Local movements of shorebirds in the Robbins Passage region: a radio-telemetry study of flight behaviour and habitat use in areas potentially affected by the proposed White Rock Ridge Wind Farm.

A Report commissioned by Eureka Funds Management Limited, proponent for the White Rock Ridge Wind Farm

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1.0 EXECUTIVE SUMMARY

Local movements of Red-necked Stints (*Calidris ruficollis*) and Ruddy Turnstone (*Arenaria interpres*) in the Robbins Passage region of northern Tasmania were studied with radio-telemetry techniques, building on previous studies based on daytime observations. The purpose of the study was to investigate whether the internationally important shorebird populations in this region might be affected by the proposed White Rock Ridge Wind Farm on Robbins Island. The study was designed to assess whether the flight paths of shorebirds put them at risk of collision with wind turbines (planned to be placed along the crest and western slopes of White Rock Ridge), or with transmission lines from Robbins Island to the mainland or other sensitive areas related to the wind farm site.

The study took place from 3rd December 2010 to 24th January 2011. Radio-transmitters were placed on 30 Red-necked Stints cannon-netted on Robbins Island between 13-15 December 2010, and on 12 Ruddy Turnstones cannon-netted on Perkins Island on 17 December 2010. The movements of these birds were followed over the next six weeks with an automatic radio-telemetry array, consisting of 9 receivers stationed at strategic sites on Robbins Island, Perkins Island and Kangaroo Island. These receivers scanned continuously for the deployed radio-transmitters, by night as well as by day. The automatic radio-telemetry was supplemented by handheld radio-telemetry and direct observation which confirmed that behaviour of the tagged birds was consistent with that of other Red-necked Stints in the region.

Relatively few data were collected for the radio-tagged Ruddy Turnstones, most of which left the study area within 3 days of being tagged and released and only returned briefly to Perkins Island in January. Some Ruddy Turnstones were however recorded moving from Perkins Island to Robbins Island two days after they were tagged and released. Although it is (rightly) conventional to consider Perkins and Robbins Island as part of the same complex of shorebird sites for population monitoring purposes, the frequency of movements between the sites appears to be very low.

A very large data set was obtained for Red-necked Stint (>8,000 detections). The radio-tagged birds remained on the west coast of Robbins Island during the study, moving between low-tide foraging grounds on tidal flats to the west of the island, and high tide roosts on the west coast of Robbins Island; many radio-tracked birds also roosted to the west of their foraging grounds, on Kangaroo Island. Shorebird roost selection varied over the study period. There was a strong tendency for Red-necked Stints to use different roosts by day and night. Roosts used predominantly by day included Bird Point, Knot Point and Kangaroo Island. A roost at the Five Islets was found to be used by more Red-necked Stints by night than by day, and some evidence was obtained for a high tide roost in Mosquito Inlet which is used by night but not by day. Roost selection was dynamic over time; for example the high tide roost on Bird Point was not used by many radio-tagged birds in the first few weeks of the study, but it was the most commonly used day-time roost in the last half of January. No movements of stints were observed between Perkins and Robbins Islands

There was no evidence that any of the birds radio-tagged in this study flew through Robbins Crossing – i.e. the relatively narrow intertidal passage between the southern end of Robbins Island and the mainland where overhead power transmission lines for the proposed wind farm are likely to be situated.

There were no movements of radio-tagged shorebirds over the southern automatic radio-tracking station on White Rock Ridge close to the most important two shorebird roosts on Robbins Island. Extensive data from both handheld and automatic radio-telemetry showed that the daily routines of

Red-necked Stints in this area did not involve any movements east of the shoreline of western Robbins Island. This was corroborated by findings from extensive daytime observations.

Some Red-necked Stints made complex movements at the northern end of Robbins Island, occurring in Mosquito Inlet on rising tides at night; some such individuals then moved to a previously unknown high tide roost in the northern Mosquito Inlet area, and others moved down the west coast of Robbins Island to roosts such as the Five Islets. This movement was observed regularly when receiver stations were operational. The flight path used by Red-necked Stints when making this movement could not be established with certainty. It may involve a flight over the tidal flats of the Walker Crossing, consistent with the usual tendency of shorebirds to fly over mudflats or water in preference to making flights over land. Shorebirds making such a movement would not be at risk of impact with wind turbines on White Rock Ridge. Alternatively, however, shorebirds moving from Mosquito Inlet to the west coast might take a “short cut” of *c*. 2 km, by flying directly over the northernmost end of White Rock Ridge. The latter movement pattern would involve flight over currently proposed wind turbine sites at the northern end of the project area.

We conclude that much of the proposed White Rock Ridge Wind Farm development – including transmission lines across Robbins Passage, and most of the turbines on White Rock Ridge – does not pose a collision risk to shorebirds. However, it is possible that shorebirds fly over the northernmost 2.5 km of White Rock Ridge as part of a regular night time movement between the west coast of Robbins Island, and a night-time roost in northern Mosquito Inlet (Figure 1). Further study of this area would be required to assess whether turbines on the northernmost 2.5 km of White Rock Ridge pose a collision risk to shorebirds.

Legend

- Potential Shorebird Movement
- WRR North
- Mosquito Inlet ART
- Bird Point
- Knot Point
- Test
- 1 Test Numbers

0 0.25 0.5 1 Kilometers

Figure 1 :Potential shorebird movement between Mosquito Inlet and the west coast of Robbins Island

Project: White Rock Wind Farm

Client: Eureka Funds Management

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2.0 INTRODUCTION

Eureka Funds Management engaged Brett Lane and Associates Pty Ltd (BL&A) and the Arthur Rylah Institute (ARI) to conduct a shorebird survey during the 2010/2011 non-breeding season at the Robbins Passage region in north-west Tasmania. The purpose of this investigation was to study the local movements of shorebirds in the Robbins Passage region, using radio-telemetry to study the flight behaviour and habitat use in areas potentially affected by the proposed White Rock Ridge Wind Farm.

Up to 23,000 migratory and resident shorebirds inhabit the Robbins Passage region in north-western Tasmania each summer. Due to the high number of migratory shorebirds that visit the Robbins Passage region it has been identified as an internationally important shorebird site. Migratory shorebirds are listed as migratory species on the Commonwealth *Environmental Protection of Biodiversity and Conservation 1999* (EPBC Act). They are also listed on several international treaties and conventions which aim to protect migratory shorebirds and conserve their habitat.

The Robbins Passage region includes Robbins Island, Perkins Island, Walker Island, Kangaroo Island, Wallaby Island and all the intertidal sand flats in between. Previous studies have been undertaken by BL&A in late 2002, early 2003 and early 2009 (BL&A 2010). These studies showed that there were two major foraging areas in the Robbins Passage region: the sand flats on the western side of Robbins Island and the sand flats on the western side of Perkins Island. Important high tide roost sites in Robbins Passage include Bird Point, Knot Point, Five Islets and Kangaroo Island on the north-west coast of Robbins Island; the Shipwreck Point area on the northern tip of Perkins Island, and the Jetty on the south east of Robbins Island.

In the previous studies, shorebird movements to and from roosting sites were recorded during daylight hours (BL&A 2010). The great majority of movements were made over open water, both offshore and along the coastline. Very few movements were recorded traversing the island or moving inland; there was just two observations of flocks flying over White Rock Ridge (40 birds from Bird Point, and a flock of several hundred from south of Bird Point), in over 100 hours of direct observation at the west coast of Robbins Island in 2003 and 2009 during rising and/or falling tides. However, count data at key shorebird roosts in the Robbins Passage area indicated that shifts in roosting and, possibly, foraging location can occur, perhaps in association with changes in weather conditions. The flight routes shorebirds used when making these movements were unknown.

There was therefore a need to undertake further studies to assess whether shorebirds might be at risk of collision with turbines at the proposed White Rock Ridge Wind Farm. Potential impacts that could arise from the proposed wind farm development include:

- Shorebirds colliding with turbines (planned to be placed along the crest and western slopes of White Rock Ridge)
- Shorebirds colliding with transmission lines from Robbins Island to the mainland (exact location not yet known, but likely to be placed on the south or south-west of Robbins Island where the channel to the mainland is narrowest).

Shorebirds can have complex movement patterns on tidal flat systems (e.g. Rogers et al. 2006a, 2006b). They make several 'commuting' flights per day between foraging grounds on intertidal flats (only accessible when the tide is low) and roosts (sites where birds rest when the tide is high). Movements can happen both by day and night, as shorebirds typically forage whenever tidal flats are exposed, whether it is dark or light. High tide roosts are usually quite localised, shorebirds selecting very open sites as far from tall vegetation or topography as possible. In some previous studies in some other sites in Australia and overseas, shorebirds have been found to use different roosts by day and night (e.g. Rogers 2003), so it cannot be assumed that movement patterns of shorebirds in Robbins Passage at night are the same as those used by day.

Shorebirds may also shift foraging or roosting areas over longer time frames. Different roost sites may be used in different tide conditions (e.g. some roosts may be suitable on most high tides, but submerged on spring tides). Wind direction might also influence roost selection, with roosting shorebirds avoiding exposure to very strong winds when possible. In addition, abundance of prey resources on tidal flats is dynamic, with suitability or abundance of prey potentially fluctuating due to such factors as: prey depletion by shorebirds and other predators; location of spatfalls of larval benthic animals; growth of preferred prey species (e.g. many bivalve species can be consumed by shorebirds as spat, but when fully grown they are too large for shorebirds to ingest). When shorebirds change foraging grounds in response to such prey variations, they can also switch roosting sites in order to roost as close as possible to the preferred feeding site (e.g. van Gils et al. 2006). Accordingly, their local movement patterns can change.

This study used automatic radio-telemetry (supplemented by handheld radio-telemetry and direct observation) as a tool to investigate whether shorebirds might be affected by the White Rock Ridge wind farm development. Automatic radio-telemetry can provide important data that cannot be obtained through direct observation. First, data can be collected 24 hours a day, allowing data to be collected when it is too dark for direct observation. Secondly, data from known individuals can be collected over a time-frame of weeks, allowing an assessment of whether shifts in preferred roosting or foraging sites influence local movement patterns.

Specific objectives of this investigation were to:

- Determine the ‘commuting’ movement patterns of shorebirds on the western coast of Robbins Island, both by day and night. These are the only roost sites near to the proposed turbine sites on White Rock Ridge.

- Determine whether shorebirds move between the two major foraging areas west of Robbins Island and west of Perkins Island, and if so, whether their flight path crosses White Rock Ridge, or passes through the Robbins Crossing area.

- Document whether shorebirds fly over White Rock Ridge at any other times, in particular if they fly from the west coast of Robbins Island over the ridge to Mosquito Inlet.

The findings from this investigation are to be used to assess the risk of impacts from the proposed wind farm on shorebirds.

3.0 METHODS

3.1 Overview of study design

The study was undertaken between 3rd December 2010 and 24th January 2011. Most of the automatic radio-telemetry array was set up between 3rd and 9th December 2010; and birds were captured for radio-telemetry between 10th and 17th December 2010. Thereafter the automatic radio-telemetry array collected data continuously. Teams of 2-4 people were nevertheless needed in the field subsequently, to maintain the automatic radio-telemetry array and to carry out supplementary handheld telemetry and direct observations. This fieldwork was carried out between 18th-21st December 2010, 4th-9th January 2011, and 17th-26th January 2010; the final two days were spent packing up, so the last collection of automatic radio-telemetry data took place on 24th January 2011.

The weather was poor during much of the study. It was carried out in an exceptionally wet summer and (as was also the case in coastal Victoria), counts of Red-necked Stint, Curlew Sandpiper and Sharp-tailed Sandpiper were considerably lower than they had been in previous years, presumably because many birds spent the non-breeding season in recently flooded inland Australian wetlands rather than migrating to the coast (ARI, unpubl. data). Numbers of some strictly coastal species, including Bar-tailed Godwit and Red Knot, were also unusually low on the west coast of Robbins Island in the early stages of the study, when we suspect many birds were roosting on Kangaroo Island. The low numbers of birds and poor weather made catching operations difficult, and it proved impossible to capture Bar-tailed Godwits and Red Knots, for which we also had study permits. The wet weather made some important access tracks impassable for much of the study, limiting handheld radio-telemetry (especially on White Rock Ridge) and our capacity to maintain the automatic radio-telemetry array; some stations experienced power failures as a result.

However, the poor weather was fortuitous in another respect, as it enabled study of movements of radio-tagged shorebirds in a variety of weather conditions, including westerly and easterly gales. Wind conditions during the study are summarised in Figure 2.

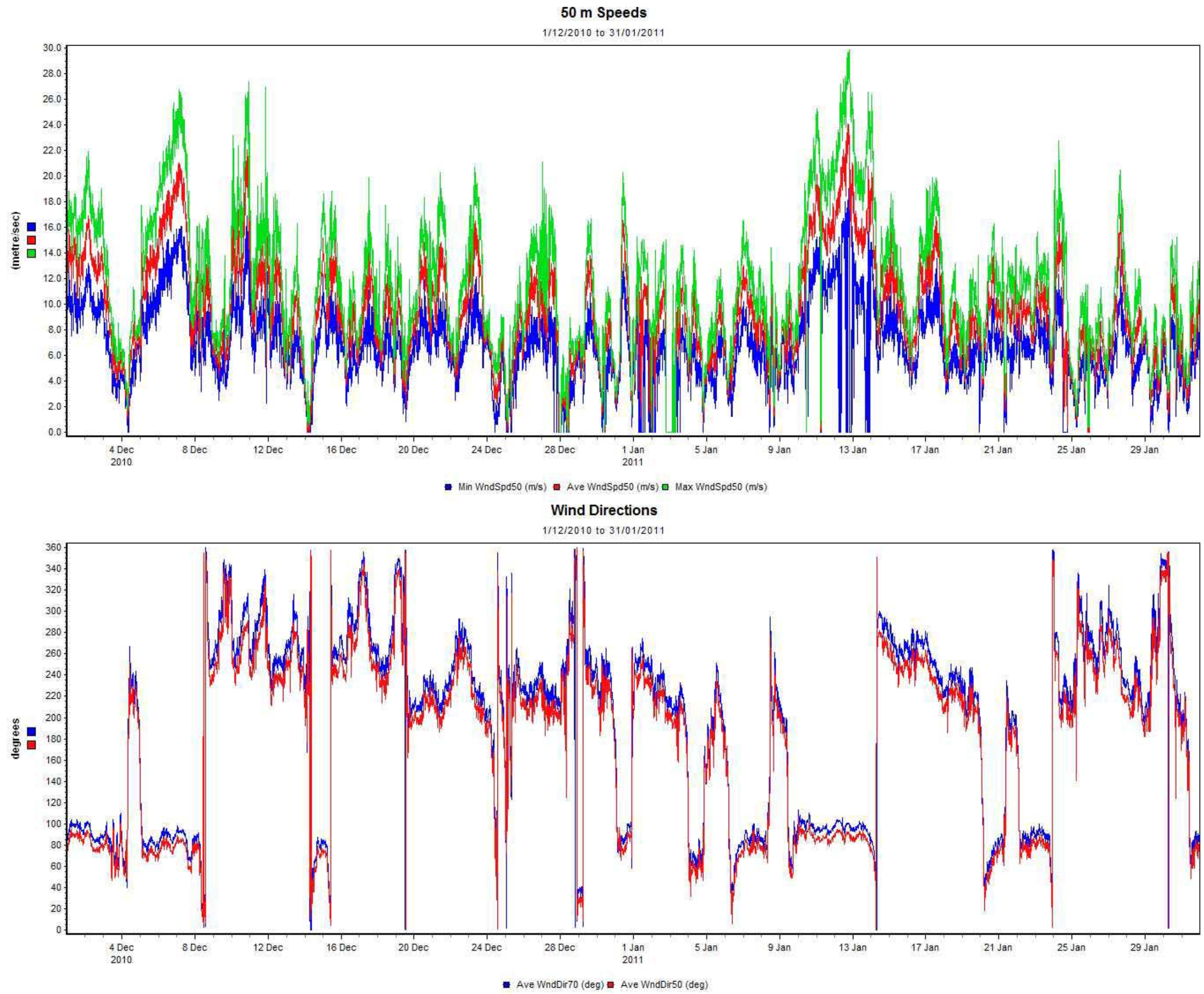


Figure 2: Wind speed (top panel) and directions recorded 50m above White Rock Ridge during the study. Data provided by Eureka Funds Managment. In the top panel, minimum, average and maximum wind speeds are coloured blue, red and green respectively. Wind direction (in degrees) is presented in the lower panel; the red lines represent direction at 50 m above White Rock Ridge, the blue lines represent direction at 70 m above White Rock Ridge.

Birds were captured by cannon-netting, using equipment loaned by the Victorian Wader Study Group as authorised under Permit No. FA 10210 from the Department of Primary Industries, Parks, Water and Environment. Thirty Red-necked Stints were radio-tagged, one captured at Bird Point (Western Robbins Island), on 13th December 2010, and the remainder in a catch of 38 Red-necked Stints at Bird Point on 15th December 2010 (29 were radio-tagged, and the remainder released after banding). Ruddy Turnstones proved impossible to catch on the west coast of Robbins Island, as very few roosted there in December. Instead, 12 Ruddy Turnstone were cannon-netted and radio-tagged at Perkins Island on 17th December 2010. A Curlew Sandpiper *Calidris ferruginea* was also captured, and released without a radio-tag after being banded. All birds were fitted with individually numbered metal leg bands and two coloured plastic leg-flags (orange over blue). The leg-flag code used is standard for migratory shorebirds banded in Tasmania (following guidelines set by Wetlands International and the Australian Bird and Bat Banding Scheme). The leg-flags made radio-tagged birds tagged more readily detectable through telescope observations, which were important in checking that the behaviour of radio-tagged birds in the field was similar to that of their flock mates.

All birds were fitted with 'pip' transmitters from Biotrack Pty Ltd. Weights of the transmitters ranged from 0.8 g (on Red-necked Stints, non-breeding mass c. 28 g) to 1.3 g (on Ruddy Turnstones, 1% of average non-breeding mass of 130 g). The radio-transmitters were superglued to the trimmed rump feathers of the birds, a method which keeps them firmly in place until the next body moult is completed. Detection range for the transmitters was expected to range between 1 and 3 km given a clear line of sight. This expectation (checked with test transmitters) proved to be reasonable, and in fact considerably longer detection ranges were achieved from the elevation of White Rock Ridge.

Radio-tracking procedures and other fieldwork are described more fully in the following sections. The broad strategy of the study was to establish a radio-telemetry array which would keep track of the locations of birds for as many hours per day as possible. Although the applied aims of the project were quite specific (to establish whether there was a risk of shorebirds colliding with turbines on White Rock Ridge, or with transmission lines across Robbins Crossing), limitations of the technology available meant that these questions could not answered solely by placing receivers at the exact sites where wind farm development has been proposed. Rather, it was necessary to develop a full understanding of the movement routines of the study species, so that across the Wind Farm site could be placed in context. Accordingly, the ARTS were supplemented by a structured program of both hand-held telemetry and visual observations across the study area.

3.2 The Automatic Radio-telemetry Array

Wildlife radio-telemetry studies are widely used to investigate the behaviour of individual animals. Small radio-transmitters are attached to animals which are then released, and subsequently re-located using radio-receivers. This approach has the great advantage that the behaviour of animals can be investigated in circumstances when direct observation is not feasible.

In this study we used 'pip' transmitters, also known as 'bleepers' (Figure 3). The head of the transmitter contains a battery and electronics, attached to a long thin antenna which emits a single 'beep' on a unique frequency at regular intervals. The strength of the pulse is limited by battery size, so on small birds detection range is a few kilometres at most. The transmitters used in this study sent out signals in the 150MhZ range, and each transmitter used in the study had an individual frequency that differed from the other transmitters by at least 0.015 MHz. All transmitters were tested before being fitted to birds.

Figure 3: Ruddy Turnstone being fitted with radio-transmitter (top left); leg-flags used to allow radio-tagged individuals to be picked out an observed in the field (top right); a Red-necked Stint with fitted radio-transmitter, the antenna trailing beyond the tail (bottom image).

An array of automatic radio-telemetry stations (ARTS) was established, consisting of nine separate receiving stations. Each station (example shown in Figure 4) consisted of a weatherproof box containing an SRX400 or an SRX600 receiver (from Lotek Pty Ltd). Each receiver was connected to a power source (a truck battery trickle-charged by a solar panel) and to two antenna mounted on a 3 m mast. A small omnidirectional antenna was used to detect nearby signals (within *c*. 500 m) from any direction. A large six-element Yagi antenna was also used, to scan for transmitters at longer range in a particular direction. Yagi antennae are not perfectly directional, and transmitters which are sufficiently close may be detected even if they are behind the antenna. The theoretical detection cone of a typical 6-Element Yagi Antenna is shown in Figure 4, demonstrating an area of detection of approximately 60 degrees either side of the central antenna direction.

Figure 4: The automatic receiving station at White Rock Ridge North.

The automatic receivers scanned for the frequencies programmed into them for this study, and logged detected signals provided they passed through filters designed to screen out most background noise (further filtering of records was required in the analysis stage). Scans by the receivers were made sequentially for each transmitter used in this study. Each scan lasted for four seconds, this scan duration allowing at least three pulses to be detected; a relatively long scan duration was preferred in order to collect several measurements of pulse interval, required for robust filtering out of false records. A total of 54 frequencies were scanned for in this study: 42 of these frequencies were for radio-transmitters which had been deployed in the field, and the remainder were dummy frequencies or test frequencies, used to determine the error rate of the receivers in logging signals and to assess the detection range of the transmitters. As scans were carried out separately for each antenna, the total duration required to scan through all transmitter frequencies before starting the next scan cycle was 4 seconds x 54 frequencies x 2 antenna = 7 minutes and 12 seconds.

Automated Radio Telemetry Stations (ARTS) were installed at strategic vantage points across the Robbins Passage region (Figure 5). Some stations were chosen as they were known to be of importance as roosting and foraging areas, and would therefore be important in identifying the daily routines of birds. Others were placed in less well-known sites to assess whether birds could move across the proposed White Rock Ridge wind farm site. A description of each station is provided below.

1. White Rock Ridge South. The site was selected to assess whether birds flew over this section of White Rock Ridge, and was placed approximately on the direct line of flight between the known shorebird roosts on Perkins Island, and important roosts on the north-western coast of Robbins Island (Knot Point and Five Islets). There was a clear line of sight to Knot Point and adjacent tidal flats, and the Yagi antenna was pointed in this direction (ENE). Although these sites were > 2 km from the station, the height of the station (77 m above sea-level) made detection of birds possible at long range with the Yagi antenna, but not the omnidirectional antenna.

2. White Rock Ridge North. This was the position of the second ARTS station located along White Rock Ridge at 46 metres above sea level. The Yagi Antenna on this station was pointed ESE, towards central and southern Mosquito Inlet. The station was erected to detect birds flying over the ridge at this point, or (with the Yagi antenna) to detect shorebirds foraging in Mosquito Inlet. In the event, results indicated that the station could also sometimes detect radio-tagged birds in the Bird Point area.

3. Mosquito Inlet. This ARTS station was located on the shores of Mosquito Inlet, ten metres above sea level. The Yagi Antenna was pointed north-east so that the detection cone would include birds flying through the Walker Crossing, foraging on the northern flats on Mosquito Inlet, and (provided detection range was long enough) roosting on the sand spit at eastern mouth of Mosquito Inlet.

4. Bird Point. This site, on the north-west coast of Robbins Island, is known from previous studies to be an important high tide roost; it was also the capture site for the Red-necked Stints radio-tagged in this study. The ARTS station was located on the sand dunes overlooking the Bird Point high tide roosting site, and much of the roost area was within range of the omnidirectional antenna. The Yagi Antenna was pointed north-west, pointing over both the Bird Point roost (to detect roosting birds potentially beyond the range of the omnidirectional antenna), and over tidal sand flats to the west and north of Knot Point.

5. Knot Point. This ARTS station was located on the sand dunes overlooking the important high tide roosting site at Knot Point. The Yagi Antenna was pointed out overlooking the roost site and the sand flats to the west of Robbins Island. Experiments with test transmitters showed that one of the islets that made up Five Islets was also in the range of the Yagi Antenna.

6. Five Islets. This ARTS station was located on the sand dunes overlooking the majority of the Five Islets. The Yagi Antenna was pointed WSW and overlooked the islets and sand flats. This point was chosen as it was known to be a popular roosting site and foraging area for migratory shorebirds.

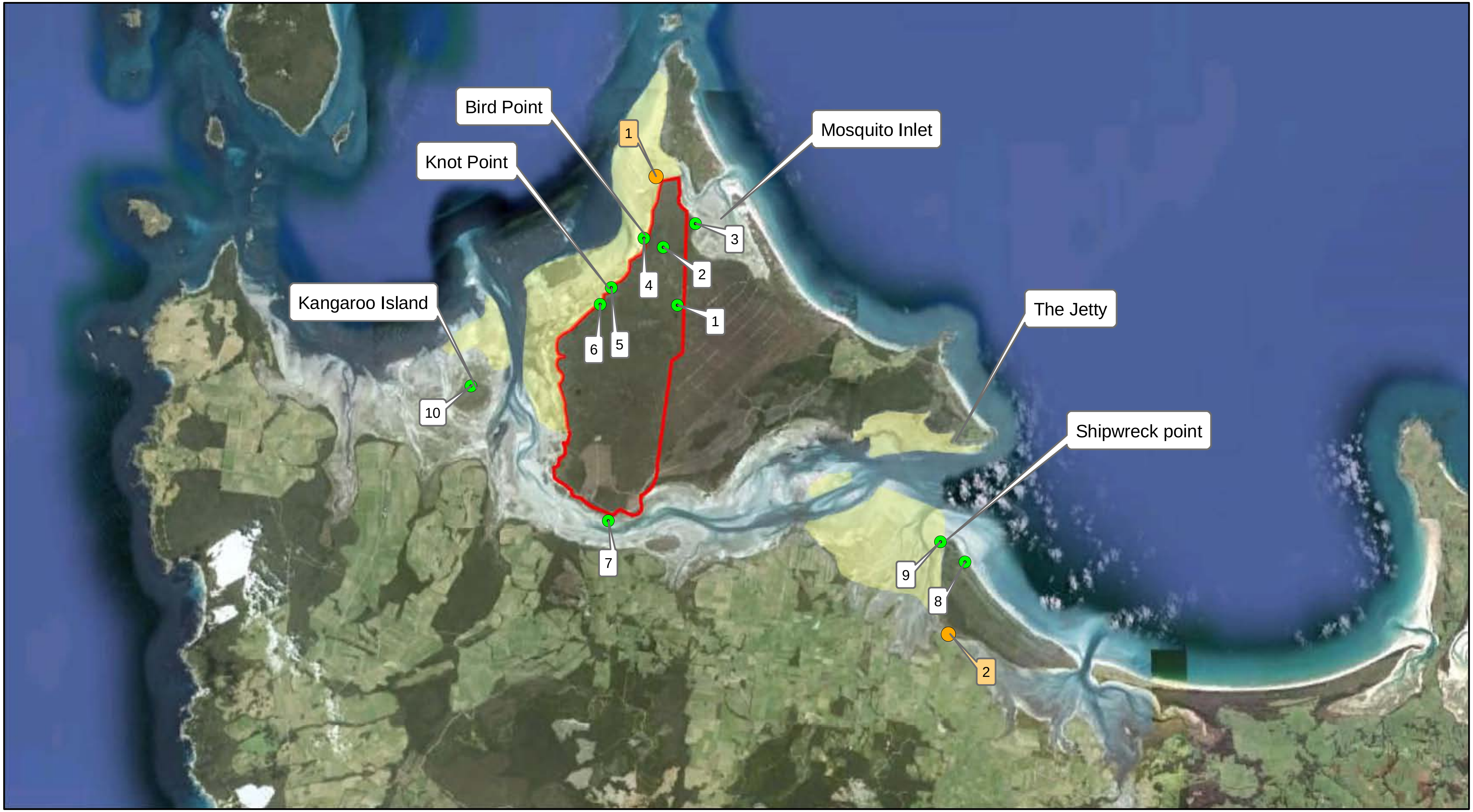
7. Black Phil's Point. This ARTS station was located on a point on the south side of Robbins Island. The Yagi antenna was directed S, overlooking the sand flats. This position was chosen in an

attempt to capture signals of birds in Robbins Crossing if they use this route when moving between Robbins and Perkins Islands.

8. Perkins South. This ARTS station was located on the sand dunes overlooking shorebird roosting areas on the north east coast of Perkins Island. The Yagi Antenna faced SE, overlooking the areas most often used by roosting Ruddy Turnstone and Red-necked Stint during reconnaissance in December, and in previous studies by BL&A. This roost was the capture point for the Ruddy Turnstone.

9. Shipwreck Point. This ARTS station was located on the northern point of Perkins Island. The Yagi Antenna was directed W, overlooking the tidal flats area in Big Bay. The station was set up in part to attempt to scan for birds foraging on Big Bay at low tide, and also to scan at high tide for birds which chose to roost at the tip of Shipwreck Point rather than at the traditional Perkins South roost (1.5 km to the south). The Shipwreck Point station was taken down on the 6th January 2011 and moved to Kangaroo Island.

10. Kangaroo Island. This ARTS station was located on the northern side of Kangaroo Island. The Yagi Antenna was pointed north overlooking the roost site and sand flats to the north. This position was chosen due to it being a popular roosting site by migratory shorebirds. This ARTS operated between 6th and 24th January 2011 once it became apparent that this island was being used more regularly than originally anticipated. Logistical difficulties early in the investigation limited access to this island.



Legend

- Proposed Wind Farm Boundary
- Shorebird Habitats
- ARTS Locations
- 1 ARTS Station Numbers
- Automatic Depth Recorder
- 1 Automatic Depth Recorder Numbers

0 2.5 5 10 Kilometers

Figure 5: Location of ARTS Stations & Depth Guages		
Project: White Rock Wind Farm		
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3.3 Handheld telemetry and direct observation

In addition to the ARTS stations, handheld radio tracking devices were used intensively during the study. The receivers (Communications Specialist R1000) were attached to 3-element Yagi antennas (Lotek Pty Ltd), mounted on short poles and held so the antenna was c. 2 m above the ground. In total 111 scans were made for all frequencies of test transmitters and transmitters deployed on birds: 11 scans between 19 and 21 December 2011; 69 between 5 and 7 Jan 2011; and 28 between 19 and 23 January 2011 (Table 1). These were used to help track down individual birds and observe their behaviour. It was prudent to the study to ascertain if the birds that were caught and tagged were behaving like the other shorebirds in the study area, both of the same species and of other species.

Once a signal was picked up by the handheld receivers, the observer scanned the sand flats or roost site for that individual bird, using a tripod-mounted telescope to look for flagged legs and the antenna of the radio-transmitter projecting beyond the tail tip. Once the bird was located it was monitored and notes were recorded on its behaviour and whether or not it was behaving similarly to the other shorebirds in the area.

The handheld receivers were also used to locate frequently used foraging areas. On the western side of Robbins Island, during low tides a field worker walked out on the flats to the tidal edge, scanning through the frequencies and recording which individual birds were foraging in the area. As the tide rose the birds moved closer to the coast line until they eventually flew to their roosting site. The direction the birds flew was recorded to reveal where their roosting site was.

While this exercise was being undertaken, another field worker was positioned at a roosting site two hours before the peak of high tide at Bird Point, Knot Point or Kangaroo Island. The frequencies were scanned through using the handheld receiver during this time and confirmed signals were recorded. Observations were made as to what time shorebirds arrived at the roost, their general behaviour patterns and abundance of species. The daily routine of the shorebirds was determined by making these observations.

Scanning of frequencies was undertaken at different positions along White Rock Ridge. This involved scanning through the frequencies using the handheld receivers.

In addition, the handheld telemetry enabled field workers to establish which birds could and could not be located, enabling focussed searches to be made for individuals which appeared to have left the study area. Searches for 'missing' individuals, mainly Ruddy Turnstone, were not only undertaken in the core study area, but in other potential sites including the south-eastern coast of Robbins Island, and at traditional shorebird roosts near Stanley.

A final objective of the handheld telemetry was to check the tuning of the radio-transmitters; sometimes the frequency of transmitters alters slightly after being deployed on a bird. This proved not to be a problem during this study, and there was no need to reprogram the frequencies scanned by the automatic radio-receivers.

Table 1: Number of records of each radio-tagged individual made by handheld radio-telemetry. Eight of 12 Ruddy Turnstone and 27 of 30 Red-necked Stint were relocated through handheld telemetry. In total 56 scans out of 280 were made in which no radio-tagged birds could be located.

Bird Tag	19-21 Dec	5-9 Jan	18-23 Jan.	Total
Ruddy Turnstone				
BIG 11	1	0	0	1
BIG 12	3	0	0	3
BIG 13	1	0	0	1
BIG 14	1	2	0	3
BIG 16	1	0	0	1
BIG 17	1	0	0	1
BIG 18	1	0	0	1
BIG 19	1	0	0	1
BIG 20	1	0	0	1
Red-necked Stint				
RNS 1	0	2	1	3
RNS 11	1	5	0	6
RNS 12	0	5	0	5
RNS 13	0	4	0	4
RNS 14	0	3	0	3
RNS 15	1	11	5	17
RNS 16	1	4	1	6
RNS 17	0	6	1	7
RNS 18	0	5	0	5
RNS 19	0	10	0	10
RNS 2	0	11	0	11
RNS 20	2	1	2	5
RNS 21	5	12	5	22
RNS 22	0	4	0	4
RNS 23	5	10	1	16
RNS 24	0	17	5	22
RNS 25	0	9	2	11
RNS 26	3	7	2	12
RNS 27	0	12	0	12
RNS 29	1	11	0	12
RNS 30	2	12	1	15
RNS 32	2	9	0	11
RNS 5	0	5	3	8
RNS 6	2	3	0	5
RNS 7	0	2	0	2
RNS 8	5	10	0	15
RNS 9	5	10	0	15
Total	49	202	29	280

3.4 Tide records

Shorebird movements in intertidal settings are strongly influenced by tide conditions. We used automatic depth recorders (Odyssey Pty Ltd) to keep a continuous measure of water depth at two sites (Figure 5). One was at Walker Crossing, the other at the crossing to Perkins Island. They confirmed that the sites have two high and two low tides per day, that high tides at night were usually a few centimetres higher than those by day during the study period. The difference between peak tide heights during neap and spring cycles was relatively small (>60 cm).

Results from the tide gauges showed despite some fluctuations related to wind direction, the time of high tide could be predicted reasonably accurately on the basis of published tide time-tables for Burnie. Time of high tide at Walker Crossing (and on the flats to the west of Robbins Island where most birds occurred) was approximately equal to the predicted time of high tide at Burnie plus two hours (Figure 6).

As the tide gauges were not deployed until 20th December, the predicted tide heights based on Burnie timetables were used to assign each radio-tracking record to one of the following categories: High tide (within 2 hours of predicted peak tide); Rising tide (2-4 hours before peak), Ebbing Tide (2-4 hours after peak), and low tide (all other records). There were 84 high tides during the period when radio-tagged birds were being tracked.

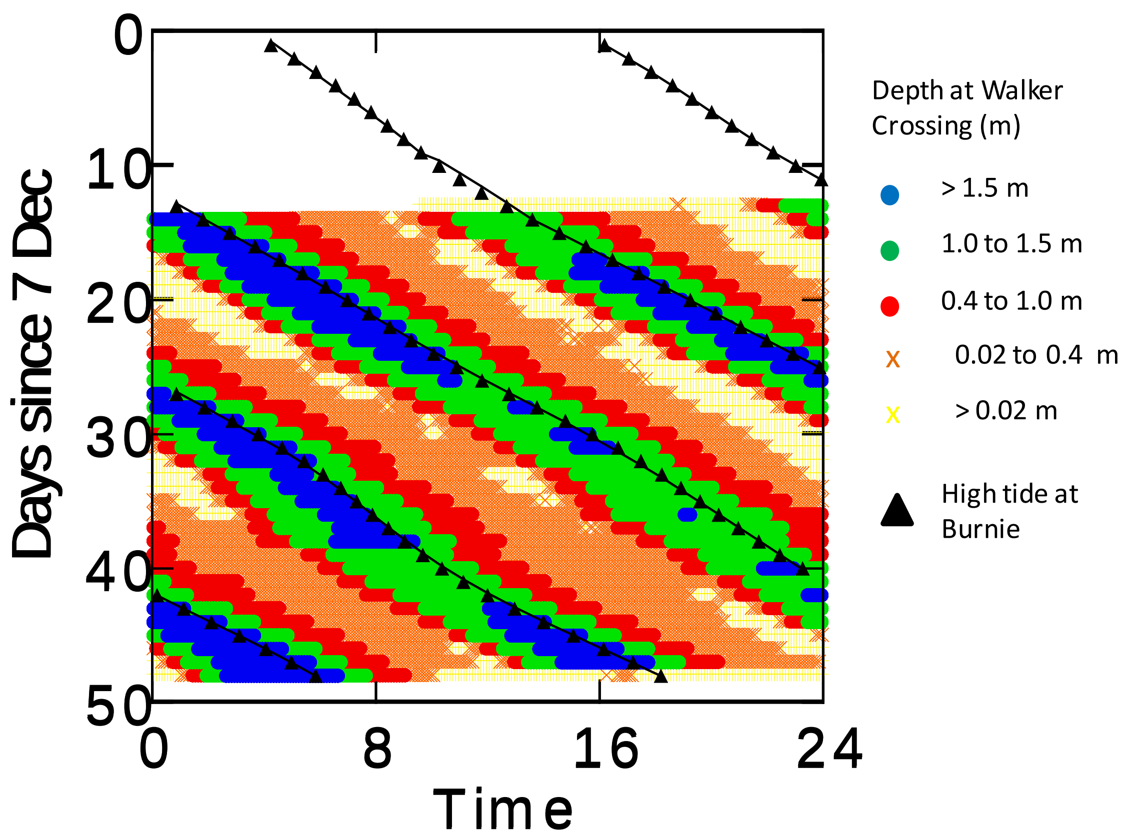

Figure 6: Water depths recorded by the tide gauge set up at Walker Crossing. Times of high tide predicted from tide timetables are also plotted, using the tide time at Burnie plus a two-hour delay.

3.5 Analysis of Automatic Radio-telemetry records

Automatic receivers scan sequentially through pre-programmed radio-frequencies, and log those scans on which signals were received. Only limited bands of radio-frequencies can be used in wildlife studies (the 150 MHz Range was used in this study), and even these frequency bands are not free of all other sources of radio-waves. In addition to the desired signals from deployed radio-transmitters, there is also a varying amount of background noise, and there can be occasional bursts of electromagnetic radiation (caused by e.g. nearby motors, electrical storms, fluctuations in power supply) that can mimic the signals made by radio-transmitters and hance be recorded by the data-loggers. In practice these false records can be numerous, and careful analysis to distinguish real from false records is always an important part of automatic radio-telemetry studies.

'Pip' transmitters (from Biotrack Ltd, UK) were used in this study. Transmitters of this kind, also widely known as 'beepers', emit a single 'beep' at regular intervals: in this study, 46 Beeps per Minute (BPM) for Red-necked Stint transmitters, and 53 BPM for Ruddy Turnstone transmitters. Signals were considered acceptable if:

1. Pulse duration was within the range of 43-49 BPM for Red-necked Stints, and 50-56 BPM for Ruddy Turnstone. A data file using only this filtering step was retained so that we could check for any evidence of brief flyovers of strategic points, but except where stated, we used a more refined data file in which records were only retained:

2. If signals were received at least three times during each four-second scan (i.e. two measurements of pulse interval were available).

3. If consecutive pulse intervals varied by less than 20 milliseconds (*c*. 0.7 BPM).

Even with this tight filtering, some 'false' signals were recorded. We assessed how frequently false records were made by examining scans made for dummy frequencies belonging to transmitters which were known to be switched off and in storage – i.e. for test transmitters, and for bird transmitters before they had been attached to birds. These data are summarised in Figure 7 and Table 2. On average, a false record that passed through the basic filters on the automatic receivers was made on 0.02% of scans. Some frequencies were more prone to interference than others, and some stations had a higher error rate than others. The highest error rates were recorded at the Five Islets station (0.119%) and White Rock Ridge North (0.049%), while no errors at all were recorded some other stations (Table 1). These error rates could be used to make an estimate the expected number of 'false' records (final column of Table 1). This estimate is approximate only; it is not possible to make a more precise estimate with confidence limits as some transmitter frequencies may have been more influenced by interference than others.

The error rates recorded in this study are not out of the ordinary for radio-telemetry studies carried out with beep transmitters, and tighter filters using signal strength would have led to discarding a very large proportion of 'good records'. However, it is important to be aware that there is some potential error for error, especially when looking at isolated records.

To avoid drawing incorrect conclusions from false records, we therefore also assessed records bearing in consideration an overview from the automatic radio-telemetry array and handheld records. Underlying concepts were that (1) An individuals could not be in two sites at one time; (2) that if an individual was at one site over a period of time, it would generate several signals. Records were allocated to the following time intervals:

- High tide: Within two hours of the peak of high tide;
- Rising tide: Two to four hours before the peak of high tide
- Ebbing tide: Two to four hours after the peak of high tide.
- All other records were allocated as low tide, the nadir of which was assumed to fall halfway between the peaks of two consecutive high tides.

Location of each bird during each tide interval was assessed according to the following criteria:

HIGH CONFIDENCE

1 Records accepted if >3 records from one particular site, and none from elsewhere

2 Records accepted if >3 records from one particular site, and only one from elsewhere

3 Records from multiple sites. If >2 from each, then it was assumed that it used two sites, or was (in the case of WRR S) in the same place but detected by two stations.

4 All records were accepted if corroborated by handheld telemetry or direct observation

MODERATE CONFIDENCE

5 Two records from one station and none from elsewhere.

6 Two records from one station, and one from elsewhere. Assumed the bird was at the most commonly used station.

7 Two records from multiple stations. If these included WRR S and west coast sites, we treated WRR S as a west coast site and assigned the record to most commonly used site. Otherwise it was assumed that there was a movement between sites

8 One record from a west coast site, and one from WRR S. Assumed WRR S picked up a west coast bird, and treated that west coast site as the locality

LOW CONFIDENCE

9 One record from one site only.

10 One record only from two sites. Assigned bird to the site with the lowest error rate.

11 No records - location unknown

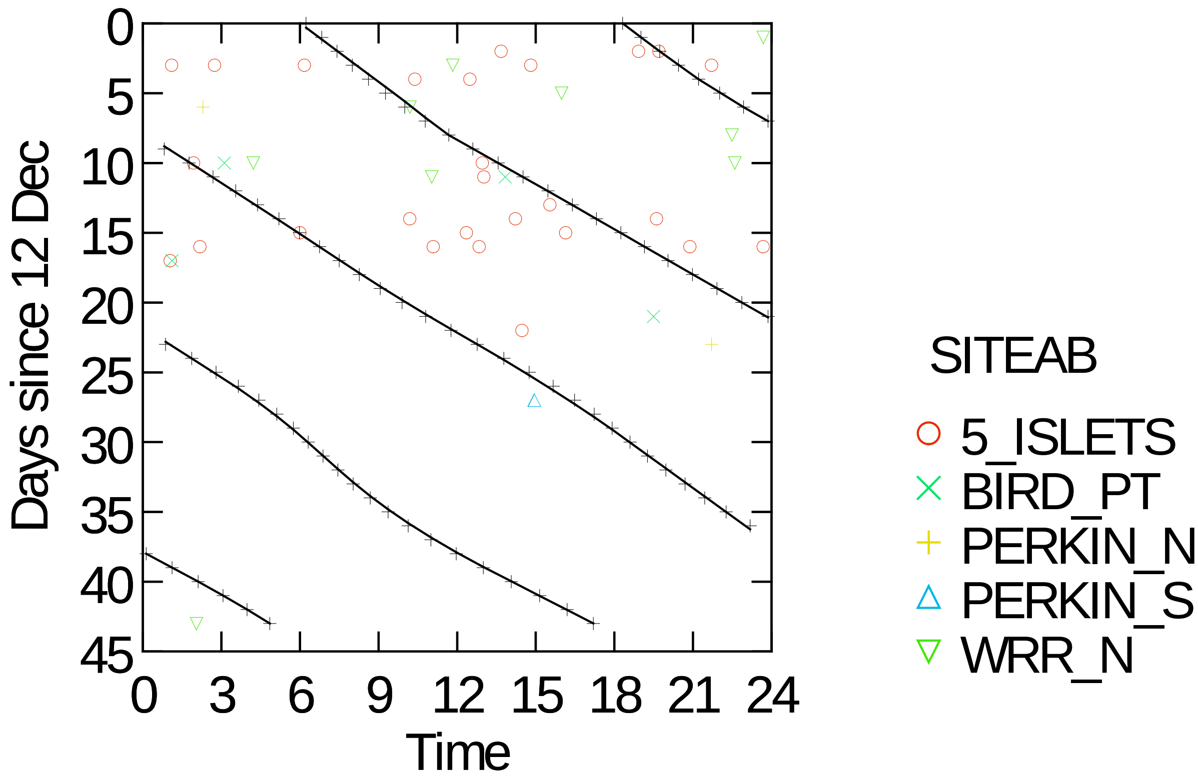

Figure 7: Records of dummy tags during the study period at Robbins Passage.

Table 2: Number of false reports of dummy frequencies recorded by automatic receivers in the study area with a filtering procedure that only retained signals if they were repeated at least three times during a scan and varied by less than 0.7BPM within the scan.

ART Station	Number of dummy records	Error rate per scan	Approximate number of scans for deployed transmitters	Expected number of false records during the study period
Bird Pt	6	0.0259%	258050	14.6
Five Islets	28	0.1182%	322560	83.4
Kangaroo	0	0.0000%	112900	0
Knot Pt	0	0.0000%	290300	0
Mosquito	0	0.0000%	40320	0
Perkins S	2	0.0087%	169300	3.2
Shipwreck Pt	2	0.0118%	185470	4.8
WRR N	9	0.0489%	209660	20.6
WRR S	0	0.0000%	282240	0
Black Phil's Pt	0	0.0000%	298370	0
			0	
Total	**47**	**Average = 0.02%**	**1870848**	**126.7**

4 RESULTS

4.1 Daytime observations and handheld telemetry records

This section of the report summarises observations made during the investigation separate from automatic radio-tracking. These comprised a combination of daytime observations and handheld radio-telemetry (see specifications in Section 3). Observations from these two methods are considered separately below. The observations described here refer only to birds using habitats in the vicinity of the proposed wind farm, on the western and northern shores of Robbins and Walker Islands and Kangaroo Island.

4.1.1 Daytime observations

Shorebirds of a number of species use the Robbins passage area. During the investigation period, shorebirds behaved in a manner consistent with previous findings about their behaviour (see BL&A 2010).

In summary, they foraged at low tide on the wide sand- and mud-flats on the west coast of Robbins Island, north from about Little River to the west side of Walker Island. As the tide rose, they gathered on Kangaroo Island or on small islands and points on the west coast, specifically at Bird and Knot Points, or on Five Islets. Figure 5 shows the location of these foraging habitats and roosting sites.

Up to 4,000 birds, the largest number of shorebird observed anywhere during the investigation, were observed at the Kangaroo Island roost site. This was a critical roosting site this year. It is noteworthy that smaller numbers were observed at Bird and Knot Points this year compared with other years (Birds Tasmania data; BL&A 2010).

Birds were observed flying low over the sea or tidal flats (i.e. less than 10 m elevation) between foraging and roosting habitats. On occasions, if flushed by a bird of prey or an observer, birds were observed flying higher, up to 30 metres above the sea and mudflats.

During daylight hours, when such observations were possible, shorebird flights were only observed over tidal flats or open water, and between foraging and roosting sites. There were no observations of birds flying over the White Rock Ridge on Robbins Island, or flying inland. During previous daytime observational work reported in BL&A (2010), few observations were made of birds flying over the White Rock Ridge, and most observations similarly involved low flights over the sea and tidal flats between these known foraging and roosting habitats.

Note that an attempt to watch for shorebird movements from roosts at night during full moon was made in summer 2009, without success. This was one of the reasons for using radio-tracking.

4.1.2 Hand-held radio-telemetry

Hand-held radio-tracking was undertaken with two aims:

- to confirm the location of birds within known habitats for cross-referencing with the results of the automatic radio-tracking; and
- to determine if radio-tagged birds were flying over areas of interest to the proposed wind farm project.

Use of known habitats

Hand-held radio-tracking on the west coast of Robbins Island indicated that during the day there were regular, tide-induced movements of shorebirds foraging on the sand flats and as the peak of high tide approached the shorebirds moved to Kangaroo Island to roost. Less frequently, birds were radio-tracked moving to Bird and Knot Points. After high tide, the birds would fly north (approximately 500 metres) to exposed sand flats and continue foraging , gradually moving further north as the tide dropped until many reached the western coast of Robbins Island and the southern part of the west coast of Walker Island.

Eleven scans of all frequencies at Perkins Island failed to locate any radio-tagged Red-necked Stints. Section 4.4.2 of the report describes the detection of radio-tagged Ruddy Turnstones shortly after catching on the west coast of Robbins Island, after which time they disappeared from the Robbins Passage region. One Ruddy Turnstone tag was found on Perkins Island on 7th January, three weeks after the tag had been deployed. This raised the concern that other Ruddy Turnstones (a shorebird species with a short sturdy bill) may have managed to detach their radio-transmitters. Thereafter, all Ruddy Turnstones seen during fieldwork were scanned carefully to see whether they had leg-flags but no radio-transmitters, but no flagged birds were found, though several hundred were scanned on the west coast of Robbins Island. Seven of the remaining 11 Ruddy Turnstone were detected later during the study through the automatic receivers, though they were never relocated by handheld telemetry.

One day was spent at roost sites in the Stanley area, well east of Robbins Island in an effort to try and relocate the Ruddy Turnstones that disappeared from the Robbins and Perkins Islands areas shortly after they were caught. In addition, scans were made of the Ruddy Turnstone flock that occurs regularly near the boat ramp in the south-west of Robbins Island. No radio-tagged or leg-flagged Ruddy Turnstones were found at these sites.

During the study period, which included a number of strong easterlies, and strong cold fronts from the west and south-west, there were no detected movements of Red-necked Stints between Perkins and Robbins Island. There were only two movements between the sites made by some Ruddy Turnstone (further confirmed by automatic radio-telemetry, see section 4.4.2). This disproves an earlier hypothesis that inclement weather on the west coast of Robbins Island may result in movements of shorebirds away from the exposed west coast of Robbins Island to the more sheltered roost at Perkins Island. This hypothesis arose as a consequence of trends in counted shorebird numbers between the two areas in earlier counting studies (BL&A 2010). However, the Kangaroo Island roost could not be counted during these earlier investigations. This radio-tracking investigation (hand-held and automatic) has shown how significant this roost is, including during inclement weather. It is a north-facing site with good saltmarsh cover in places where birds shelter from strong winds.

Use of wind farm project areas

In addition to hand-held radio-tracking within regular shorebird habitats, additional tracking was undertaken in key areas of interest to the wind farm project.

Scans through frequencies on White Rock Ridge (the proposed wind farm site) failed to detect any stints flying over the ridge. On one occasion a signal was detected on the ridge but based on the direction of the signal and a concurrent record from the automatic receiver at Knot Point, it was most likely coming from the west coast and not from shorebirds moving across the ridge. From the ridge, habitats on the west coast of Robbins Island are within the range of a Yagi antenna, as evidenced by the fixed, automatic Yagi results (from test transmitters and directly observed radio-tagged birds) from both ridge-top stations. Further results from the automatic radio tracking work on the ridges are described in section 4.4.3.

Scans through frequencies at Black Phil's Point on the southern end of Robbins Island near where the proposed overhead powerline is to be constructed, also failed to detect any stints. It is noteworthy that several hours of observations during tidal changes at this location in previous studies (BL&A 2010) also failed to locate any shorebirds, other than a small number of low-flying Pied and Sooty Oystercatchers (less than 5 metres above sea-level). Similarly, in the course of 30 low-tide surveys carried out between October 2004 and March 2006, Spruzen *et al*. (2008) observed only small numbers of Pied Oystercatchers, and no migratory shorebirds, in the passage between southern Robbins Island and the mainland.

4.2 Automatic radio-telemetry: site use

Overall the radio-telemetry array carried out *c*. 2 million scans for radio-tagged birds. Most of these were null scans (no birds detected), but in *c*. 50,000 cases a signal was received. Following rigorous filtering to eliminate false records, our main analyses were carried out on a file of 8515 records of deployed radio-tags.

Sites and timing of records of radio-tagged Red-necked Stint are shown in Figure 8. A large number of records were made from the stations on the west of Robbins Island, with the highest numbers of records tending to be when the tide was high. As expected, records at low tide were less common, as the tide on the extensive tidal flats ebbed so far that foraging Red-necked Stints on the tidal flats were often out of range of the land-based ART stations. There were a number of records from the stations positioned on White Rock Ridge. As will be discussed later in the report, most or all of these represent long-range detections of birds on tidal flats rather than flights over White Rock Ridge.

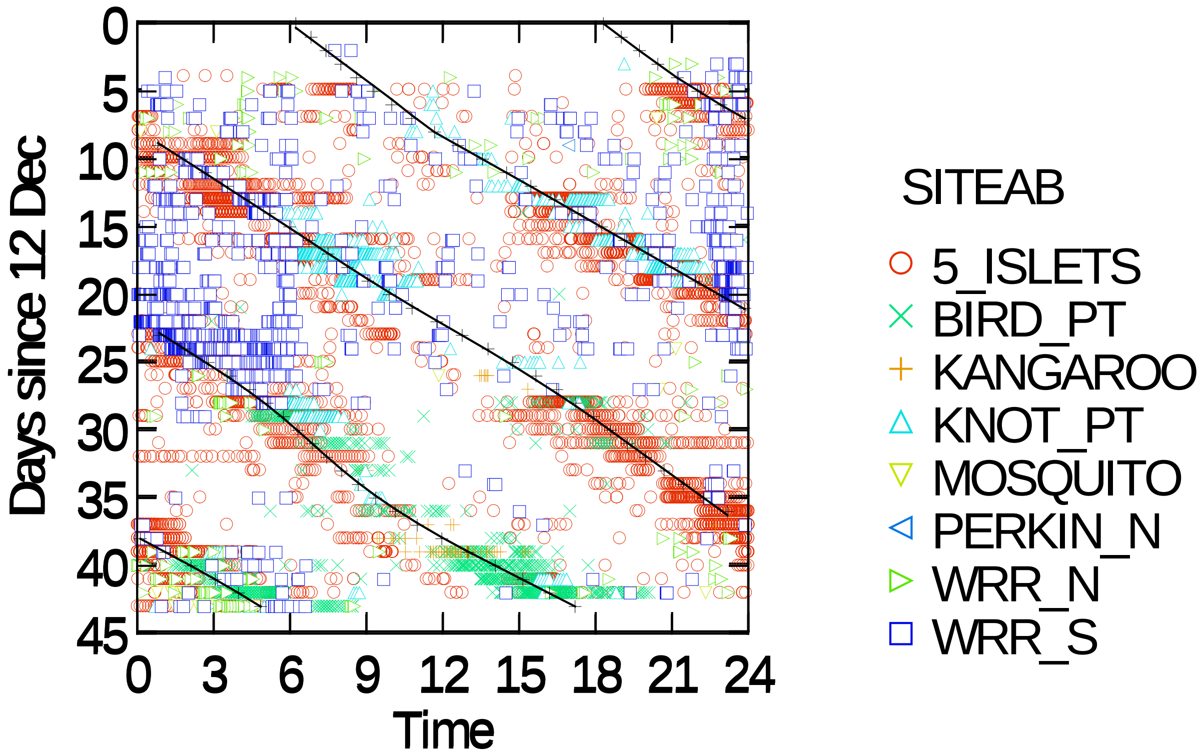

Figure 8: Records of Red-necked Stint from the automatic radio-telemetry array.

Sites and timing of records of radio-tagged Ruddy Turnstone are shown in Figure 9. There were clusters of records from Perkins Island from 17-19 December 2010 (shortly after the birds were banded on Perkins Island), and from 6-8 January 2011. Other records from the west coast of Robbins Island were isolated and sporadic, suggesting they considered mostly or entirely of false records. This possibility is discussed later in the report.

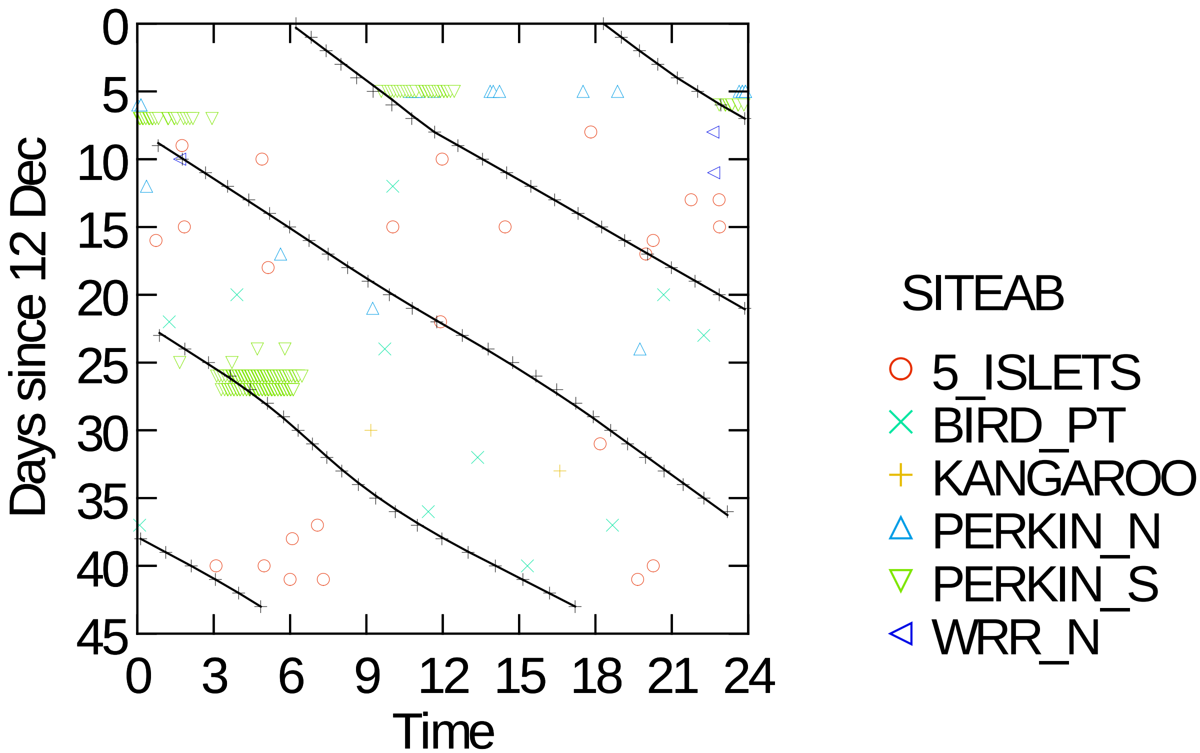

Figure 9: Records of Ruddy Turnstone from the automatic radio-telemetry array.

The automatic receiver at Five Islets recorded 4752 signals from radio-tagged birds, far more than any other station in the study. Records of Red-necked Stint at the Five Islets station are shown in Figure 10. The station operated continuously through the study, and 85.1% of the logged records came from the Yagi antenna. Most of the records were centred around high tide, especially at night, and the majority of records were made during westerly winds (47.8%) or southerly winds (28.2%). There were also numerous low tide records. In general signal strength was lower at high tide, but there were occasionally powerful signals at low tide, probably caused by birds taking flight and thus reaching an elevation at which there was a more direct line of sight between the bird and the antenna. Reception of individual birds was patchy. In some cases where birds were known (from direct observation or handheld telemetry) to be present at the Five Islets for over two hours, there were only one or two records logged by the automatic station. Direct observation indicated that in large part the inconsistency in signal power was caused by orientation of the birds; a stronger signal was received when the antenna of the transmitter was perpendicular to the Yagi antenna of the automatic receiver, and there could be no signals at all when the radio-tagged faced the automatic receiver, or moved behind an object or flockmate that disrupted the line of sight between receiver and transmitter.

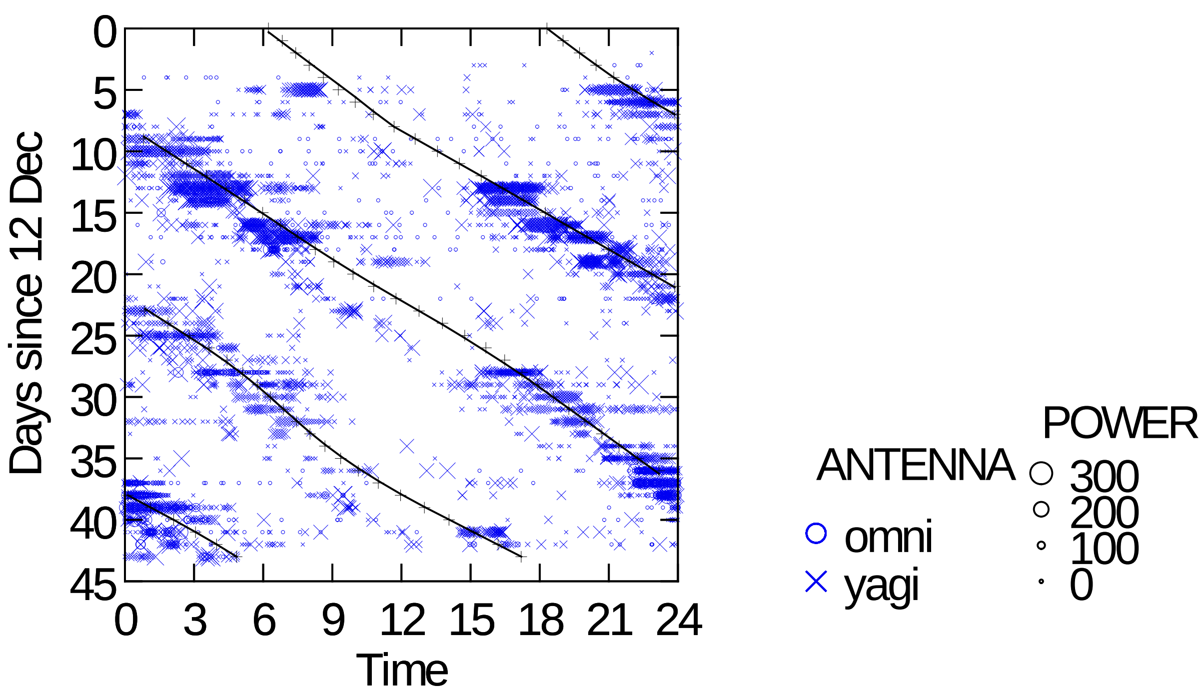

Figure 10: Signals received from Red-necked Stints by the ART Station at Five Islets. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

The station at Knot Point operated throughout the study and collected 817 records. Records from the automatic receiver at Knot Point (Figure 11) were made mostly by the omnidirectional antenna at high tide, and most were made during westerly winds (32.4% of records) or westerly winds (32.4% of records). In one respect, however, records from Knot Point showed a strikingly different pattern to those from Five Islets: the majority of records (see later) were made by day rather than at night.

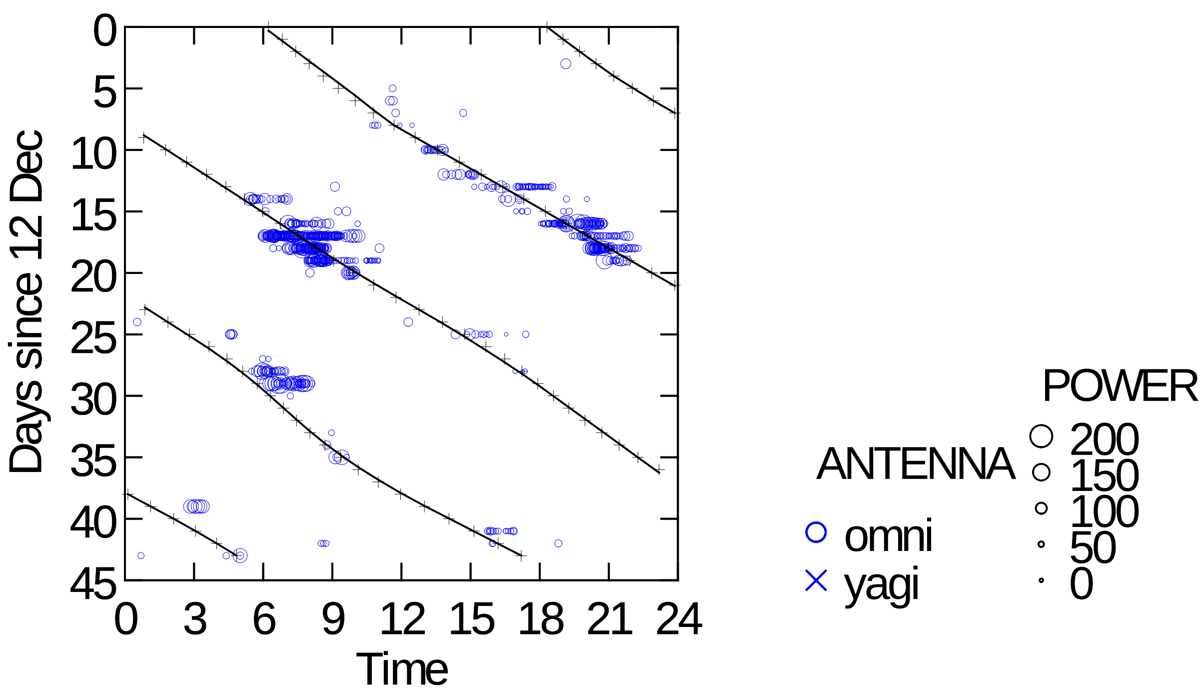

Figure 11: Signals received from Red-necked Stints by the ART Station at Knot Point. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

The station at Bird Point (Figure 12) operated continuously from 13 Dec., apart from a brief power failure on 15 Dec (the day on which Red-necked Stints were captured and radio-tagged at Bird Point). Most of the 905 received signals came from the omnidirectional antenna, even though the Yagi Antenna was directed at the roost where most birds were expected to be; it is possible that there was a problem with the cable to the Yagi antenna.

As at Knot Point, signals from the automatic radio-tracking station at Bird Point were mostly recorded on daytime high tides. Unlike Knot Point, however, most records (78.0%) were made during easterly winds. This may be why most records were made in the latter half of January, a period when easterly winds were dominant (see Figure 2). Bird Point is likely to be the most sheltered roost on the west coast of Robbins Island during strong winds, as it has a complex shoreline with a number of open area facing different directions. In addition, Bird Point remains above water on even the highest of tides; in contrast, the roosts at Knot Point and Five Islets can be mostly or possibly wholly submerged in such conditions.

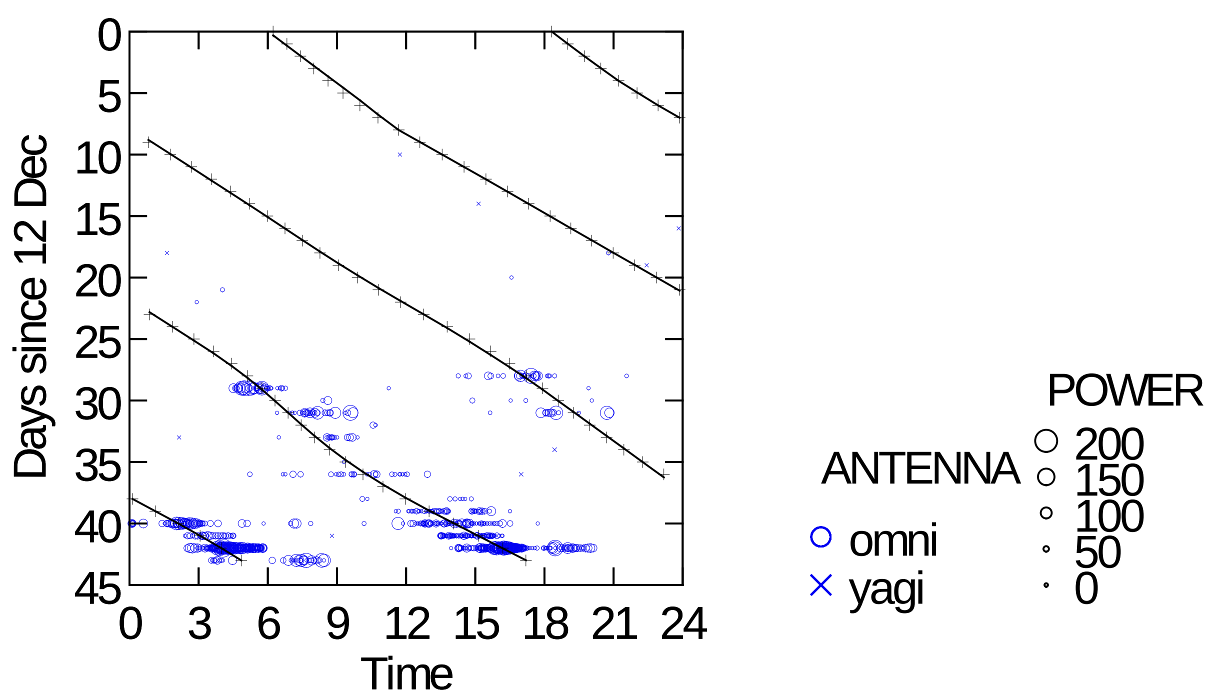

Figure 12: Signals received from Red-necked Stints by the ART Station at Bird Point. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

The automatic radio-tracking station at Kangaroo Island (Figure 13) was not set up until 7 Jan, hence the lack of records before day 25. The station operated continuously thereafter, but the Yagi antenna proved to be inoperable, so records were only collected by the omnidirectional antenna. In addition, the nearest dry ground on which the station could be set was some 300m from the main roost site. As a result, only a small proportion of the radio-tagged birds at Kangaroo Island were detected by the automatic station – e.g. on 6 Jan, handheld radio-telemetry confirmed that 17 radio-tagged Red-necked Stint were present at Kangaroo Island at high tide, but only two of these were detected by the automatic station.

Although only 75 records were made from Kangaroo Island, it is noteworthy that almost all (7.3%) were made during daytime high tides.

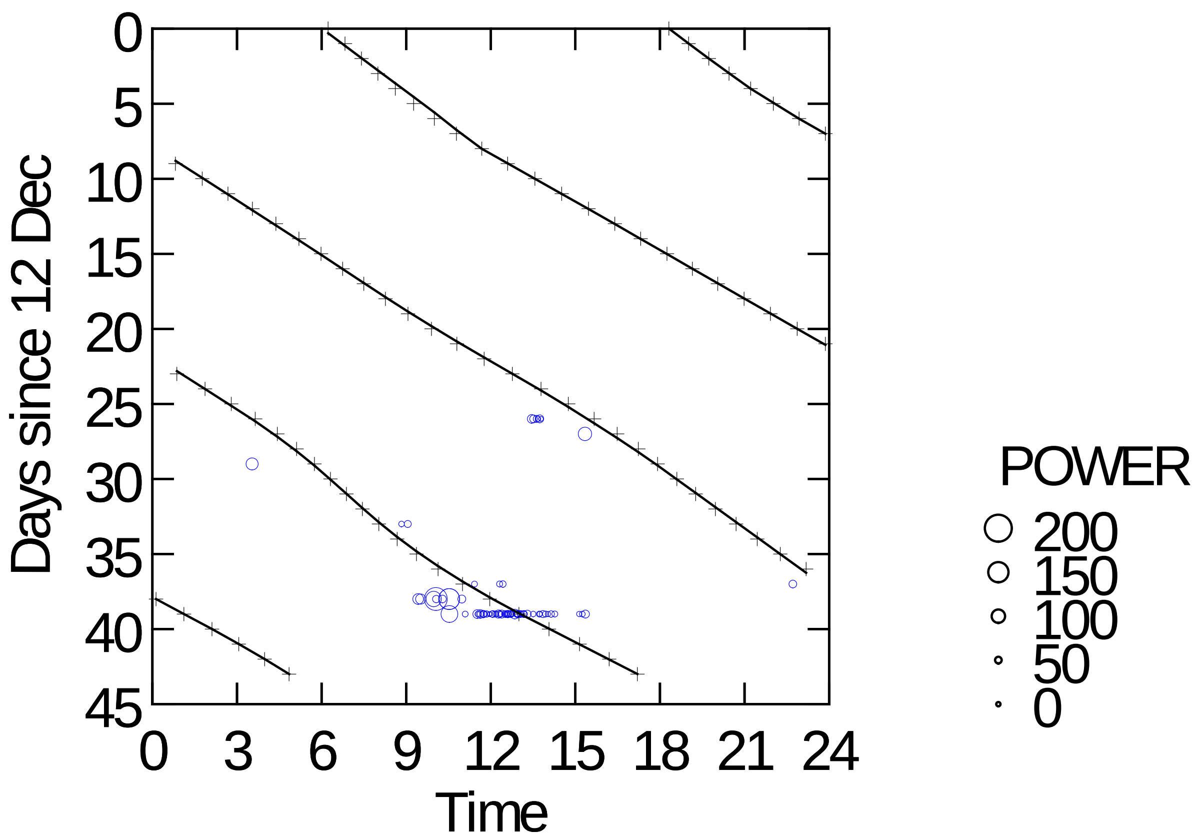

Figure 13: Signals received from Red-necked Stints by the ART Station at Kangaroo Island. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

The Automatic Radio-tracking Station on White Rock Ridge South operated throughout the study (Figure 14) and collected 1250 records. Records from the Yagi antenna frequently coincided with concurrent records from Knot Point and especially Five Islets, but there were no records from the omnidirectional antenna (except of test transmitters on White Rock Ridge). Most records were made at high tide (49.2%) and there were proportionately more records on ebbing tides (36.5%) than on rising tides (14.2%). A disproportionate number of records (70.7%) were made at night, apparently because of detections of birds that roosted at the Five Islets and then moved onto adjacent tidal flats to feed as the tide ebbed. The feeding grounds used on ebbing tides were used less on rising tides, when more birds gathered to the north, e.g. on tidal flats north and west of Bird Point.

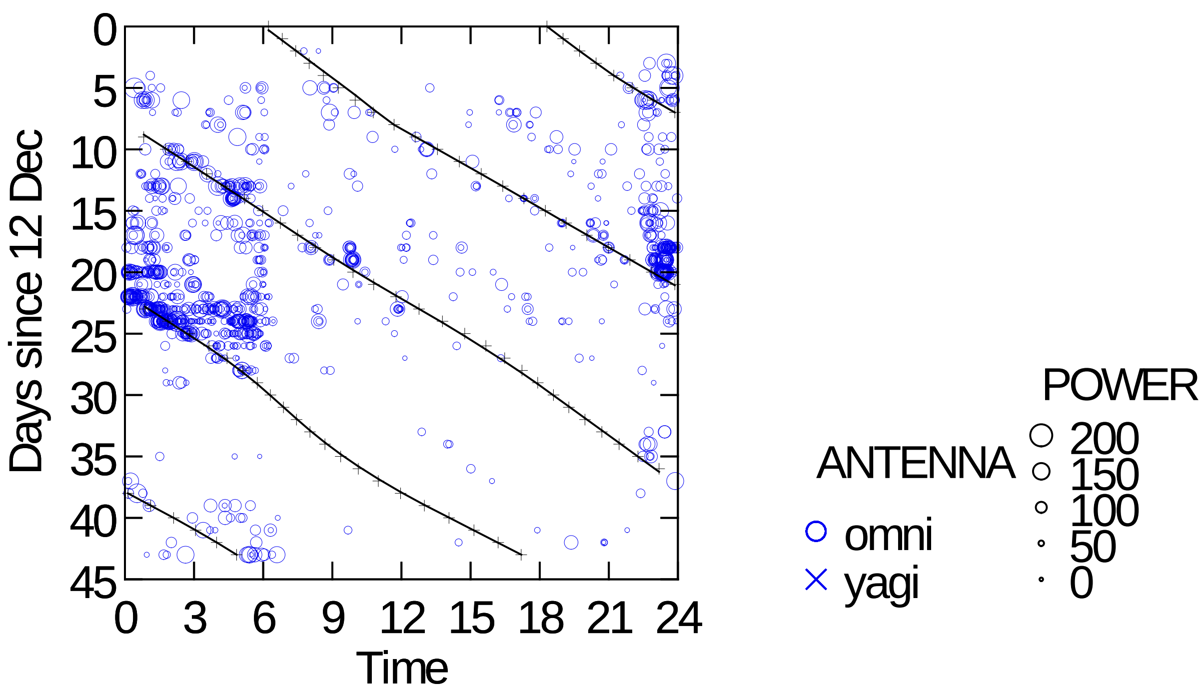

Figure 14: Signals received from Red-necked Stints by the ART Station at White Rock Ridge South. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

The station at White Rock Ridge North experienced some power failures, and although it was deployed from 13 December to 24 January, it did not record any data between 23 Dec. and 6 Jan, or between 10 and 19 Jan. At other times it recorded 288 signals from Red-necked Stints (Figure 15), mainly at night (74.6% of records, and mainly on high (52.7%) or rising (31.3%) tides. Records were received by both the Yagi and omnidirectional antennae, but signals from the Yagi Antenna (directed at southern and central Mosquito Inlet) were fewer and weaker than those from the omnidirectional antenna. It is thought that the station mainly detected birds at Bird Pont and adjacent tidal flats, with the high elevation of the station having such positive effects on detection range that the Yagi antenna sometimes detected reflected signals from behind. Interpretation of signals from the station at White Rock Ridge North (Figure 15) was complex, and is discussed more fully in section 4.5.5.

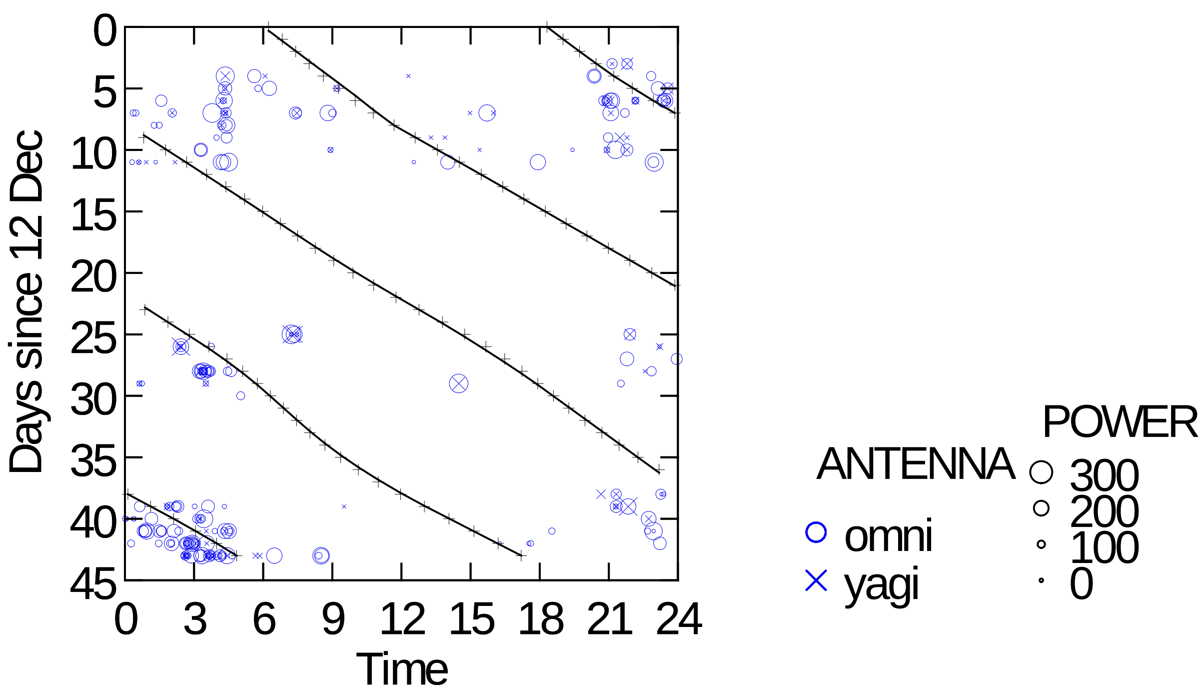

Figure 15: Signals received from Red-necked Stints by the ART Station at White Rock Ridge North. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

The Mosquito Inlet station (Figure 16) had persistent power failures, and was only operational for *c*. 7 days: 19-20 Dec., 5-8 Jan. and 23-24 Jan. While operational it received 40 signals, all from Red-necked Stints detected by the Yagi Antenna. Of these records, 36 were made at night, and 34 were made on rising or high tides. Intepretation of these records is discussed in section 4.4.5.

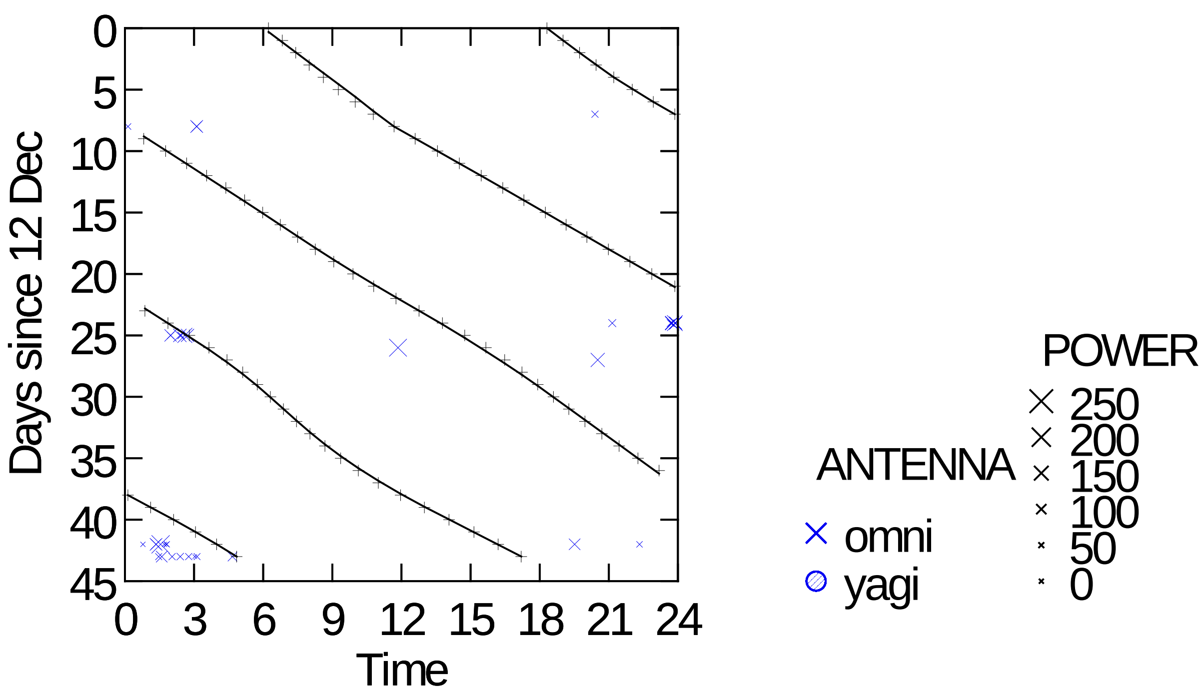

Figure 16: Signals received from Red-necked Stints by the ART Station at Mosquito Inlet. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

The station at the main roost site on Perkins Island (Figure 17) operated continuously during the study. It detected 247 signals, all from Ruddy Turnstone and nearly all over two short time periods, one between 17-19 December 2010 (just after the Ruddy Turnstone were radio-tagged), and one between 6-8 January 2011. All records were made at high tide (78.5%) or less than four hours after high tide (21.5%). Most records were made at night (86.2%); both during the December period of observations when night-time high tides were c. 20 cm lower than daytime high tides, and during the early January period of observations when predicted high tides heights were roughly equivalent by day and night. Most records were made by the Yagi Antenna (96.8%), which was directed at the main roost site, a long broad beach running to the south-east.

It is not clear why the appearance of Ruddy Turnstones at the Perkins Island roost was so intermittent. An important factor may be beach-washed sea-weed (wrack). During reconnaissance and the catching attempts in December 2010, there were piles of beach-cast kelp on the beach, which Ruddy Turnstone used as windbreaks when roosting; they also foraged intermittently at the base of the kelp piles, apparently hunting maggots. At this time winds were persistently from the west or north-west (bearing 260-340 ^{o}) but on 19th December the wind direction swing to the south-west (210-230 ^{o}) and on the next visit we made to the island on 21st December, almost no kelp wrack remained on the beaches. In the brief period in January when some Ruddy Turnstone returned to the Perkins Island roost, easterly winds prevailed and there was some fresh beach-cast kelp on the beaches.

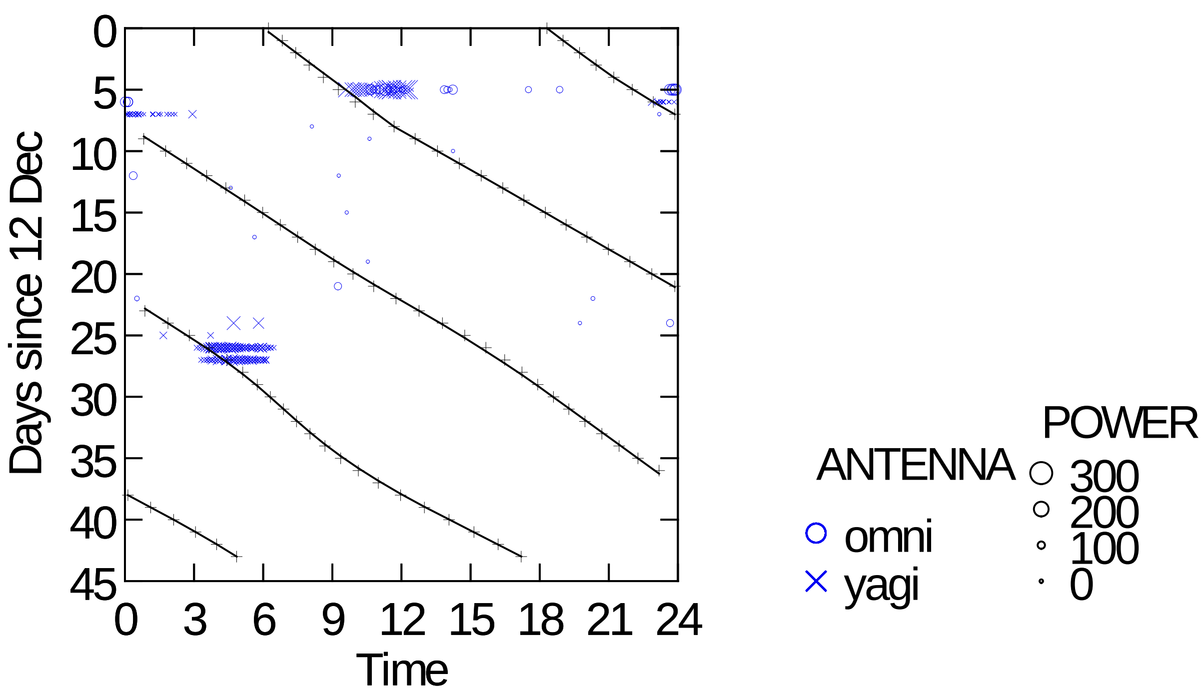

Figure 17: Signals received from Ruddy Turnstone by the ART Station at Perkins Island South. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

Signals received by the station at Shipwreck Point (northern tip of Robbins Island) (Figure 18) mirrored those from the roost at Perkins Island South, although sample sizes were much lower (only 22 records, all from Ruddy Turnstone). In part the smaller number of signals may reflect the fact that the Yagi Antenna was not working. In addition, direct observation by day suggested that Shipwreck point is not the preferred roost of shorebirds on northern Perkins Island, but is used occasionally when the beaches to the south-east are disturbed.

The Shipwreck Point station operated continuously from 16th December until 6th January, but it was then taken down, so the receiver could be deployed at Kangaroo Island.

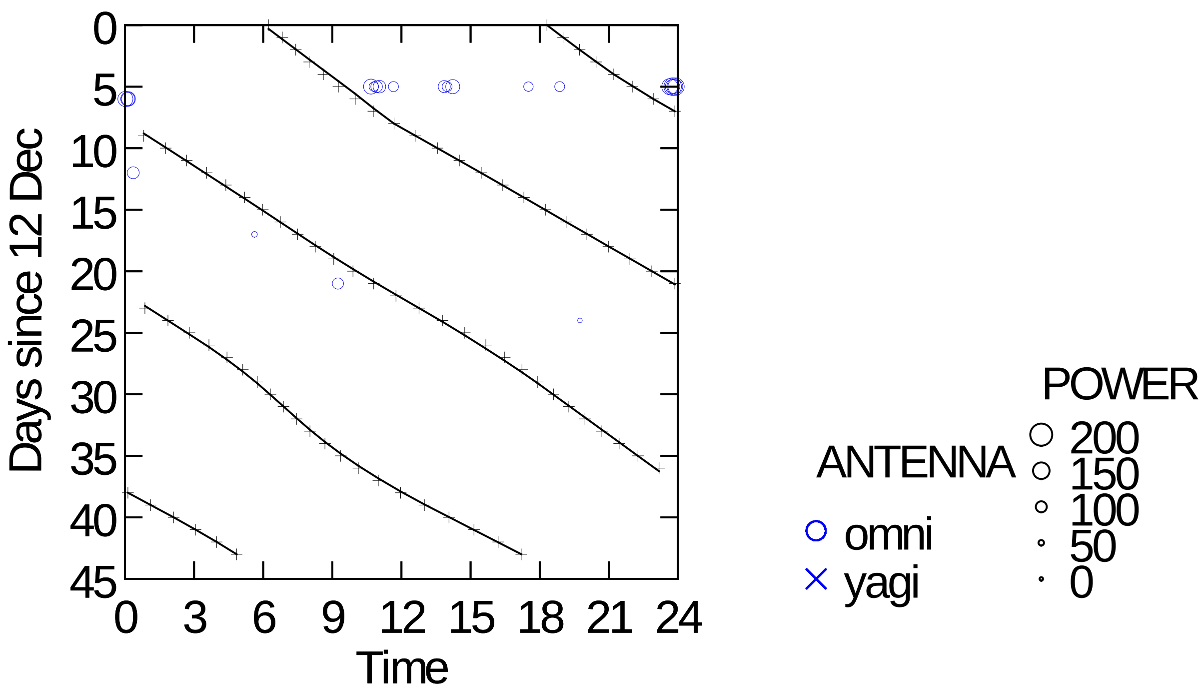

Figure 18: Signals received from Ruddy Turnstone by the ART Station at Shipwreck Point, northern Perkins Island. Results from the Yagi and omnidirectional antenna are represented with different symbols; symbol size is proportional to signal power.

4.3 Automatic radio-telemetry: routines of individual birds

No two individuals showed identical movement patterns during the study. Examples of the variations seen in movement patterns are provided in Figures 19 to 21. Figure 19 summarises the ART-established site use of the Red-necked Stint individual (RNS 24) for which we were most often able to establish the roost and feeding ground locations. It was most often recorded roosting at the Five Islets, but on some tides it roosted at Knot Point or (especially towards the end of the study period) at Bird Point; foraging grounds at low tide also varied, but it was usually recorded by stations on the west coast of Robbins Island. It was relatively rarely recorded on high tides in the middle of the day; we suspect that it frequently roosted at Kangaroo Island, where we did not erect an automatic radio-tracking station until midway through the study period.

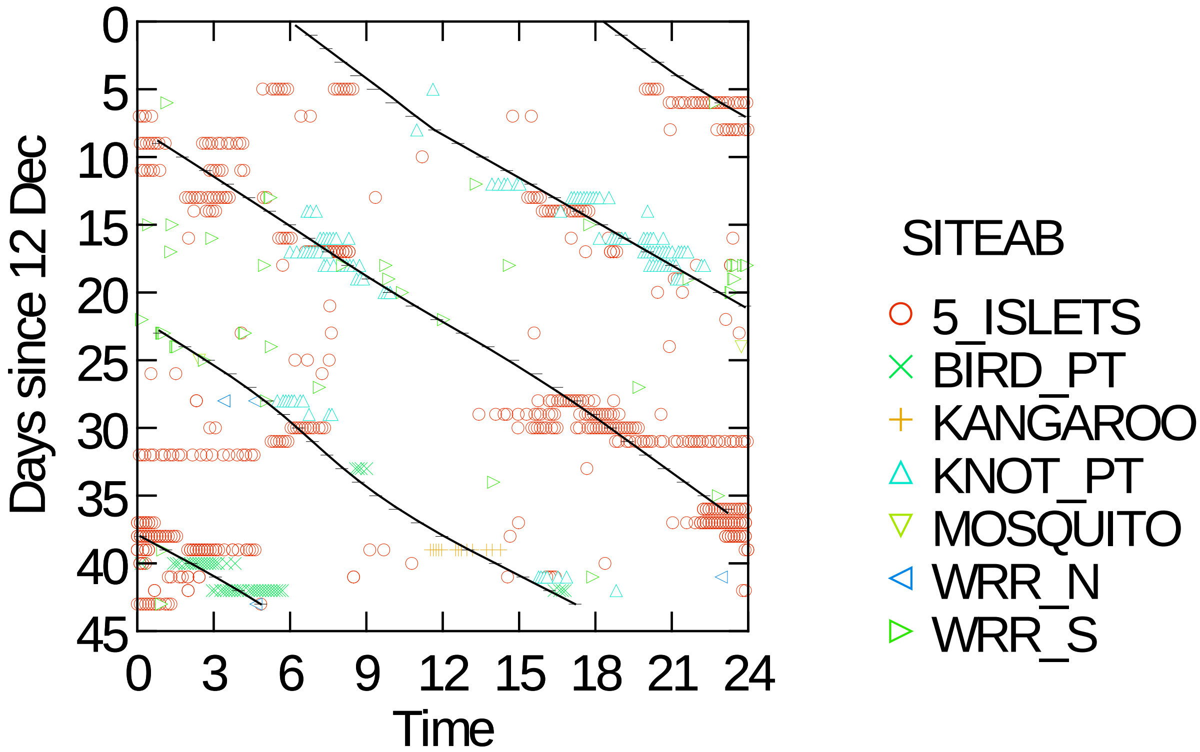

Figure 19: Automatic radio-telemetry records from the most frequently recorded Red-necked Stint (Transmitter RNS 24; roost site located on 49 of the 84 high tides during the study period).

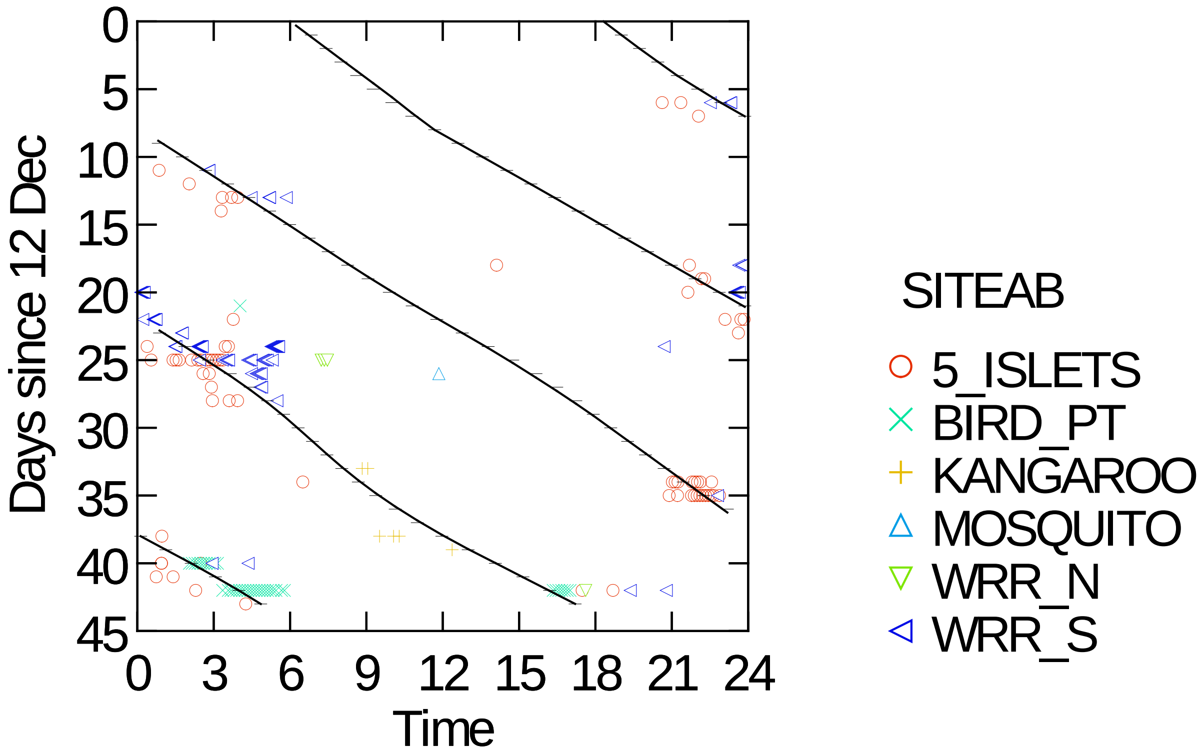

Figure 20: Automatic radio-telemetry records from the Red-necked Stint (Transmitter RNS 11) for which the number of records was closest to the average recorded for all Red-necked Stints (Roost site located on 31 of the high tides during this study).

Figure 20 summarises the records from ARTS of RNS 11, the individual for which the number of established roosting and feeding locations was closest to the average for all Red-necked Stints. Like RNS 24, this individual often roosted at the Five Islets, used Bird Point as a roost later in the study, and was under-reported on mid-day high tides, probably because of a movement to Kangaroo Island. It differed from RNS 24 in that as the tide began to ebb, it was more frequently detected by the Yagi antenna on White Rock Ridge South than by the station at Five Islets. Such a pattern could have been caused by the bird choosing foraging areas on the ebbing tide which were concealed from the Five Islets stations by coastal dunes.

Finally, Figure 21 shows the movements of the most frequently recorded Ruddy Turnstone, RuTu 8. There were few records of this individual: several records from Perkins Island shortly after it was captured, but like most of the other radio-tagged Ruddy Turnstones, it usually avoided detection for the remainder of the study period, except for a three-day period (days 25-27 of the study) when it returned briefly to Perkins Island. Other records were mainly from the west coast of Robbins Island, and being isolated records, they are not considered very reliable – though from handheld telemetry we do know that the bird did occur briefly on the west coast of Robbins Island on 19th December 2010.

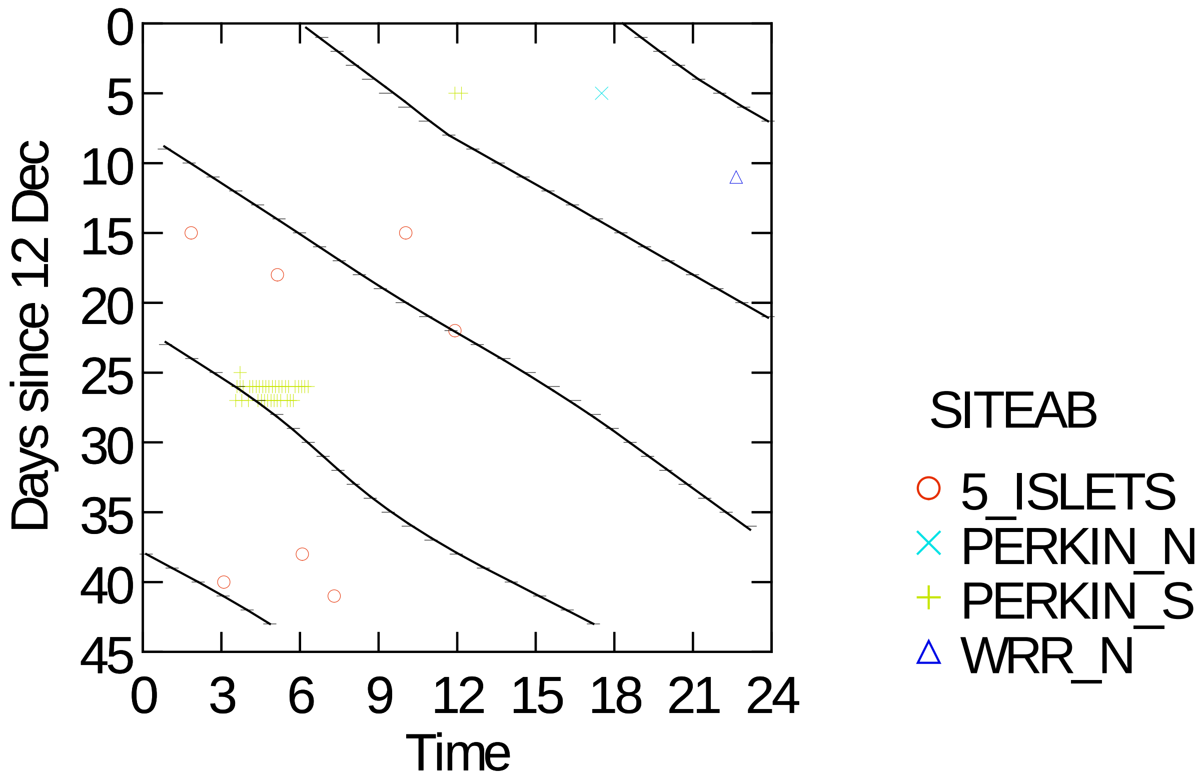

Figure 21: Automatic radio-telemetry records from the most frequently recorded Ruddy Turnstone (Transmitter RuTu 8).

Most of the Red-necked Stints radio-tagged in this study were cannon-netted from a single flock at Bird Point. They did not remain in the same flock throughout the study period. Although it was clear from both direct observation and radio-telemetry records that the radio-tagged birds joined Red-necked Stint flocks, on any given tide different radio-tagged birds were found in several discrete flocks which roosted and fed at different sites. If a Red-necked Stint flock found on the west coast of Robbins Island was large, it would generally contain some of the radio-tagged birds. It is therefore reasonable to consider the movements of the radio-tagged birds to be representative of Red-necked Stint movements in the study area.

Movement patterns varied during the study period. For example, Red-necked Stints used the Five Islets throughout the study, but use of the site declined in January, while at the same time there was an increase in the number of birds that roosted at Bird Point (Table 3).

Table 3: Numbers of high tides spent by radio-tagged Red-necked Stints at the main roosts of the Robbins Passage region, December 2010 to January 2011

Tide No	Bird Point	Five Islets	Knot Point	Kangaroo Island	Perkins Island
14 to 16 Dec. 2010	0	14	1	0	0
17 to 22 Dec. 2010	2	69	6	0	1
22 to 27 Dec. 2010	6	69	22	0	2
27 to 31 Dec 2010	3	74	83	0	0
1 to 6 Jan. 2011	1	43	5	20	1
7 to 11 Jan. 2011	17	51	13	3	0
12 to 16 Jan. 2011	16	35	4	1	0
17 to 22 Jan. 2011	26	55	1	14	0
22 to 24 Jan. 2011	37	26	2	0	0

Movement itineraries of indivudal birds are summarised in Tables 4 and 5. On both ebbing and rising tides, the great majority of documented movements involved birds moving between foraging grounds off the west coast of Robbins Island, and high tide roosts on either Kangaroo Island or the west coast of Robbins Island (Bird Point, Knot Point or Five Islets). When the analysis was restricted to birds for which confidence of site identification was high, such movements constituted 96.5% of movements on ebbing tides, and 92.3% of movements on rising tides. We suspect the estimated proportion of movements between western tidal flats and roosts on or to the west of Robbins Island would have been still higher had the ARTS on Kangaroo Island been fully operational and set up earlier in the study.

There were very few movements of Ruddy Turnstones between Perkins and Robbins Island and none by Red-necked Stints. Most such movements recorded involved Ruddy Turnstone early in the study (discussed further in the next section). However, preliminary examination of the data suggested there were some movements of Red-necked Stints between the tidal flats west of Robbins Island, and two stations in the north of the island (White Rock Ridge North and Mosquito Inlet). When analysis was restricted to birds for which confidence of site identification was high, such movements constituted 3.5% of observed movements on ebbing tides and 7.0 % of movements on rising tides. As the ARTS in the north of Robbins Island had Yagi Antenna directed into Mosquito Inlet, it is possible that these movements might indicate some movement of birds across the northern tip of Robbins Island or through Walker's Crossing, or both; they are therefore examined more fully in Section 4.4.5.

Table 4: Number of documented movements of individual radio-tagged birds between high tide and the following low tide.

	Red-necked Stint			Ruddy Turnstone		
Movement	**High**	**Low**	**total**	**High**	**Low**	**total**
Robbins I.: Western flats to west coast roosts or Kangaroo Island	110	209	319	1	8	9
Western flats to North Robbins	4	34	38	0	2	2
Perkins I. to Perkins I.	0	1	1	6	0	6
Perkins I to W Robbins I.	0	3	3	8	1	9

Table 5: Number of documented movements of individual radio-tagged birds between feeding grounds and roosts on rising tides.

	Red-necked Stint			Ruddy Turnstone		
Movement	**High**	**Low**	**total**	**High**	**Low**	**total**
Robbins I.: Western flats to west coast roosts or Kangaroo Island	144	190	334	1	11	12
Western flats to North Robbins	12	30	42	0	1	1
Perkins I. to Perkins I.	0	0	0	0	0	0
Perkins I to W Robbins I.	0	1	1	0	1	1

4.4 Movements over proposed White Rock Ridge Wind Farm

4.4.1 Nocturnal movements

Roost use by shorebirds sometimes differs by day and night. To assess whether this is the case in Robbins Passage, we examined occurrence of radio-tagged Red-necked Stints at the key roosts of the study area (samples were too small to carry out a similar analysis for Ruddy Turnstone). Restricting analysis to birds detected by automatic radio-transmitters with a high level of confidence, we summed the number of high tides that each individual spent at each roost. Each high tide was classified as day or night, depending on whether or not it occurred between sunrise and sunset (times of sunrise and sunset in Smithton during the study were obtained from the website of the Australian Surveying & Land Information Group, http://www.ga.gov.au/geodesy/astro/). There were 48 day-time and 30 night-time high tides during the study. Frequency of night-time versus daytime use of each roost was assessed with Chi-squared tests; our null hypothesis was that birds were equally likely to use each roost by day and night. This hypothesis was disproved. Five Islets was used by significantly more roosting birds by night than by day; Bird Point, Knot Point and Kangaroo Island were used by significantly more roosting birds by day than by night (Table 6). The only high tide records from Mosquito Inlet were made at night, but sample sizes were too small to assess statistical significance; this issue is explored more thoroughly in section 4.4.5.

Although there were striking differences between day and night use of the major roosts, they only involved selection of different roosts on the west side of Robbins Island. The many daytime flights to high tide roosts observed in this and previous studies were made over tidal flats or the sea, and this is almost certainly the case at night also, given that these would have been the most direct routes between roosts and feeding grounds (a flight over White Rock Ridge would have involved an unnecessary detour of at least 2 km). There was no evidence that birds regularly undertook night-time movements to (or from) Perkins Island, but see section 4.4.5 for an investigation of whether birds made flights to Mosquito Inlet.

Table 6: Number of high tides spent at key roosts of the Robbins Passage region by day and by night. Expected frequency was assessed assuming that birds were equally likely to use a given roost site by day and night, and that the percentage of records of birds roosting at night should therefore comprise 38.5% of records (as 30 of the 78 high tides in the study period (38.5 %) occurred at night). The significance of differences between observed and expected values was assessed with Chi-squared tests.

	Observed		Expected		Chi-squared			
High tide roost	Day	Night	Day	Night	Day	Night	d.f.	*P*
Bird Point	83	25	66.461	41.538	4.1154	6.5847	2	> 0.05
Knot Pt	102	35	84.307	52.692	3.7128	5.9404	2	>0.1
Five Islets	178	267	273.846	171.153	33.5461	53.6738	2	>0.01
Kangaroo Island	18	0	11.076	6.923	4.3269	6.9231	2	> 0.05
Mosquito Inlet	0	3	1.846	1.153	1.8462	2.9538	2	n.s.
Perkins Island	3	1	2.461	1.538	0.1178	0.1885	2	n.s.
total	384	331	440	275				
		Chi-squared:			47.6652	76.2644	8	>0.01

4.4.2 Movements between Perkins and Robbins Islands

Movements between Perkins and Robbins Island were rare during the study period. All Red-necked Stints used in this study were captured at Bird Point, on the north-west coast of Robbins Island. There were only records of four individual Red-necked Stints from Perkins Island at high tide, all records of low confidence from only one of the two stations on the island. We are confident that at least three of the records were false, as they were inconsistent with records from other automatic stations on the west coast of Robbins Island at about the same time. One transmitter (RNS 27) was recorded during a single scan at Shipwreck Point on the evening of 17th Dec, during high tide, and a single signal was recorded again two hours later as the tide ebbed. This record did not clash with records from other stations (though the bird was recorded 24 hours before, and 24 hours later, at Five Islets), but consecutive pulse intervals differed by *c*. 4 PBM, indicating the record was false.

It was confirmed that movement of Ruddy Turnstones occurred from Perkins Island to Robbins Island. All 12 Ruddy Turnstone radio-tagged in this study were captured on Perkins Island on 17th December, and records from the ARTS there confirmed that nine of these birds returned there for the following 1-3 night-time high tides, with the last records between 1:00 and 3:00 on 19th December. Seven hours later, seven of the radio-tagged Turnstones had moved to Knot Point, on the west coast of Robbins Island, where their presence was confirmed by handheld radio-telemetry; they only stayed there briefly and only two of the birds were simultaneously detected by the ARTS array. Three of these individuals later returned briefly to Perkins Island, where they were recorded between 5-8 January 2011 along with five other radio-tagged Turnstone which had not been detected on Robbins Island.

At all other times, including the period between 19 Dec and 5 Jan, the radio-tagged Ruddy Turnstone were remarkably elusive; it is possible that they left the Robbins Passage area. They were not found on any of the handheld radio-scans carried out on Robbins Island between 5-9 Jan and 18-23 Jan. There were scattered records from the ARTS on the west coast of Robbins Island, but they were single isolated records with weak signal strength, considered to be of low reliability, and probably false (there were 34 such records, cf. a prediction of 34 false records on the basis of the frequency of errors in scans for dummy tags on the stations on the west coast of Robbins Island, see Table 1). We do not know if the eight individuals that returned to Perkins Island in early January stopped on the coast of Robbins Island, as they were not detected by any automatic or handheld receivers. We can therefore only be confident that one movement of Ruddy Turnstones (7 of 12 tagged individuals) occurred between Perkins and Robbins Island during the study period, on the morning of 19th December. The potential flight paths used on flights between Robbins and Perkins Island are examined in the following sections.

4.4.3 Flights over White Rock Ridge

Field observers were active on the northern half of White Rock Ridge or the adjacent west coast of Robbins Island during daytime hours (including high tide) on 19 of the days of the study (5 Dec, 7 Dec, 10-15 Dec., 19 Dec., 5-8 January and 18-23 January). No flights of shorebirds over White Rock Ridge were observed during this period. Observations were not systematic, and in theory movements of small numbers of birds over White Rock Ridge might have been overlooked. However, we are confident that we would have detected any such movements by large flocks, as these were the focus of our observations both when trying to catch birds (10-15 Dec) and when subsequently conducting handheld radio-telemetry. The lack of observed movements of shorebirds over White Rock Ridge was consistent with previous daytime observations carried out in former focussed surveys by BLA (2010).

Two automatic radio-telemetry stations were situated on White Rock Ridge. Records from these stations were examined to assess whether they showed any evidence for movements over the ridge, particularly at night when observations had never been made previously.

For the station at White Rock Ridge South, identification of records from birds flying over the ridge was straightforward. The station had two antennae. The omnidirectional antenna was capable of detecting birds within a radius of several hundred metres of the station. The exact detection range of this antenna could not be calibrated, as the ground on the top of the ridge was too uneven to conduct experiments with test transmitters. However, on the basis of range-test experiments conducted at stations on flat ground, we would anticipate the minimum range to be on the order of c. 500 m, and probably greater for flying birds. The maximum detection range was known to be less than 2 km, as the omnidirectinal antenna did not detect test transmitters or directly observed radio-tags at Knot Point, Five Islets or the nearest tidal flats on the west coast. In contrast, such test transmitters were readily detected by the Yagi Antenna at White Rock Ridge South. We would therefore expect birds flying over White Rock Ridge to have been detected by the omnidirectional antenna, and also by the Yagi antenna if the birds were west of the station.

The Yagi antenna on White Rock Ridge South received 1201 signals from radio-transmitters deployed on Red-necked Stints. In contrast, no signals at all were received from the omindirectional antenna, though experiments with test receivers demonstrated that it was fully operational. We found no evidence that radio-tagged Red-necked Stints flew over White Rock Ridge South during the study. We also found no evidence that Ruddy Turnstone did so, despite also examining unfiltered records to see it there was any evidence for Ruddy Turnstone flying over in the period (17-19 Dec.) when several individuals made a confirmed movement to Robbins Island from Perkins Island.

Assessing flights over the station at White Rock Ridge North was less straightforward, and this problem is investigated in section 4.4.5.

4.4.4 Movements through Robbins Crossing

A station was set up at Black Phil’s Point to scan for birds passing through the sandy intertidal passage separating southern Robbins Island from the mainland (Figure 22). The passage is c. 1.2 km wide at Black Phil’s Point, so birds in this region should have been within range of the Yagi antenna, and probably within range of the omnidirectional antenna.

There were no confirmed signals of any radio-tagged birds from Black Phil’s Point. We also searched through unfiltered records from the station. There were only 11 such records, and all were demonstrably false, pertaining to dummy frequencies or to a bird known to be on the Five Islets.

Figure 22: Robbins Crossing looking south east towards the mainland from Black Phil's Point.

4.4.5 Movements from Mosquito Inlet

Mosquito Inlet is a large tidal sandy embayment at the north of Robbins Island, to the east of White Rock Ridge. Superficially it appears to have habitat that is suitable for shorebirds, with extensive tidal flats at low tide, and a long sandspit at the eastern entrance which might be suitable as a roost at high tide. However, shorebirds have hardly ever been seen in the inlet during daytime observations. We saw no shorebirds there at all during opportunistic daytime observations during this study. In addition, none were recorded in surveys by BLA (2010), and they were almost absent during the high tide counts carried out regularly by Birds Tasmania since the early 1980's. We are not aware of any previous surveys assessing whether shorebirds occurred there at night.

In this study, two ARTS were set up with the potential to detect birds in Mosquito Inlet (Figure 23). "WRR North" was on the top of White Rock Ridge, 42m above sea-level and c. 2km from the closest section of Mosquito Inlet. The Yagi antenna was directed due east to detect birds in the southern half of the inlet. "Mosquito Inlet" was set on a point near the shores of the inlet, on a small cliff about 10m above ground level. The Yagi antenna was directed at the north-eastern entrance of Mosquito Inlet, with the intention of detecting both birds moving beyond through the passage that separates Robbins and Walker Island, birds on the northern tidal flats of Mosquito Inlet, and potentially birds on the sandspit at the north-eastern entrance to Mosquito Inlet.

Figure 23: Satellite image of northern Robbins Island and the passage that separates it from Walker Island; Mosquito Inlet is the large embayment on the east of Robbins Island. The markers show the positions of the nearest ARTS: Mosquito Inlet, WRR North, Bird Point and Knot Point. Sites where a test transmitter were deployed on 7 January 2011 are also shown; it was only detected by the Mosquito Inlet ARTS at site Test2.

Unfortunately both of these stations developed power supply issues, and both operated sporadically during the study. The Mosquito Inlet station was deployed from 13 December to 24 January but was only operational for *c*. 7 days: 19-20 Dec., 5-8 Jan. and 23-24 Jan. The White Rock Ridge station was also deployed from 13 December to 24 January but was only operational for *c*. 18 days: 13 -22 Dec., 6-10 Jan. and 19-24 Jan.

Experiments with dummy transmitters showed that the station at White Rock Ridge North made false detections of birds on 0.05% of scans (see Section 3.5), making it difficult to draw strong inferences from single isolated records. In addition, the northern end of White Rock Ridge is closer to the western flats of Robbins Island than is White Rock Ridge South, and the White Rock Ridge North station was within 850 m of Bird Point. The station was shielded from Bird Point by the crest of White Rock Ridge, but might have detected birds from Bird Point or adjacent tidal flats had there been some curvature or reflection of signals.

In total the station on White Rock Ridge North received signals from deployed transmitters on 272 occasions; 194 of these signals were detected by the omnidirectional antenna, and 78 by the Yagi antenna. The number of received signals far exceeded the expected number of false signals (*c*. 21, see Table 1), suggesting that many of them were real.

A large proportion of the signals from White Rock Ridge North were paired: on 53 occasions transmitters were detected by the omnidirectional antenna, and five seconds later were detected again when the receiver switched to the Yagi Antenna. In most cases (41 of 53), the signal from the omnidirectional antenna was stronger than that from the Yagi, and in the other cases the difference was negligible. Most unpaired signals came from the omnidirectional antenna (n = 141) and few came from the Yagi (n = 25). As the Yagi antenna was directed east with a clear line of sight to Mosquito Inlet (a site > 2 km away, out of range of the omnidirectional antenna), these observations strongly suggest that the majority of records from this station did not represent birds on Mosquito Inlet, and in fact came from the opposite direction, to the west. Further support for this interpretation comes from two tides (one high and one low) on which an individual Red-necked Stint was recorded repeatedly and concurrently by the stations at Bird Point and White Rock Ridge North.

Over half (58.7%) of the signals received by White Rock Ridge North were recorded within two hours of high tide; 24% were received within 2 hours of low tide and the remainder on either ebbing or rising tides. A high proportion of records (68.5%) occurred between sunset and sunrise, and a still higher proportion (74.6%) was recorded in the early morning or late afternoon of a tide series in which the high tide peaked at night. There was, however, no significant difference between signal strength at high or low tide. Moreover, it is unlikely that we were systematically recording birds that were actually settled at a high tide roost, as in most cases only 1-2 signals were received from each individual per tide cycle. By contrast, other stations with a clear line of sight to established roosts often received more than ten records from individual birds during a high tide cycle.

It is likely most records obtained from White Rock Ridge North were from birds in flight; this would explain why most signals only lasted briefly, and also why their signals were reasonably strong. Looking at records made at about the same time by other stations could therefore help to identify the flight path. On 56 occasions, a signal or series of signals from individual Red-necked Stints received at White Rock Ridge North occurred within two hours of birds being recorded by stations at the Five Islets (34 records), Bird Point (10 records), Mosquito Inlet (12 records) or the White Rock Ridge South Yagi (3 records), usually on rising tides (42 of 56 records). On 81 occasions, a signal or series of signals from individual Red-necked Stints received at White Rock Ridge North was followed within two hours by records from the stations at the Five Islets or Knot Point (23 records), Bird Point (15 records), Mosquito Inlet (4 records) or the White Rock Ridge South Yagi (39 records). Such records occurred with about equal frequency during rising and ebbing tides.

The station at Mosquito Inlet had a lower error rate than that on White Rock Ridge North, and did not detect any dummy frequencies during the (relatively short) period when it was operational. All records made by the station were made by the Yagi antenna only, although experiments with test transmitters showed that the omnidirectional antenna was working adequately and could detect a test transmitter at least 550m away. This test transmitter was also detected by the Yagi Antenna, with a signal strength (218) exceeding that of all records that were made of radio-tagged birds (40 records, average signal strength 105, range 47 to 201). Bearing in mind that the detection range of handheld test transmitters is usually less than that of transmitters deployed on live birds, it is clear that the birds detected by the Mosquito Inlet Yagi were reasonably distant.

Nearly all signals received by the Yagi antenna at Mosquito Inlet were detected at night, the single exception being a record at 11:40 on 7th January which we believe to have been false, as it was not corroborated by a concurrent hand-held radio-scan in Mosquito Inlet. Of the remaining 39 signals, 33 were received 00:10 to 3:50 hours before a night-time high tide. Tide heights during these rising tide observations (measured by the nearby tide gauge at Walker Island) ranged from 0.4 to 2.01 m, indicating that birds were sometimes detected when extensive tidal flats were exposed, and were sometimes detected when the tide was very high and the tidal flats would have been submerged. There was also record 0:14 minutes after high tide. The 5 remaining records were made 3-6 hours after the tide peaked, when tide levels were low enough to expose extensive tidal flats; two of them involved birds that had previously been detected on the rising tide.

Records from the station at Mosquito Inlet therefore showed a similar pattern to that shown by records from White Rock Ridge North, in that the great majority of records were made at night, and the great majority of records were made on rising tides. We examined the data to see how well records from individual birds corresponded between the two stations. Eighteen individual radio-tagged Red-necked Stints were recorded by the Mosquito Inlet Station, with as many 13 individuals being recorded on the rising tide of 5th January; 6 were recorded on 23 January and 5 on 24th January. Pooling consecutive records of the same birds within the same tide cycle, there were 34 occasions when individual birds were logged by the Mosquito Inlet receiver. On all of these occasions, the bird involved was recorded 0-3 hours later at another station: 13 subsequent records were made at White Rock Ridge North (with a time lag of at least 10 minutes, there were no concurrent records from the two stations); 13 subsequent records were made at Five Islets, 5 at White Rock Ridge South and one each at Bird Point and Knot Point. By contrast, there were only 12 occasions when birds were located at another site before moving on to Mosquito Inlet in the next 6 hours. Eight of these records were of birds moving from Five Islets, and four were birds from Bird Point or White Rock Ridge North.

We consider the most plausible explanation of these observations is that at night some radio-tagged Red-necked Stints gathered on a rising tide on the flats of northern Mosquito Inlet and the flats to the north-west of Robbins Island (north of Bird Point), before moving either south to a preferred night-time roost at Five Islets, or to a preferred night-time roost in Mosquito Inlet. We indeed saw pre-roost gatherings on the tidal flats north of Bird Point on at least one evening when cannon-netting there in mid- December. The exact location of the high tide roost used at night in the Mosquito Inlet is not certain, but as no other suitable habitat is obvious, we suspect it must be on the sand spit at the north-eastern mouth of the inlet – the Mosquito Inlet station was less than 2km from this sand spit, so potentially within detection range. The scenario described above would also explain the records made by White Rock Ridge North, a station which was only c.850 m from Bird Point. Although the station was just obscured from the flats by the western lip of White Rock ridge, birds would have had a direct line of sight to the station if they flew only a few metres above the tidal flats. Moreover, the reasonably close proximity of the elevated station would probably allow records to be detected by the Yagi antenna – although it was pointed east, Yagi antenna also receive some reflected signals from behind at relatively close range.

This movement pattern involves movements of some birds on rising night-time high tides from Mosquito Inlet to the west coast of Robbins Island. The most direct route for such a movement would include a flight over the northern end of White Rock Ridge. Alternatively, they might take a detour of ~ 2 km to fly to the west coast through the passage that separates Walker Island from Robbins Island, in keeping with the tendency that shorebirds usually prefer to fly over water or tidal flats rather than land. We cannot be certain which route was used. The possibility that birds fly directly over the northern end of White Rock Ridge is not strongly supported by the data collected by the station on White Rock Ridge North, as signals from the east-directed Yagi were consistently weaker than those from the omnidirectional antenna (suggesting the birds were mostly detected on the western side of the ridge). However, we obtained no direct evidence for a flight through the Walker Passage. We would have expected some of the birds flying through Walker Passage to be detected by the omnidirectional antenna at Mosquito Inlet. No such signals were detected, but this might reflect the short period in which that station was operational and recording data.

5 DISCUSSION

Shorebird movements in the Robbins Passage area proved to be reasonably complex. Many questions about the Ruddy Turnstones radio-tagged in this study remained unresolved, as the birds apparently left the region for most of the study period. The radio-telemetry work did establish that their occurrence at Perkins Island was intermittent, perhaps coinciding with periods when beachcast kelp provided a foraging resource and shelter from strong winds. One movement was confirmed from Perkins Island to the west coast of Robbins Island, involving 7 of the 12 radio-tagged Turnstone between 17-19 December. The flight route taken by these birds was unknown but it appears not to have involved a flight across Robbins Passage, or either of the ART stations on White Rock Ridge.

Data collected from Red-necked Stints were far more comprehensive, and revealed the essentials of their local movement patterns around the west coast of Robbins Island. It is probable that the movement patterns found in Red-necked Stint would also apply to other migratory shorebird species found on the west coast of Robbins Island, given that during all daytime observations other shorebird species roosted in mixed flocks with Red-necked Stints, and foraged at low tide in areas where there were also concentrations of the more numerous Red-necked Stint.

Broadly, the radio-tagged stints foraged on the tidal flats west of Robbins Island at low tide, and then moved as the tide rose, either to Kangaroo Island, or to roosts on the west coast of Robbins Island (Five Islets, Knot Point or Bird Point). Usage of these roosts varied according to environmental conditions. The roost at Five Islets was used more often by night than by day, whereas the roosts at Knot Point, Bird Point and probably Kangaroo Island were used most often by day. This finding is consistent with previous experience that at night shorebirds select roosts perceived as safer (Rogers 2006a), in the most open setting possible with no nearby cover that might be used for concealment by predators. The Five Islets would appear to meet these criteria, being low-lying with very short vegetation, in addition to being surrounded by water. In contrast the roosts at Bird Point and especially Knot Point are close to rocks and tall shrubs that might provide concealment to predators.

Red-necked Stints most often roosted at the Five Islets and Knot Point during westerly to southerly winds, but most records of birds roosting at Bird Point were made during easterlies. This might explain why many stints which roosted mainly at Knot Point and Five Islets in the early stages of the study moved to Bird Point late in the study. Whatever the cause, the radio-tracking data confirm that roost usage by stints on the west coast of Robbins Island is dynamic.

There was also evidence of temporal variation in selection of foraging grounds. The tidal flats near Five Islets were used more on ebbing than rising tides. In contrast, tidal flats to the west of the automatic radio-tracking stations at Bird Point and White Rock Ridge North (some 4km north of the Five Islets) were used most often on rising tides, especially at night. Importantly, evidence was found indicating that this movement to northern Robbins Island was related to a movement into Mosquito Inlet on rising tides at night, with some birds apparently occurring on the tidal flats of Mosquito Inlet on rising tides, and roosting on the shores of Mosquito Inlet at night, most probably on the sand spit at the north-eastern mouth of the inlet. This movement is discussed in more detail below.

This study was undertaken to assess the risk that the proposed wind farm on White Rock Ridge might pose to migratory shorebirds. Relevant discoveries were:

1. There was no evidence of shorebirds moving through the section of Robbins Passage that separates southern Robbins Island from the mainland, and it seems that such movements did

not occur during the study. Proposed overhead power transmission lines across this passage are therefore unlikely to pose a threat to migratory shorebirds.

2. No evidence was found for shorebirds making flights over the automatic radio-tracking station at White Rock Ridge South. Moreover, the general behavioural patterns revealed by this study indicate that such movements are unlikely to occur. Daily “commuting” flights were made between foraging grounds and roosts which were both to the west of White Rock Ridge, giving shorebirds no reason to fly inland over the ridge. It had previously been suggested that shorebirds may move between Perkins Island and the west coast of Robbins Island; if this movement was undertaken in the most direct flight possible, it would result in birds flying over White Rock Ridge. However, it was clear from the results of the radio-telemetry that movements between Perkins and Robbins Island do not occur on a regular basis. There were no movements of radio-tagged Red-necked Stint between western Robbins Island and Perkins Island during this study. There was one movement of Ruddy Turnstone from Perkins to Robbins Island in the early stages of this study. It was not possible to detect the flight path used when this movement occurred, but the flights were not detected by any of the receiver stations set up on White Rock Ridge.

3. Evidence was found of a movement of shorebirds into Mosquito Inlet on rising tides. This movement only occurred at night, explaining why it has not been noted during previous observational fieldwork by day. It appeared from automatic radio-telemetry records that birds gathered on the tidal flats of Mosquito Inlet during rising night-time tides, with some birds then flying to a roost in the north-east of Mosquito Inlet (probably on the spit on the south side of the eastern mouth of the inlet), and others flying to the Bird Point area on the north-west coast of Robbins Island. It was not possible to conclusively establish the flight path used by birds moving from Mosquito Inlet to the north-west of Robbins. The two shortest routes possible are: (1) : through Walkers Crossing, a flight which would not involve a close approach to proposed turbinesites; (2) a more direct line across the northernmost section of White Rock Ridge, a site where turbines are proposed..

The area of northern White Rock Ridge where there is a risk of shorebirds colliding with proposed wind turbines is shown in Figure 1. At this primary stage a total of 16 proposed wind turbines fall in this area. Further study would be required to establish whether or not shorebirds are affected by these proposed wind turbines. To resolve the outstanding questions, focussed observational work should be undertaken, carefully selecting a fieldwork period in which some night-time observations on rising tides could be made with the assistance of a full moon.

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