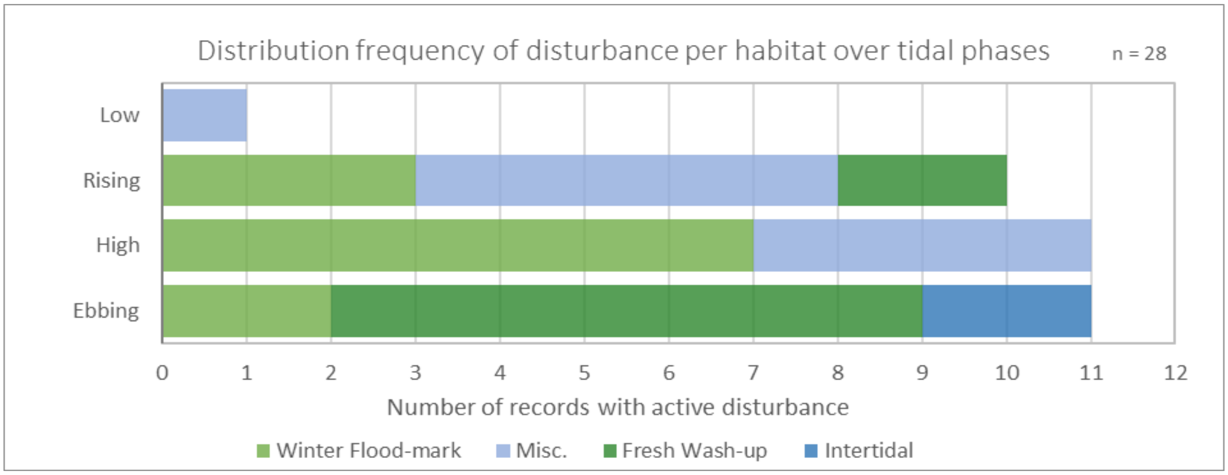

Figure 23: Graph showing the number of records a potential disruption factor was observed causing a disruption per foraging habitat.

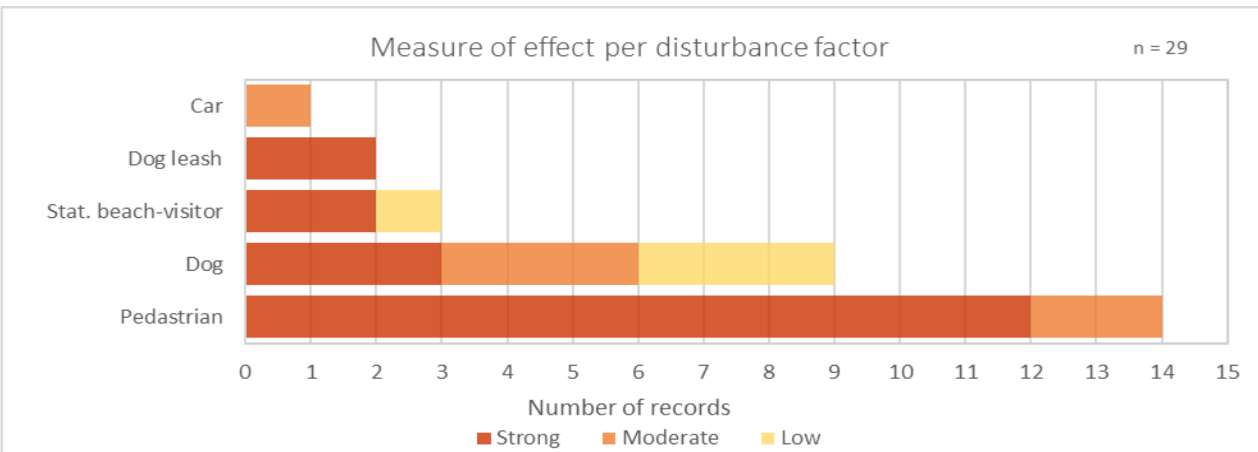

Figure 24: Graph showing the measure of the effect of a disturbance per factor. Strong = all RP react, moderate = most RP react, low = some ringed plover reacts.

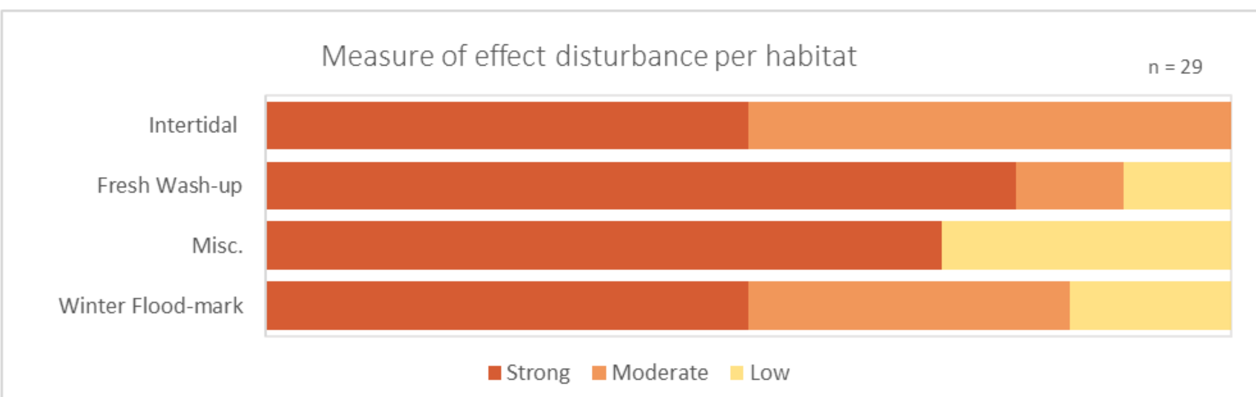

Figure 25: Graph showing the measure of the effect of a disturbance per habitat. Strong = all RP react, moderate = most RP react, low = some ringed plover reacts.

Disturbance in relation to time-based parameters

Figure 26 shows the distribution of disturbances over the period of the day. In half of the records a potential disturbance factors were present a disturbance occurred during the evening. Disturbances during the evening only occurred on the fresh wash-up. Disturbance occurred the least in records where a disturbance factor was present during the morning (5.5%), where disturbance occurred mostly on the fresh wash-up, but also on the winter flood-mark and dune area. During the afternoon, most disturbances occurred at the winter flood-mark and dune area. Figure 27 shows the distribution of all records with a disturbance over 12 tidal phases. Disturbances were significantly high during two hours before low water, but there seems to be no significant relation between the two factors.

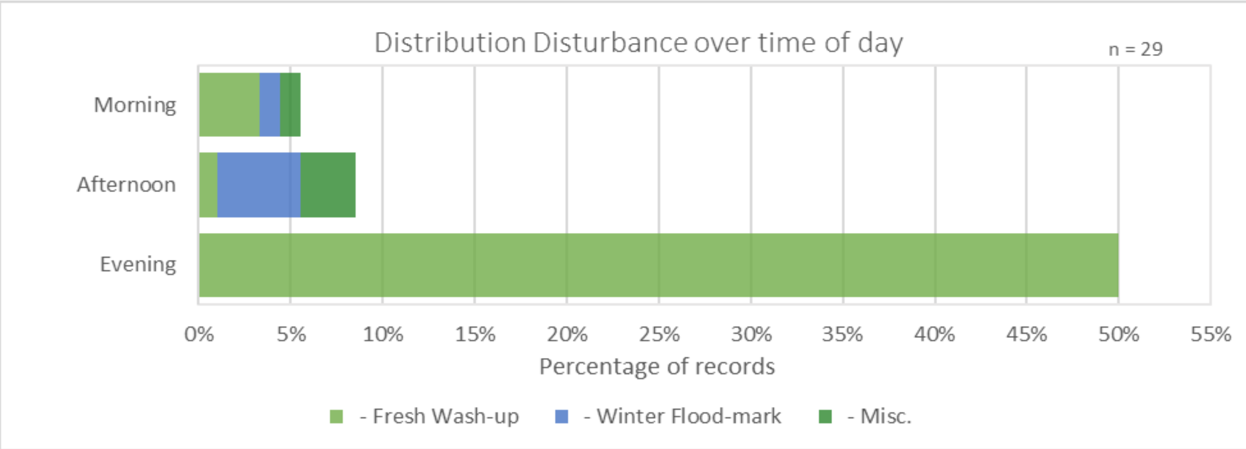

Figure 26: Graph showing the percentage of records a disruption factor causes disruption distributed over the time of the day: Morning = 5:00 – 11:55, afternoon = 12:00 – 17:55, Evening = 18:00 – 21:30. After 21:30 is considered night, but observations during the night are not included in comparison (see Chapter 3, pg XX). Percentage is taken from the total number of records disturbance factors were present during the respective time of the day.

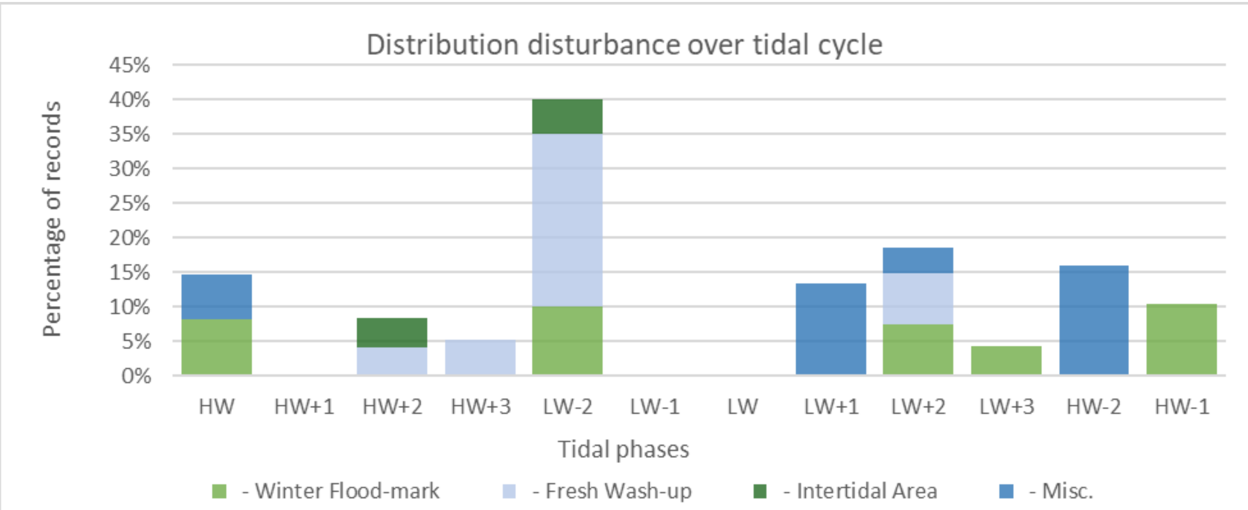

Figure 27: Graph showing the percentage of records a disruption factor causes disruption distributed over the tidal phases: HW = High water, LW = Low water, +X indicates the number of hours past LW or HW, -X indicates the number of hours prior to LW or HW. In the Netherlands, a tidal cycle has a duration of approximately 12 hours (from High water to Hight water). Percentage is taken from the total number of records disturbance factors were present during the respective tidal phase. n = 29.

4.4 PREY TYPES AND FOOD AVAILABILITY

Figure 28 shows the average number of each prey type found on the surface or in/around macroalgae in the samples taken (0.5 m2). The most abundant prey group found on the surface and in/on macroalgae were *Diptera,* especially in the winter flood-mark (WFM = 10.3, FW = 7.0 per sample), followed by *Coleoptera (WFM = 8.3, FW = 5.2)*. Moderately available prey types were *Amphipoda*, although only found in the fresh wash-up (3.55). Prey groups with relatively low abundance were *Diptera* / *Coleoptera* larvae (WFM = 2.7, FW = 0.5) and other prey like *Arachnida* and *Diplopoda* (WFM = 0.45, FW = 0.75).

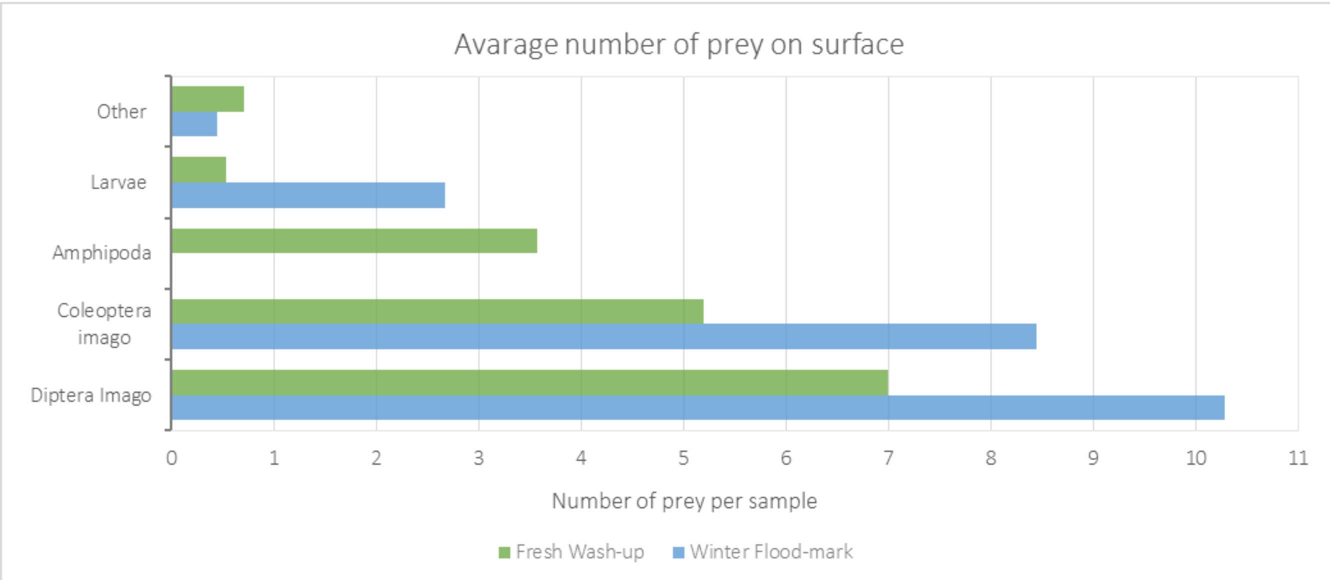

Figure 28: Graph showing the average estimated number of prey per sample of both habitats. n = 136.

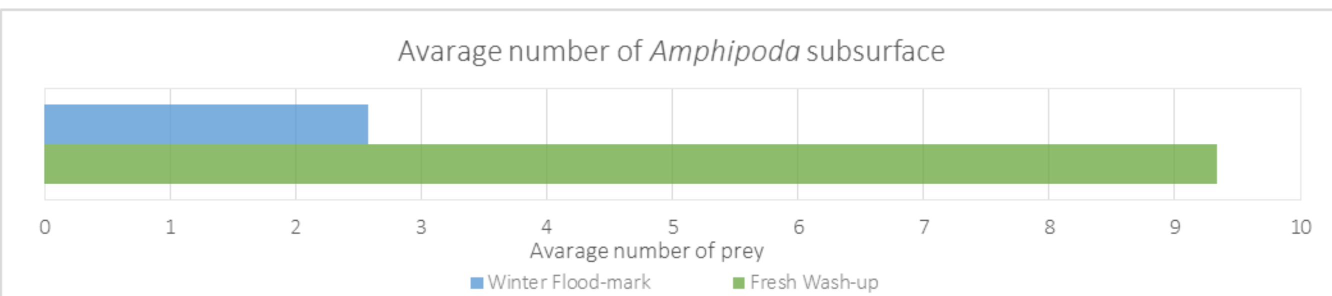

Figure 29: Graph showing the average estimated number of flying Diptera per sample. n = 24.

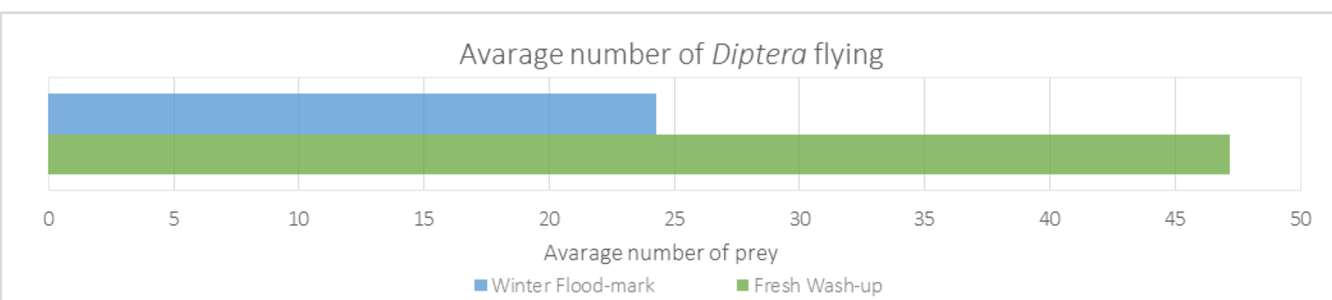

Figure 30: Graph showing the average estimated number of Amphipoda per subsurface sample. n = 24.

Figure 31 until 35 show that the frequency (in percentage of all samples taken) of each abundance class as sampled in the field. Noticeable is that Amphipoda on the surface of fresh wash-up are either found in moderate densities (10_25), or very low (0 or 0_3). Flying Diptera have a more dispersed pattern for both habitats, but abundance Diptera on the surface of winter flood-mark are also more divided. Coleoptera shows a similar pattern for the winter flood-mark but is more evenly dispersed on the fresh wash-up. Other prey types found were *Arachnida* (Spiders) and *Diplopoda* (Millipedes).

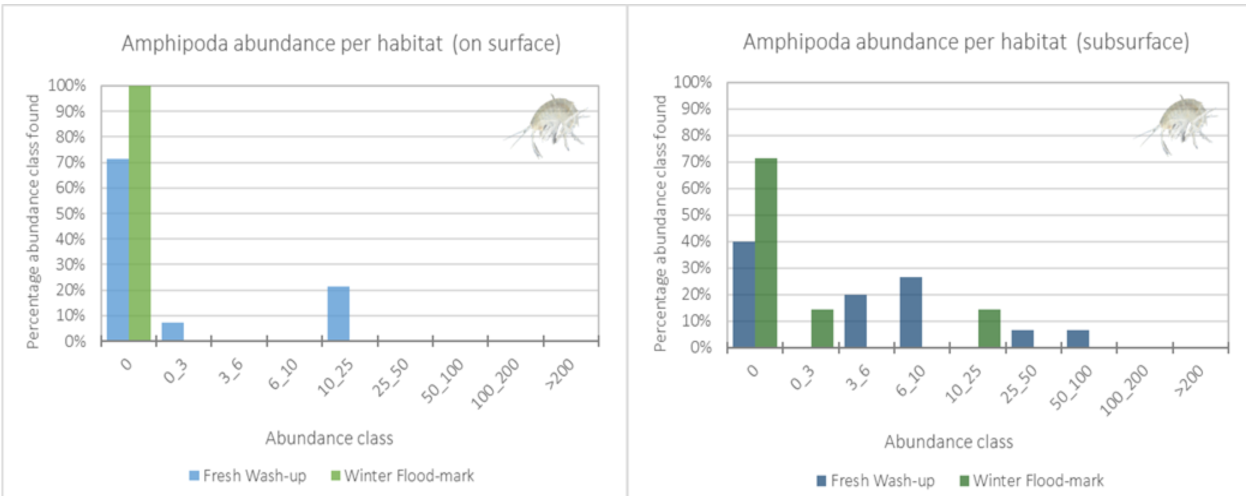

Figure 31: Graph showing the percentage of samples each abundance class of Amphipoda was found for each habitat. Left shows on surface (n = 21), right shows subsurface samples (n = 24).

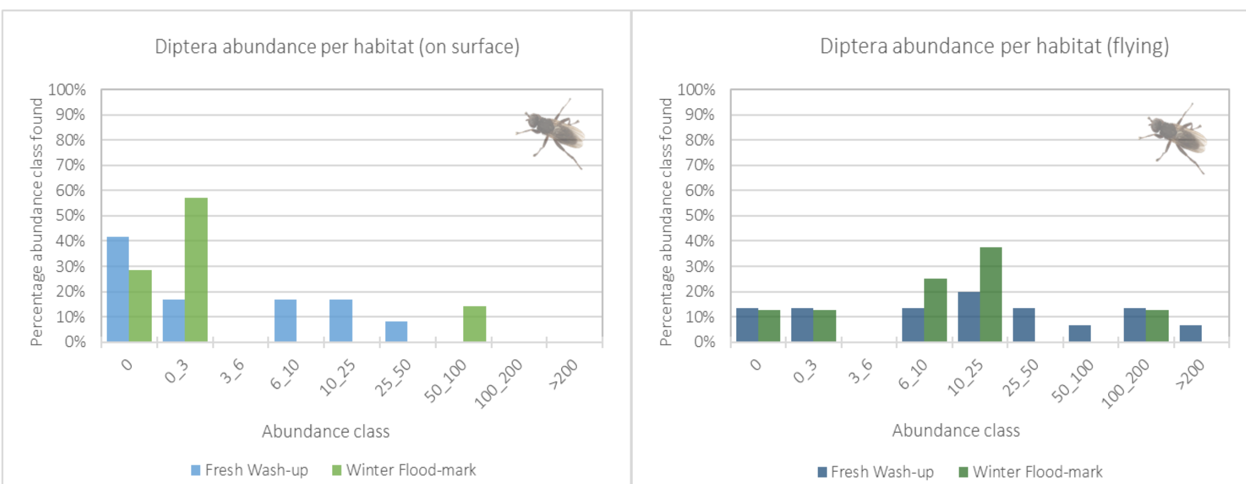

Figure 32: Graph showing the percentage of samples each abundance class of Diptera was found for each habitat. Left shows on surface (n = 21), right shows samples Diptera flying away walking along a 20 track (n = 24).

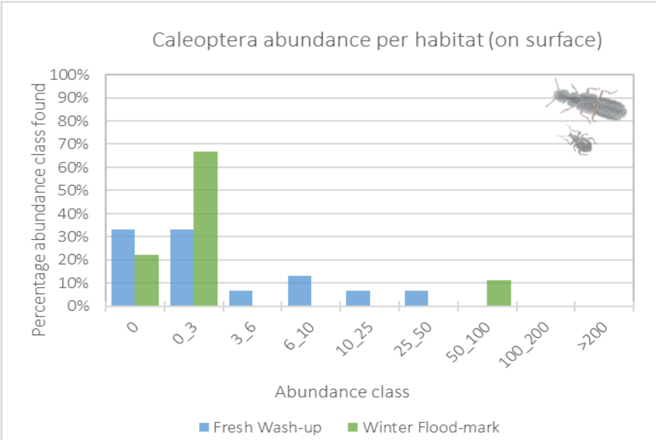

Figure 33: Graph showing the percentage of samples each abundance class of Coleoptera was found for each habitat. n = 21.

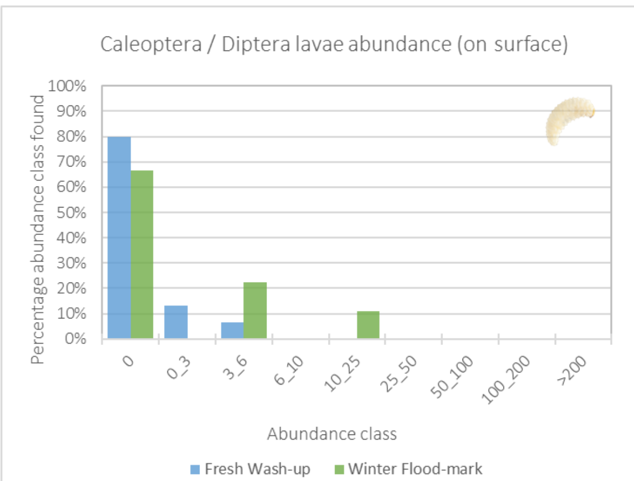

Figure 34: Graph showing the percentage of samples each abundance class of Coleoptera or Diptera larvae was found for each habitat. n = 21.

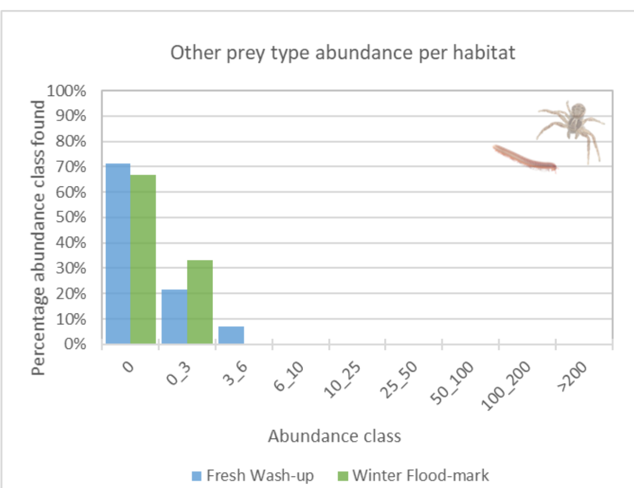

Figure 35: Graph showing the percentage of samples each abundance class of other prey types were found for each habitat. n = 21.

5. Discussion

To facilitate presence of breeding pairs with nests, and ultimately increase breeding success, it is necessary to adjust beach management to complement essential habitat requirements. For the identification of important foraging habitats, it is essential to gain insight on what important food sources on sandy beaches in the province of Zeeland are, what types of prey are available, and in what microhabitat or zones disturbance may limit foraging time / opportunities. This study investigated foraging activity of present breeding pairs of Ringed Plover on the beach of Oranjezon and the Veerse Gatdam / Banjaardstrand. The main objectives are: (I) To determine the relative importance of three different microhabitat(s) for foraging, (II) To identify major disturbance factors associated with the key foraging habitats, (III) To find potential correlations between the foraging activity and disturbance on the foraging habitats with e.g. time-based parameters (time of the day or tidal stage). Three key foraging habitats were investigated in this study: the intertidal area (area between low water line and high water line), fresh wash-up (depositions by prior high tide) and the winter flood-mark (depositions of winter or spring tides higher on the beach).

Foraging behaviour and habitat use

Foraging activity in defined plots was monitored, during roughly 300 5-minute time blocks, from a stationary outlook using a X20 – 60 scope and 10-48 binoculars during a 5-week period (March – May 2020). Results showed that foraging activity was highest on the intertidal area. However, the general presence of Plovers on the winter flood-mark was significantly higher than the other habitats but was used primarily for resting and grooming. Even though the difference between the fraction of foraging activity of the winter flood-mark and fresh wash-up seems insignificant, the difference is more pronounced when compared to the relative fraction of foraging activity of all time spent on respective habitat. Considering the high overall presence on the winter flood-mark, a higher occurrence of foraging may be explained by opportunistic and more sporadic feeding behaviour, as Ringed Plover might pick-up prey when they notice it nearby. This may also cost them less energy than walking the sometimes-longer distance (varies with location and time) to the two other foraging habitats away from the primary resting habitat. This indicates that the fresh wash-up is, as a foraging habitat, more significant than the winter flood-mark. This result is consistent with the findings of I. Tulp (1997). Comparing the cumulative result of the two tidal deposition habitats and the intertidal area, the difference becomes minor. In addition, the far greater surface area may also contribute to the high occurrence of foraging on the intertidal area. Therefore, it is suggested that, both the intertidal area and tidal depositions can be considered as an important foraging habitat in terms of monitored preference, with a preference to the fresh wash-up compared to the winter flood-mark.

Foraging behaviour in relation to time-based parameters

Overall, Ringed plover seemed to show a preference of foraging in the evening (50% > morning = 20%, afternoon = 27%). During the evening and morning there seemed to be a preference for the intertidal area, the winter flood-mark was least popular, whereas foraging activity in the afternoon was highest on the fresh wash-up. The afternoon was also the most popular period from all observations of RP on the fresh wash-up. This indicates that RP prefer foraging on the fresh wash-up in the afternoon especially and prefer the intertidal area on other occasions. This may be explained by opportunistic, feeding behaviour, as higher temperatures increase insect activity, and may generate more stimuli for RP to forage on the fresh wash-up. The high foraging activity observed during the night all took place on the fresh wash-up. However, due to the low number of samples (n=12), no confident conclusion can be derived about the relative importance of foraging during the night from these results, but it does hint that foraging activity during night-time may be important on some occasions, especially on the fresh wash-up. These observations were all done under conditions with relatively good visibility during an (almost) full moon. XX Study Portugal. It may be possible that RP forage until full during the night and wait until hungry again as the next day advances, explaining the low frequency of foraging during the morning. This is an assumption that cannot be validated with these results alone, however.

No significant relation was found between foraging activity and tidal phase on the tidal deposition habitats, but there seemed to be a preference for foraging on the intertidal area during ebbing (from high to low water) compared to rising, which could be explained by the high macrozoobenthic/ecological activity during a retrieving tide as stated in the hypothesis XX. There can be some inconsistent peaks observed, but those may be explained by foraging around the tideways present on both beaches. RP were often observed foraging on, and around the banks of the tideways during the monitoring activities. These tideways may increase the period during which RP can forage on the intertidal area, as tideways may locally increase polychaete abundance. Apparently, RP forage on the intertidal area during other tidal periods than ebbing, whilst the intertidal area is, by definition, not or limited available. Other small wader species that use the traditional sandpiper-like probing strategy to forage, e.g. Sanderling and Red Knot, require the ebbing tide to reach prey species like polychaetes and molluscs XX. Foraging activity may not be in direct relation to the tidal cycle, but RP may forage when hungry instead of a more planned strategy. Another explanation may be that Polychaetes were not present in high densities in the study area, but RP additionally feed on other prey types that may be washed ashore and could technically be considered fresh wash-up, or reside on the surface of the intertidal area, e.g. *Amphipoda* and other *Crustaceans*, *Molluscs* and *Diptera*. These would likely accumulate along the banks of the tideways and be accessible regardless of the tidal cycle if the intertidal area is accessible. The results therefore suggest that RP feed on other prey aside the intertidal area associated prey types like polychaetes, and do not, at least not exclusively, depend so much on the tidal cycle compared to other small waders. Both explanations would indicate that RP may be more resilient when it comes to scenarios where the abundance of macrozoobenthic prey types is compromised, e.g. caused by a sand nourishment, and would be able to fall back on a different foraging strategy.

PREY TYPES

Prey types and foraging on the intertidal area

The abundance of prey or polychaete holes found on the intertidal area was extremely low (2 small *Polychaete* in +/- 40 samples). This is surprising, especially since the high forage activity on the intertidal area. Perhaps the sampling method missed *Polychaetes* deeper in the sediment than 50 cm, but since Ringed Plover are probably unable to reach prey at these depths, this is considered irrelevant. Or possibly the sampling method missed small *Polychaetes* (<0.5mm), that Ringed Plover were able to detect, which is likely according to literature (Pienkowski, 1983).

An alternative or additional explanation may be that larger *Polychaetes* and *Molluscs* were not present in high densities in the study area, but Ringed Plover either located small prey where abundant, or foraged on different types of prey like *Crustaceans* or *Diptera* on the surface, as suggested earlier. The coarse sand and the presence of deep tideways and gullies indicate a relatively dynamic intertidal area, which may explain low abundance of polychaetes that generally prefer finer sediments like clay or silt

(Omena & Amaral, 2003. Considering the high foraging activity on the intertidal area and lack of *Polychaetes* in tidal depositions and intertidal area in these results, this suggestion would implicate that the diet of Ringed Plover in the study area consisted mainly of *Amphipoda*, *Diptera* and *Coleoptera*. However, *Polychaetes* and *Molluscs* may be picked up from the surface as well. Current literature suggests that Ringed Plover diet consisted mainly of small polychaetes picked up on the intertidal area (Pienkowski, 1982; Perez-Hurtado et. al., 1997). However, deviation of these results from other studies can be considered reasonable as beach-characteristics or the situation of wintering birds may differ significantly.

Prey types and foraging on tidal depositions

Prey types present in the tidal deposition habitats were: Kelp Flies and other *Diptera* and its larvae (on surface and on macroalgae), *Amphipoda* (beach hoppers), *Coleoptera* (Beetles) and its larvae, *Arachnida* (Spiders) and *Diplopoda* (Millipedes). The fresh wash-up typically contained high abundance of flying Kelp flies and other Diptera and Amphipoda, either on surface, in macroalgae masses or subsurface (top 5 cm). The winter flood-mark was characterised by high abundance of Kelp Flies and other *Diptera*, and Coleoptera on the surface or in macroalgae masses mixed with sand. Surprisingly, no *Collembola* (Springtails) and pupae of any species were found. Possibly the sample method missed larvae and pupae that were inside the stipe, thallus, or blades of macroalgae. Since the prey types were not identified to the taxa level, this is difficult to assess. Results show that overall, prey abundance on surface samples was highest on the winter flood-mark.

Most abundant prey types overall were *Diptera*, *Amphipoda* and *Coleoptera*. The estimated abundance of *Diptera* flying away whilst walking alongside a 20m track was almost double on the fresh wash-up (~47/20m2) compared to the winter flood-mark. *Diptera* were more frequent encountered on the fresh wash-up overall but were more mobile and flew away easily when approached. *Coleoptera* were more abundant on the winter flood-mark. *Amphipoda* were significantly more abundant on the fresh wash-up, and, unlike on the winter flood-mark, were also encountered on the surface and macroalgae aside subsurface. This may be explained by the lack of moist on the surface of the winter flood-mark, where Amphipoda may be likely to stay dug into the sediment to prevent dehydration during the day, as *Amphipoda* were found in more substantial abundance in subsurface samples of the winter flood-mark. However, in the top 5 cm layer of sediment, the abundance of *Amphipoda* was considerably higher on the fresh wash-up regardless. Moreover, during attempts to monitor Ringed Plover during the night, the abundance of prey *Amphipoda* was checked as well. The abundance of *Amphipoda* on the fresh wash-up was often observed to be extremely high during the night (>200 / XXm2). Although this has not been sampled systematically, it does hint that a considerable abundance of Amphipoda are present on or around the habitats that come to the surface during the night. Considering the high abundance of Amphipoda during the night and the high forage activity on the fresh wash-up, it is likely that Ringed Plover utilize this phenomenon, indicating the importance of the tidal depositions as foraging habitat is significant. It is suggested that the diet of Ringed Plover in the study area consisted mainly of *Crustaceans* (mainly *Amphipoda*), *Diptera* and *Coleoptera*. However, *Polychaetes* and *Molluscs* may be picked up from the intertidal area surface as well.

The quantity of macroalgae masses on the fresh wash-up were relatively low on some occasions. Fresh wash-up is a highly dynamic habitat, that varies in general quantity, density and even type of wash-up. Photographs have been taken from all prey type samples, and the samples could consist of wash-up with thin algae dispersed over a wider area, thick masses of macroalgae unevenly dispersed or even only grinded shells (see Appendix 4). This resulted in relatively low averages of estimated abundance compared to the winter flood-mark where, by definition, macroalgae remained in the same place for a longer period.

Fresh wash-up is a highly dynamic habitat, that varies in general quantity, density, and consistency like a variety of macroalgae species. The variation of abundance may be far greater than the winter flood-mark, whereas the winter flood-mark may represent a generally lower abundance, but more consistent. It is stressed that the importance of both tidal deposition habitats may be of greater importance to chicks than results of this study have shown, as the diet of chicks consist mainly of insects, and were seen foraging on fresh wash-up in earlier studies (Tulp, 1997).

Relevance to chicks

No chicks hatched in the study area during the project, but the relevance to foraging habitat preference for chicks remains absolute. I. Tulp (1997) found that chicks were mainly encountered in the fresh wash-up, but noted that it was more probable that the intertidal area was the preferred foraging habitat (indicated by wet clay/silt on bills and feet), but was avoided due to disturbance by pedestrians walking along the water line. However, the diet of Kentish- and Ringed Plover chicks consists primarily of insects (Cramp & Simmons, 1983; Pienkowski, 1983). It is therefore stressed that the importance of both tidal deposition habitats may be of greater importance to chicks than results of this study have shown, and it is suggested that the tidal depositions are a more important foraging habitat than previously assumed.

DISTURBANCE

This study took place during the worldwide corona-virus pandemic under extensive measures taken by the government and, as a result, (foreign) tourist and other big crowds were completely absent from the study area. The results therefore merely show a situation of relatively low recreational intensity, without the occasional peaks during holidays or even weekends. It may not be possible to relate recreational intensity to factors like foraging activity and disturbance, but these data could serve as a unique control group if this study, or a similar one, would be replicated during high season in another year. In the context of other relevant projects that are currently on-going, like "Strandbroeders" and "Het Groene Strand", it would be especially valuable to compare these results to the situation when measures for the conservation of beach-nesting birds and the natural value of beach areas will be taken.

Potential disturbance factors

Results showed that the overall occurrence of disturbance was extremely low (28 cases in 23 out of roughly 300 records). This is likely due to the low overall presence of potential disturbance factors in the study area with pedestrians being most frequent (0.8 per record). After pedestrians, the most frequent encountered potential disturbance factor were stationary beach-visitors (0.6 per record), followed by recreational fisherman and dogs without a leash (~0.1 per record). Potential disturbance factors were present on the intertidal area most frequently, likely due to the far greater surface area than the other two habitats, followed by miscellaneous habitat (primarily dunes) and fresh wash-up. When the cumulative result of both tidal depositions is compared with the intertidal area the difference becomes minor, indicating a generally evenly dispersion of disturbance factors on the beach. Disturbance factors inducing disturbance of Ringed Plover most frequently were pedestrians as well (total of 14 times), which had a mostly strong, and sometimes moderate effect (all or most birds visibly reacted). The second most frequent disturbance was induced by dogs without a leash (total of 9 times), of which the measure of effect differed between strong, moderate, and low, followed by stationary beach-visitors (3 times), which mostly had a strong effect, and otherwise low. Other disturbance factors included dogs without a leash (twice) and a car driving on the winter flood-mark (once).

Active disturbance

Most disturbance occurred on the winter flood-mark overall, (total of 10 times), which was the only habitat to include disturbances by stationary beach-visitors and cars. Almost half of disturbances on the winter flood-mark were induced by dogs without a leash. Disturbances on the dune area where equally as high as on the winter flood-mark but would not likely have limited foraging activity as it is not considered a key foraging habitat. Disturbance on the fresh wash-up was moderately high, with most disturbances caused by pedestrians. Disturbance on the intertidal area occurred only once, even though it was the habitat where most potential disturbance factors were present. This can probably be explained by the far greater surface area compared to the two tidal depositions habitats. The two tidal deposition habitats may offer less options to skirt or circumvent present disturbance factors.

Disturbance in relation to foraging behaviour

Considering the high overall presence of Ringed Plover on the winter flood-mark, with the most frequent activity being resting and grooming, it is surprising it inhabited the most disturbances. Possibly a narrower beach during high tide would increase disturbance significantly, and thus dictating the relative frequency of disturbance. However, results did not show a substantial difference in occurrence of disturbance between higher and lower tides. Similarly, disturbance factors were most frequently encountered during the evening, which was unexpected considering the high foraging activity during that period. Presence of disturbance factors in the evening was largely on the fresh wash-up. Additionally, active disturbance was observed most frequently during the evening on the fresh wash-up as well. However, Ringed Plover were by no means observed to forage on the fresh wash up during the evening less than on other locations or compared to other habitats. The overall low occurrence of disturbance may not have significantly influenced foraging activity. Consequently, no significant correlation was found between foraging activity and disturbance, as the frequency of disturbance was over all too low to proof a determining factor influencing Ringed Plover foraging behaviour and habitat use in this study area.

6. Conclusion

It is suggested that, both the intertidal area and tidal depositions can be considered an important foraging habitat in terms of monitored preference, with a preference to the fresh wash-up compared to the winter flood-mark, which confirmed the hypothesis. The winter flood-mark is primarily used for other purposes than foraging (resting and grooming), which is likely because it is, or near the breeding habitat as hypothesised. Foraging on the winter flood-mark may be a more opportunistic and sporadic feeding behaviour, as Ringed Plover might pick-up prey when they notice it nearby. Ringed Plover seemed to prefer foraging during the evening, whereas foraging activity was lowest in the morning. No significant relation was found between foraging activity and tidal phase on the tidal deposition habitats, but there seemed to be a preference for foraging on the intertidal area during ebbing (from high to low water) compared to rising, which could be explained by the high macrozoobenthic/ecological activity during a retrieving tide as stated in the hypothesis.

The abundance of prey or *Polychaete* holes found on the intertidal area was extremely low. RP were often observed foraging on, and around the banks of the tideways during the monitoring activities. Higher densities of polychaetes may have been present in or around these tideways. Tideways may therefore increase the period during which RP can forage on the intertidal area. Moreover, results suggest that RP foraging in the intertidal area may feed on other prey aside the intertidal area associated prey types like *Diptera*. Thus, Ringed Plover do not, at least not exclusively, depend so much on an ebbing tide compared to other small wader species.

Prey types present in the tidal deposition habitats were: Kelp Flies and other *Diptera* and its larvae (on surface and on macroalgae), *Amphipoda* (beach hoppers), *Coleoptera* (Beetles) and its larvae, *Arachnida* (Spiders) and *Diplopoda* (Millipedes). The fresh wash-up typically contained high abundance of flying Kelp flies and other Diptera and Amphipoda, either on surface, in macroalgae masses or subsurface (top 5 cm). The winter flood-mark was characterised by high abundance of Kelp Flies and other *Diptera*, and Coleoptera on the surface or in macroalgae masses mixed with sand.

Most abundant prey types overall were *Diptera*, *Amphipoda* and *Coleoptera*. *Diptera* were more frequent encountered on the fresh wash-up overall but were more mobile and flew away easily when approached. *Coleoptera* were more abundant on the winter flood-mark. *Amphipoda* were significantly more abundant on the fresh wash-up, and, unlike on the winter flood-mark, were also encountered on the surface and macroalgae aside subsurface. It was hypothesised that results would show that the high macrozoobenthic activity during the night meant high foraging activity on fresh wash-up. *Amphipoda* were observed in extremely high densities during the night, all of which were on the fresh wash-up. Night observations also hint that RP utilize this phenomenon as foraging activity was notable on the fresh wash-up during the night. However, due to the low number of samples (n=12), no confident conclusion can be derived about the relative importance of foraging during the night from these results, but it does hint that foraging activity during night-time may be important on some occasions, especially on the fresh wash-up, which would hint towards the hypothesis. It is suggested that the diet of Ringed Plover in the study area consisted mainly of *Crustaceans* (mainly *Amphipoda*), *Diptera* and *Coleoptera*, and very small *Polychaetes* and *Molluscs*.

Fresh wash-up is a highly dynamic habitat, that varies in general quantity, density, and consistency like a variety of macroalgae species. The variation of abundance may be far greater than the winter flood-mark, whereas the winter flood-mark may represent a generally lower abundance, but more consistent. It is stressed that the importance of both tidal deposition habitats may be of greater importance to chicks than results of this study have shown, as the diet of chicks consist mainly of insects, and were seen foraging on fresh wash-up in earlier studies (Tulp, 1997).

This study took place during the worldwide corona-virus pandemic under extensive measures taken by the government and, as a result, (foreign) tourist and other big crowds were completely absent from the study area. The results therefore merely show a situation of relatively low recreational intensity, without the occasional peaks during holidays or even weekends.

Results showed that the overall occurrence of disturbance was extremely low. The potential disturbance factor that was encountered most frequently were pedestrians, followed by stationary beach-visitors. Additional abundant potential disturbance factors were recreational fisherman and dogs without a leash.

Disturbance was induced most frequently by pedestrians as well, which had a mostly strong, and sometimes moderate effect. Most pedestrians induced disruption of RP present on the tidal deposition habitats, particularly on the fresh wash-up. The second most frequent disturbance was induced by dogs without a leash, of which the measure of effect differed between strong, moderate, and low. Disturbance was induced most frequently on the winter flood-mark and dune area, which was in or near the breeding habitat. Additional disturbances were induced by stationary beach-visitors which mostly had a strong effect, and otherwise low, dogs without a leash and a car driving on the winter flood-mark.

Disturbances occurred notably more on the tidal deposition habitats, particularly the winter flood-mark, compared to the intertidal area. Potential disturbance factors were most frequent on the intertidal area, but due to the significantly larger surface area RP were likely to skirt or avoid potential disturbance factors. During the evening. disturbance factors were most frequently encountered, and most disturbances occurred as well, even though foraging activity was highest. No significant relation was found between disturbance and the tidal cycle. The overall low occurrence of disturbance may not have significantly influenced foraging activity. Consequently, no significant correlation was found between foraging activity and disturbance, as the frequency of disturbance was over all too low to proof a determining factor influencing Ringed Plover foraging behaviour and habitat use in this study area.

7. Recommendations

Practical suggestions

Cleaning the beach of tidal depositions

It is suggested that limiting or halting cleaning the beach of tidal depositions near present breeding territories or potential breeding habitat will increase food availability, and likely for chicks in particular. It is advised to leave both tidal depositions, the fresh wash-up and winter flood-mark, where occurring naturally. Prey was abundant on the surface/macroalgae and depositing all macroalgae masses on a single pile - as has been observed in the study area – is assumed to not benefit food availability for (Ringed) Plovers and particularly chicks. Although not advised, if required to move, it is suggested to evenly disperse macroalgae masses on the winter flood-mark close by or near present territories of potential breeding habitat.

Placement of fences

It would be ideal to place a tide-resistant fence reaching from the embryonic dunes or breeding habitat to the high-water line during neap-tide on beach areas where breeding territories are present, or nest/chicks have been located. Signs with suggestions to keep dogs on their leash and keep distance from birds or chicks outside the enclosure could accommodate foraging activity and breeding success. However, these measures may be expensive (tide resistant fence), and primary function may commence if breeding pairs choose to breed in a different area (as Kentish Plover is more likely to do). An alternative would be a temporary fence from around a located nest down to the high waterline during springtide, depending on the tide resistance of the fence. Conversely, continuing placement and breaking apart the structures does require more manpower.

Future research niches

No chicks hatched in the study area during the period monitoring activities were carried out, but the relevance to foraging habitat preference for chicks remains absolute. Chicks are thought to include a higher proportion of insects in their diet, and habitats where insects are more abundant may be of greater significance. Moreover, parents of present chicks may also adjust foraging behaviour while staying close to chicks or possibly because of increased disturbance as the reaction to disturbance factors may be stronger. Further investigation on the significance of the tidal deposition habitats for foraging of chicks and their parents may help adjust beach management and conservation strategies appropriately to increase the currently low breeding success in the Netherlands more directly.

In the context of other relevant projects that are currently on-going, like “Strandbroeders” and “Het Groene Strand”, it would be especially valuable to compare these results to the situation if measures for the conservation of beach-nesting birds and the natural value of beach areas will be taken. These data could then serve as a unique control group as peaks of recreational intensity are ruled out. It is therefore highly recommended to replicate or conduct a similar study during a high recreational season in another year. One measure of which the effect is currently being investigated as part of project Strandbroeders, is the effect of enclosures to keep beach visitors on a safe distance and cages to prevent predation of nests on breeding success. Chicks may find shelter inside the enclosure or prefer foraging in it since it offers less recreational pressure. If the intertidal area is a significant foraging habitat for chicks as well, and present prey types like small polychaetes (or larger ones in other study areas) form an essential part of their nutritional requirements this may lead in malnutrition which may ultimately decrease survival of fledglings.

Ringed Plover and other beach-nesting birds also breed on shores with a lower, or missing, tidal regime, or include very different tidal depositions. Foraging activity and habitat use may be very different in areas such as the Eastern Scheldt. Beaches with a higher clay-silt content of substrate in the intertidal area may also result in different findings. It is recommended to examine habitat use, foraging activity and the effects of recreational pressure on breeding pairs and chicks in a wider range of beach areas where circumstances are evidently different to help find appropriate and fitting measures for other areas as well.

Results hinted that the importance of foraging activity during the night is probable. Additional investigation of the significance of foraging activity during the night compared to during the day may shed light on the overall (Ringed) Plover foraging ecology. Foraging activity during the night may be used as an indicator for overall disturbance during the day, as this may be used as compensation for foraging opportunities during the day.

If this methodology or a similar project is carried out in the future by for example volunteers, it will be beneficial to employ people to register disturbances and foraging activity during days with relatively high recreational activity.

On a broader note, it is hypothesised that tidal depositions may enhance development of embryonic dunes (Cadée, 2014). Embryonic dunes are considered a breeding habitat characteristic for several beach-nesting birds in the Netherlands, including Ringed Plover, Kentish Plover and Little Tern (Arts & Meininger, 1998). Further investigation may help adjust measures to increase the natural value, and thus habitat requirements of beach-nesting birds, on Dutch beaches.

- Prey identification → taxa and natural value

- Diet more closely: Food uptake (ontleden of droppings).

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APPENDIX 1: SURVEY OF EMBRYONIC AND WHITE DUNES (RIJKSWATERSTAAT, 2019)

Figure 36: Map of embryonic and white dunes Banjaardstrand

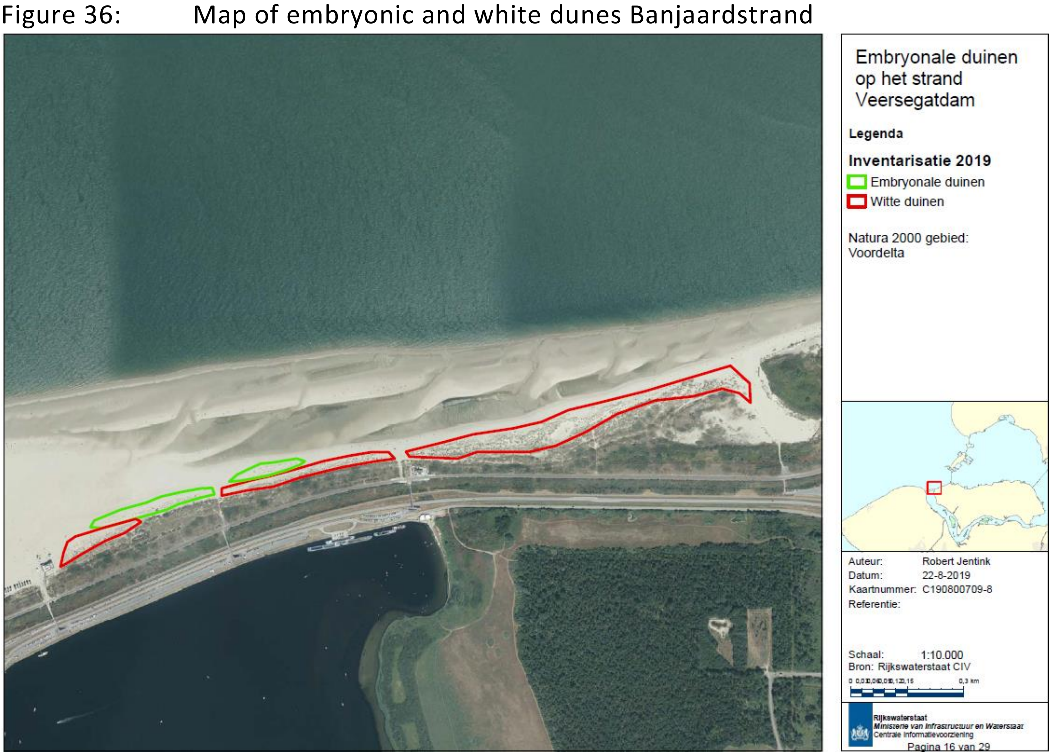

Figure 37: Map of embryonic and white dunes Veerse Gatdam

Figure 38: Map of embryonic and white dunes Breezand (between Oranjezon and Veerse Gatdam

Figure 39: Map of embryonic and white dunes Oranjezon

APPENDIX 2: RECREATIONAL INTENSITY IN STUDY AREA

Figure 40: Recreation intensity reported by Deltares (Dutch) (Deltares, 2018)

APPENDIX 3: LIST OF POTENTIAL DISRUPTION FACTOR ENTRIES

Human Disruptions

- Yacht (dry, sailing and anchored)
- Fishing ship (dry, sailing and anchored)
- Fast sailing ship (dry, sailing and anchored)
- People from ship/boat
- Kayak (dry, sailing)
- Kite surfers
- Windsurfer
- Jet ski
- Airplane
- Jet airplane
- Helicopter
- Parachute
- Motorcycle
- Car (incl. quad/jeep)
- Farming vehicle
- Truck
- Bicycle (incl. e-bike)
- Dog on leas
- Dog without leas
- Horse rider
- Pierenspitter (bait collecting) and recreational fishers with rod
- Recreational beach-visitor sedentary (swimming and sunbathing)
- Recreational beach-visitor walking
- Recreational beach-visitor with kite
- Bird-count team

Biological Disruptions

- Harbor Seal *(Phoca vitulina)*
- Grey seal *(Halichoerus grypus)*
- White-tailed Eagle
- Peregrine falcon (*Falco peregrinus*)
- Merlin (*Falco columbarius*)
- Eurasian hobby (*Falco subbuteo*)
- Common kestrel (*Falco tinnunculus*)
- Western osprey (*Pandion haliaetus*)
- Western marsh harrier (*Circus aeruginosus*)
- Hen harrier (*Circus cyaneus*)
- Common buzzard (*Buteo buteo*)
- Eurasian sparrowhawk (*Accipiter nisus*)
- Northern goshawk (*Accipiter gentilis*)
- Great black-backed gull (*Larus marinus*)
- Silver gull (Larus novaehollandiae)
- Western jackdaw (Coloeus monedula)
- Carrion crow (Corvus corone)
- Other bird sp. (specify)

- Other Disruption
- Unknown Disruption

APPENDIX 4: PHOTOGRAPHS OF PREY TYPE SAMPLES

Example of Fresh wash-up samples

Example of Winter Flood-mark samples

Bottom right an empty (practice) nest of Ringed Plover is highlighted.

Examples Intertidal area samples