Struggles ashore

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Summary

The **east Asian–Australasian Flyway** (EAAF) is one of the most species-rich flyways in the world, and is used regularly by at least 52 species of migratory shorebirds. Every year, millions of shorebirds migrate along this flyway from non-breeding areas in Southeast Asia and Australasia to breeding areas in the northern hemisphere as far north as the high Arctic. During their journeys, they stop to refuel on rich mudflats along the East Asian shores which have high densities of prey. In the early 2000s, the Yellow Sea was identified as the main area where the EAAF shorebirds fuel up ('stage') during migration.

However, the East Asian shores are becoming more and more hostile for the shorebirds and the birds are facing a number of threats such as loss of mudflats caused by land reclamation, collapse in prey stocks and unregulated hunting. Among the 25 EAAF shorebird populations with known trends, all except one are in decline. This raises a number of questions that are central to this thesis: How are shorebirds responding and coping with these rapid changes in their habitats? And, how can studying their migration ecology galvanize actions to conserve shorebirds in this flyway?

Habitat loss and prey declines often do not kill birds directly, but do reduce the fuelling rates of migratory shorebirds which need to fuel up in a rather short time. Impacts can manifest at a later time when a bird is already in another part of the world, e.g. birds using heavily-impacted sites might have to stop longer to fuel up and thus arrive late at the breeding grounds potentially missing the peak in food abundance there. Also, birds could cope by moving from heavily-impacted places to those that are relatively untouched. To understand these patterns of how the birds respond, we need to collect information throughout entire migratory journeys. This became possible at the beginning of this PhD project when solar-powered satellite transmitters were made small enough to attach to medium-sized shorebirds thus allowing us to track individual birds across the globe at high temporal resolution for multiple years. This study focuses on the Northwest Australian populations of three species in decline: The Great Knot, Red Knot and Bar-tailed Godwit. Every year these birds migrate to their breeding areas in the east Russian Arctic, stopping at mudflats in East Asia during their journeys.

Developing a harness for attaching satellite transmitters to the Knots

Tracking entire migration journeys requires long-term external attachment of transmitters. For Bar-tailed Godwit, transmitters can be attached successfully with leg-loop harnesses. However, this type of harness quickly slips off the legs of more compact species such as the Knots as they have no external 'knee'. Before we started tracking shorebirds in the EAAF, we first needed to develop a harness for Knots that could accommodate the dramatic changes in body size of the birds before and after their long migratory flights. At the Royal Netherlands Institute for Sea Research (NIOZ) on Texel,

we developed a full-body harness that fit captive Red Knots without harming them. We then tested the design with a field test in the nearby Wadden Sea.

Discovering migration patterns

Among the three study species, only the Bar-tailed Godwit had been tracked with satellite tags before our study in 2007–2008; thus our study provided the first migration tracks of the Red Knot and the Great Knot (Chapter 4 and 5). While traditionally the two Knot species are regarded as 'long jumpers' in terms of migration strategy (making long non-stop flights, often of thousands of kilometres, between stops during migration), we found they were more like 'skippers' during northward migration. Instead of flying directly to the Yellow Sea, they stopped at sites in Southeast Asia and southern China, many of which contain high-quality prey such as the bivalve *Potamocorbula laevis* (Chapter 4, Box A).

We were also able to describe the migration of the third subspecies of Bar-tailed Godwits in the EAAF, as two of the godwits tagged in Northwest Australia (who we originally identified as the more numerous *menzbieri* at the banding site) turned out to belong to the *anadyrensis* subspecies that breeds in the Anadyr River basin in Russia (Chapter 3). As *anadyrensis* cannot be distinguished from the other EAAF Godwits (*baueri* and *menzbieri*) based on size and plumage alone, their non-breeding distribution and migration routes had gone undetected prior to our study. We found two key differences in migration itineraries between the tagged *menzbieri* and *anadyrensis* and both occurred during the post-breeding migration period. First, from the breeding areas, *menzbieri* migrated northwards to stage in the New Siberian Islands, Russia, while *anadyrensis* migrated southwestward to stage along the coast in the Sea of Okhotsk, Russia. Second, although both subspecies proceeded to migrate southward to the Yellow Sea, *menzbieri* used the Yellow Sea as their main southbound staging area, whereas *anadyrensis* stopped there for a much shorter time and continued on to stage at the Indonesian side of Timor Island. We also found that the two *anadyrensis* birds used the Kamchatka Peninsula on the east side of the Sea of Okhotsk during post-breeding migration while *menzbieri* used the west side of the Sea, therefore counts conducted at Kamchatka would be one way to monitor the *anadyrensis* population.

h ow can we use the knowledge gained from tracking shorebirds in nature conservation?

Satellite tracking has revealed new migration routes and stopping areas of shorebirds in the EAAF. We explore the value of the new knowledge obtained from tracking compared to past knowledge of key shorebird sites that had been mostly based on ground observations (Chapter 5). Among the 92 sites used by the tracked Great Knots during their migration, surprisingly, 63% were not known as important shorebird sites before our study. While the majority of sites in the Yellow Sea region were known before our study, most sites in Southeast Asia, southern China and Eastern Russia were new. We highlighted coastal habitats in these other regions that are potentially important for shorebirds but lack ecological information and conservation recognition. Further, the distributional data of tracked individuals can help plan on-ground surveys at lesser-known sites, which we did in 2015–2018 along the Chinese coast. We conducted field work at 18 sites visited by the tracked Great Knots and Bar-tailed Godwits to collect information on bird numbers, bird diet and intake rates, and density and composition of prey populations (Box A). We found that the northernmost sites in the Yellow Sea (Liaohe estuary and the Yalu Jiang estuary) had the highest bird numbers yet contained relatively low densities of high-quality prey compared to sites further south.

Local movements of shorebirds at stopping sites extracted from our tracking data were used to guide conservation actions at three Yellow Sea sites in the Jiangsu Province of China in need of protection. First, at Lianyungang in north Jiangsu (Chapter 6), from analysing satellite images we found that 27% of mudflats had been lost by land reclamation in 2003–2018. We assess the site's importance for shorebirds by putting together the results of a decade of counting efforts. One criterion to assess a site's importance is if the site contains >1% of a species' entire flyway population. Lianyungang had the most species (22) meeting this criterion among the >300 shorebird sites in East Asia. We conducted three years of benthic sampling at Lianyungang and showed that the intertidal flats were dominated by small, soft-shelled bivalve species (including *P. laevis*) which are high-quality food for shorebirds. The duration of stay of satellite-tracked Great Knots and Bar-tailed Godwits revealed that some birds used the site as a short stopover and others for month-long staging. Tidal movements of the tracked birds showed locations of high-tide roosts and low-tide foraging areas that should be protected and managed.

Second, a large-scale reclamation was planned at the Dafeng-Dongtai-Rudong coast in south Jiangsu (Box B). This site was the only place where the tracked *anadyrensis* Bar-tailed Godwits stopped in the Yellow Sea, and was also used by almost half of the tracked *menzbieri* (Chapter 3). The spatial-temporal distribution of the tracked Bar-tailed Godwits served as one of the key pieces of information to urge the reconsideration of the planned reclamation in light of the area's ecological importance. Part of this site was eventually included as World Heritage site, and to date the planned reclamation has not occurred.

Third, at Tongzhou Bay in south Jiangsu, large areas of mudflats are being dredged or reclaimed for port construction (Box C). To assess the ecological impact of current and future reclamation projects, in collaboration with hydraulic engineers, distributions of satellite-tagged shorebirds were used to detect the 'ecotopes' with the bay (derived from a hydrodynamic model) that were most important for shorebirds. This allowed the loss of shorebird habitat to be quantified. In a follow-up study, the 'building with nature' concept was applied in port design. By developing a hydrodynamic model to simulate sediment transport in the bay, alternative port configurations were assessed (and compared to the null situation that no port is built) on the degree to which the existing high-value 'ecotopes' for shorebirds could be preserved and their natural growth be promoted by increasing siltation.

h ow do shorebirds cope with habitat loss and deterioration?

Consider the situation that shorebirds arrive at their staging sites and discover that mudflats are gone due to land reclamation, or that prey densities have plummeted. Other than staying-put and expanding their diet or prolonging the time spent in foraging, the birds could also cope by moving to other places. However, many species of shorebirds are known for their strong site fidelity, that is the tendency to visit the same sites year after year. In theory, this tendency can deter them from leaving a site when habitat deteriorates. Using both satellite tracking data and resighting data of banded individuals, we showed that site fidelity was lower in Great Knots than in Bar-tailed Godwits (Chapter 7). This difference was found in the non-breeding sites in Northwest Australia and also at the migratory stopover sites in the Yellow Sea. The less-site faithful Great Knots also showed more variation among individuals in site fidelity than the Godwits.

We investigated what determines individual variation in 'coping by moving' by focusing on a personality trait: the tendency to explore (Chapter 8). This trait was measured by a standardized trial before releasing the tracked Great Knots into the wild. Since more explorative birds are known to put more effort into acquiring information, they likely have more information about the locations and habitat conditions of alternative sites. This site knowledge would lower the risks and energetic and time costs of moving. We found that the individual Great Knots that were more explorative in the trials responded quicker to the collapse in prey stock at their main staging site by moving to other sites earlier than less explorative individuals. Moreover, they arrived on the breeding grounds earlier and bred more successfully.

Lastly, are these migrants coping with the deteriorations in the Yellow Sea in other ways (Chapter 9)? Is it currently more advantageous to first stop in Southeast Asia and southern China and then continue to fly to the Yellow Sea, instead of a direct flight from Northwest Australia to the Yellow Sea? And an increasing number of Great Knots are wintering in Southeast Asia. Do these birds do better than their Northwest Australia counterparts? Also, some tracked birds skipped migration. Is that a better strategy than migrating every year? To answer all these questions will require additional tracking of the migration journeys of these populations and also measuring aspects of their habitats such as food availability, their fuelling rates, survival and breeding success. I hope that this thesis will inspire future studies on how birds are dealing with the human-induced environmental problems in the world. This will eventually lead to better predictions on how these problems lead to declines in bird populations. And, by understanding how the birds are dealing, we can perhaps become better at dealing with the mess that humans created.

Samenvatting

De **o ost Aziatische-Australaziatische (o AA) trekroute** wordt gebruikt door ten minste 52 kustvogelsoorten en is daarmee is één van de meest soortenrijke routes ter wereld. Elk jaar migreren miljoenen vogels langs deze route van de overwintersgebieden in Zuidoost-Azië en Australazië naar de broedgebieden op het noordelijk halfrond tot in het noordpoolgebied. Hun reis onderbreken ze om bij te tanken op wadplaten met een hoge prooidichtheid langs de Oost-Aziatische kusten. In het begin van deze eeuw werd de Gele Zee gezien als het belangrijkste gebied om de trek te onderbreken.

De Oost-Aziatische kustgebieden worden daarvoor echter steeds minder geschikt als gevolg van bijvoorbeeld het verlies van wadplaten door landwinning, een sterke afname van prooibestanden en ongereguleerde jacht. Van de 25 kustvogelpopulaties waarvan de omvang bekend is en die van deze trekroute gebruik maken nemen er maar liefst 24 af. Dit roept een aantal vragen op, die centraal staan in dit proefschrift: Hoe gaan de vogels om met deze snelle veranderingen in hun leefgebied? En hoe kan het bestuderen van hun migratie-ecologie helpen om deze trekroutes te behouden?

Het verlies van voedselgebieden of een afname van de dichtheid aan prooidieren hoeft niet direct te leiden tot sterfte van vogels, maar wel tot een verminderde energie-opname van dieren die tijdens de trek onder een enorme tijdsdruk staan. De gevolgen daarvan kunnen zich op een later tijdstip manifesteren, wanneer de vogels zich al weer in een ander deel van de wereld bevinden. Het kan ook zo zijn dat vogels hun trek gedurende een langere periode moeten onderbreken, om genoeg voedsel op te kunnen nemen, waardoor zij (te) laat aankomen op de broedplaatsenen een piek in het voorkomen van voedsel daar mislopen. Mogelijk moeten trekvogels traditionele, maar nu zwaar verarmde plaatsen opgeven en naar alternatieven uitkijken. Om te begrijpen wat er mogelijk is en hoe de vogels reageren, moeten we informatie verzamelen over het volledige migratietraject. Dit werd mogelijk doordat er kleine satellietzenders beschikbaar kwamen, die geschikt zijn om toegepast te worden op middelgrote kustvogels. Deze zenders werken op zonne-energie, waardoor we de vogels overal, continu en gedurende meerdere jaren kunnen volgen. Deze studie richtte zich op de Noordwest-Australische populaties van drie afnemende soorten: de grote kanoet, de (rode) kanoet en de rosse grutto. Elk jaar trekken deze vogels naar hun broedgebieden in het Oost-Russische Noordpoolgebied en onderbreken ze hun reis op wadplaten in Oost-Azië.

o ntwikkeling van een harnas om satellietzenders aan kanoeten te bevestigen

Om de trekwegen helemaal te kunnen volgen, moeten de zenders lang meegaan en gekozen werd voor instrumenten die buiten op het lichaam van de vogels werden aangebracht. Bij rosse grutto werden de zenders bevestigd door middel van lussen om de poten. Deze manier van aanbrengen is ongeschikt voor de kleinere kanoeten, omdat zij geen externe ‘knie’ hebben, waardoor de lussen afglijden. Voordat we begonnen met het volgen van kustvogels in de OAA trekroute, moesten we daarom eerst een geschikt tuigje voor kanoeten ontwikkelen, waarmee weook nog eens de extreme veranderingen in lichaamsgrootte voor en na hun lange trekvluchten kon opvangen. Bij het Koninklijk Nederlands Instituut voor Onderzoek der Zee (NIOZ) op Texel hebben we een tuigje ontwikkeld en (in gevangenschap) getest, dat de kanoeten past en ze niet beschadigd. Vervolgens werd het ontwerp in het vrije veld getest en geschikt bevonden.

Migratiepatronen ontdekken

Van de drie soorten die we wilden bestuderen was alleen de rosse grutto wel eens gevolgd met satellietzenders (2007-2008); zo leverde onze studie de eerste complete routes op van de kanoet en de grote kanoet (hoofdstuk 4 en 5). Terwijl deze twee soorten traditioneel in de gradatie ‘hink-stap-sprong’ worden beschouwd als '(ver-)springers' wat betreft migratiestrategie (lange non-stop vluchten, vaak over duizenden kilometers, tussen trekonderbrekingen in), ontdekten we dat ze meer als 'hinkers' beschouwd moesten worden. In plaats van rechtstreeks naar de Gele Zee te vliegen, stopten ze al eerder op locaties in Zuidoost-Azië en Zuid-China, waar voedsel van hoge kwaliteit voorkomt, zoals de tweekleppige *Potamocorbula laevis* (hoofdstuk 4, kader A).

We waren ook in staat om de trekbewegingen van de derde ondersoort van rosse grutto's in de OAA trekroute te beschrijven, aangezien twee van de in Noordwest-Australië gezenderde grutto's (die we oorspronkelijk identificeerden als de talrijkere *menzbieri* op de vangstlocatie) bleken te behoren tot de *anadyrensis*-ondersoort die broedt in het stroomgebied van de Anadyr in Rusland (hoofdstuk 3). Omdat *anadyrensis* niet op basis van grootte en verenkleed kan worden onderscheiden van de andere OAA trekroute-grutto's (*baueri* en *menzbieri*), waren hun verspreiding buiten het broedgebied en migratieroutes onopgemerkt gebleven vóór onze studie. We vonden twee belangrijke verschillen in migratieroutes tussen de gezenderde *menzbieri* en *anadyrensis* en beide traden op tijdens de migratieperiode na het broeden. Ten eerste trok *menzbieri* vanuit de broedgebieden naar het noorden om een tussenstop te maken op de Nieuw-Siberische eilanden (Rusland), terwijl *anadyrensis* naar het zuidwesten migreerde om langs de kust in de Zee van Okhotsk, Rusland, bij te tanken. Ten tweede, hoewel beide ondersoorten verder naar het zuiden trokken naar de Gele Zee, gebruikte *menzbieri* de Gele Zee als hun belangrijkste pleisterplaats in zuidelijke richting, terwijl *anadyrensis* daar maar heel even stopte om meteen weer door te gaan naar de Indonesische kant van het eiland Timor. We ontdekten ook dat de twee *anadyrensis*-vogels het schiereiland Kamtsjatka aan de oostkant van de Zee van Okhotsk gebruikten, terwijl *menzbieri* langs de westkant van die zee trok. Tellingen uitgevoerd in Kamtsjatka zouden daarom misschien een geschikte manier zijn om ontwikkelingen in de populatie van *anadyrensis* te volgen.

h oe kan kennis verkregen door het volgen van kustvogels met satellietvolgsystemen gebruikt worden bij natuurbehoud?

Moderne satellietvolgsystemen hebben zowel nieuwe routes als pleisterplaatsen van kustvogels langs de OAA trekroute aan het licht gebracht. Om de betekenis daarvan te beoordelen, hebben we de nieuwe informatie vergeleken met wat er bekend was van de aantallen vogels op de 92 pleisterplaatsen die werden gebruikt door de gezenderde grote kanoeten. We beschouwen deze vogel als een indicatorsoort voor kustvogels langs de trekroute die afhankelijk zijn van wetlands aan de kust (hoofdstuk 5). Maar liefst 63% van deze pleisterplaatsen waren voordat we ons onderzoek uitvoerden onbekend als belangrijke kustvogellocaties. Terwijl we weinig nieuwe plekken vonden rond de Gele Zee, kwamen er tal van locaties naar voren die belangrijk waren in Zuidoost-Azië, Zuid-China en Oost-Rusland. Het bleek dus dat kustgebieden in deze regio's heel belangrijk kunnen zijn voor kustvogels, terwijl adequate ecologische informatie, maar ook erkenning voor natuurbehoud in deze gebieden ontbreekt. De nieuwe verspreidingsgegevens van de gezenderde individuen kunnen helpen bij het plannen van aanvullend onderzoek in minder bekende locaties, zoals we dat in 2015–2018 langs de Chinese kust hebben gedaan. Wij hebben veldwerk verricht op 18 locaties, die werden bezocht door de gezenderde grote kanoeten en rosse grutto's, om informatie te verzamelen over vogelaantallen, dieet, samenstelling van prooipopulaties, voedselaanbod en de snelheid van voedselopname (kader A). We ontdekten dat de noordelijkste gebieden in de Gele Zee (Liaohe estuarium en het Yalu Jiang estuarium) de hoogste aantallen wadvogels herbergden, maar relatief lage dichtheden aan geschikte prooien in vergelijking met zuidelijker gelegen gebieden.

Lokale vliegbewegingen op de pleisterplaatsen, zoals we die uit onze volggegevens konden afleiden, zijn gebruikt bij natuurbeschermingsacties in drie gebieden in de Gele Zee in de provincie Jiangsu in China die dringend aandacht vereisten voor natuurbehoud.

Bij Lianyungang in het noorden van Jiangsu (hoofdstuk 6), ontdekten we door het analyseren van de satellietbeelden dat 27% van de wadplaten verloren was gegaan door landaanwinning in de periode tussen 2003 en 2018. We hebben het belang van deze locatie voor kustvogels vastgesteld door de resultaten van een decennium aan telinspanningen samen te nemen. Voor 22 kustvogelsoorten was de populatie in Lianyungang groter dan 1% van de gehele populatie langs de OAA trekroute, wat deze pleisterplaats de belangrijkste maakt van >300 kustvogellocaties in Oost-Azië. We hebben drie jaar benthos bemonsterd in Lianyungang en daarbij aangetoond dat de getijdenplaten vol zaten met kleine tweekleppigen met zachte schelpjes (waaronder *P. laevis*) die als hoogwaardig voedsel voor kustvogels mogen worden beschouwd. Ook bleek dat dit gebied door grote kanoeten en rosse grutto's zowel voor korte als lange tussenstops werd gebruikt. Voedselvluchten van de gevolgde dieren die het getijritme volgden brachten de precieze locaties van hoogwatervluchtplaatsen aan het licht, maar ook waar er nu daadwerkelijk gefoerageerd werd en daarmee welke gebieden bijzondere bescherming verdienden.

Aan de kust van Dafeng-Dongai-Rudong in het zuiden van Jiangsu was een grootschalige drooglegging gepland (kader B), uitgerekend op de enige plaats die de gezenderde *anadyrensis* Rosse Grutto's gebruikten in de Gele Zee. Deze locatie wordt ook nog eens gebruikt door bijna de helft van alle gezenderde *menzbieri* (hoofdstuk 3). De informatie die we kregen door rosse grutto’s met zenders te volgen bleek uiteindelijk cruciaal om de geplande drooglegging voorlopig te voorkomen en dit gebied werd uiteindelijk ook opgenomen als werelderfgoed.

Bij Tongzhou Bay in het zuiden van Jiangsu worden grote delen van het slik uitgebaggerd of juist drooggelegd voor de aanleg van havens (kader C). Om de ecologische impact van huidige en toekomstige landaanwinningsprojecten te beoordelen, werden verspreidingspatronen van kustvogels met satellietzenders gebruikt om de ‘ecotopen’ (gedefinieerd door hydrologische omstandigheden) te detecteren die van de grootste betekenis zijn voor kustvogels. Hierdoor kon het verlies aan leefgebied van kustvogels worden gekwantificeerd. In een vervolgstudie is het concept ‘bouwen met de natuur’ toegepast in havenontwerp. Met hydrologische simulaties van sedimenttransport in de baai werden alternatieve havenconfiguraties beoordeeld (en vergeleken met de nulsituatie dat er geen haven wordt aangelegd). Hierbij onderzochten we of de bestaande hoogwaardige 'ecotopen' voor kustvogels kunnen worden behouden, of dat hun natuurlijke groei kan worden bevorderd door kunstmatige aanslibbing.

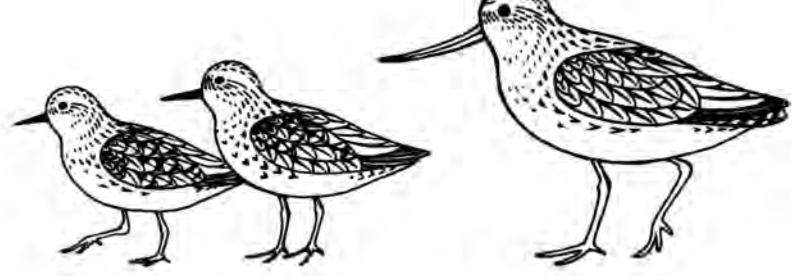
h oe gaan kustvogels om met verlies en achteruitgang van hun leefgebied?

Wanneer kustvogels bij hun traditionele pleisterplaats aankomen en daar ontdekken dat er wadplaten verloren zijn gegaan, of dat de voedseldichtheid sterk is afgenomen, blijven er nog een aantal mogelijkheden over. Blijven en minder kieskeurig zijn wat betreft hun voedselkeuze of meer tijd aan foeregeren is een mogelijkheid, maar vertrekken naar een andere plek is een andere optie. Veel soorten kustvogels leggen echter een sterke plaatstrouw aan de dag, die ze kan weerhouden om te vertrekken, zelfs wanneer de omstandigheden ongunstig zijn geworden.

Dankzij onze satellietzenders, maar ook door vogels met kleurringen te volgen, konden we aantonen dat grote kanoeten minder plaatstrouw zijn dan rosse grutto's. Dit verschil viel op in het overwinteringsgebied in Noordwest-Australië, maar ook in de Gele Zee (hoofdstuk 7). De kanoeten verschilden ook onderling sterker in hun mate van plaatstrouw dan individuele rosse grutto’s. We onderzocht wat de individuele variatie in plaatstrouw bepaalt, waarbij we ons concentreerden op een individueel verschillende neiging tot meer of minder exploratiegedrag (hoofdstuk 8). Het is bekend dat explorerende vogels meer energie steken in het verzamelen van informatie, en daarbij beschikken ze mogelijk ook over meer informatie over alternatieve plekken. De kosten om te verplaatsen zijn dan lager. Voordat we de gezenderde grote kanoeten in het wild loslieten, hebben we eerst experimenteel hun neiging tot exploreren gemeten. We ontdekten dat meer exploratieve grote kanoeten sneller reageerden op de ineenstorting van het prooibestand op hun belangrijkste pleisterplaats door naar andere plekken te verhuizen dan minder exploratieve individuen, waardoor ze eerder in hun broedgebieden aankwamen en een grotere kans hadden om jongen groot te brengen.

Ten slotte, zouden deze trekvogels op andere manieren kunnen omgaan met de verslechterende omstandigheden op hun pleisterplaatsen in de Gele Zee (hoofdstuk 9)? Is het inderdaad voordeliger om eerst de trek in in Zuidoost-Azië en Zuid-China te onderbreken, om daarna naar de Gele Zee door te vliegente bereiken tijdens de noordwaartse trek in plaats van een rechtstreekse vlucht vanuit Noordwest-Australië naar de Gele Zee? En een toenemend aantal grote kanoeten overwintert in Zuidoost-Azië. Doen deze vogels het beter dan hun soortgenoten in Noordwest-Australië? Het bleek dat sommige gezenderde vogels de trek zelfs helemaal oversloegen; is dat een betere strategie dan elk jaar trekken en broeden?

Om al deze vragen te beantwoorden, moeten we de trekroutes van deze vogels blijven volgen en de kwaliteit van hun leefgebieden blijven meten, waaronder de beschikbaarheid van voedsel en de resulterende energiereserves, de overleving en het broedsucces van de vogels die deze gebieden gebruiken. Ik hoop dat dit proefschrift toekomstige studies zal inspireren over hoe vogels omgaan met de door de mens veroorzaakte achteruitgang van leefgebieden in de wereld. Dit zal uiteindelijk leiden tot betere voorspellingen over hoe deze problemen leiden tot de achteruitgang van trekvogels. En door te begrijpen hoe de vogels hiermee omgaan, kunnen we misschien beter worden in het omgaan met de rotzooi die de mens heeft gecreëerd.



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Writing the acknowledgements is a little trip back in time; it all started with my primary supervisor Theunis Piersma, who tends to push the limits. Theunis had this vision of tracking the knots and godwits in the East Asian–Australasian Flyway with expensive satellite transmitters, and he made it possible despite the difficulty in getting the funds together. His perseverance, optimism and daring to dream big have inspired me all these years. Working with him built up my courage to not to choose the easiest path, but to do the things I felt right. Thank you, Theunis, for the opportunity and your trust in me conducting the research, for being extremely quick in responding to emails, and teaching me important life lessons.

My first taste of shorebird research was a Master's research project with Allert Bijleveld. On my second day as a student in NIOZ I was dropped off in the middle of a wavy sea and lived five weeks on an uninhabited tiny island with three other Dutchies. During the fieldwork I was deeply influenced by Allert's dedication and persistence in the field; nothing is impossible after long days of following Knot flocks around, walking 20 kms on the mudflats carrying heavy equipment including a tripod designed for people twice my size – heavy they were, they might be the reason I wasn't blown away by the strong wind. I particularly enjoyed the walks on the beach around Griend during which Emma shared her knowledge and love for the birds and wildlife in the Wadden Sea. The attention to details and critical thinking of Allert also shaped my attitudes in doing science.

After the experience in the Wadden Sea I was eager to study shorebirds in other parts of the world. I gladly took the opportunity that Theunis offered to join the satellite tracking fieldwork in Roebuck Bay, Australia in 2012. Under the 40-degree hot sun I met Chris Hassell and Lee Tibbitts, the two key people in my PhD project. Amidst the rather nerve-wrecking cannon-netting sessions, Lee was there, being the expert in satellite tagging of shorebirds, getting the work done, keeping a good spirit and making sure everyone is alright. From there on I looked up to Lee as a scientist and as a person. Chris has taught me a great deal about shorebirds and the Australian wildlife during the months that I followed him around Roebuck Bay almost daily to read colour rings of shorebirds. We also went ring-reading for the few days in Eighty Mile Beach, and then we followed the Broome Red Knots to Nanpu, Bohai Bay, China. Ady, Matt and Chris introduced me to Nanpu and I learnt from them about the many shorebirds in this amazing site and how to read as many rings as possible. At the field site I lived with Nicky Yang, one of the first people studying shorebirds in Bohai Bay. She infected me with her enthusiasm and positivity, and shared her experience of conducting fieldwork in China. Nanpu was a combination of extremes: there were huge flocks of all species of shorebirds in almost full breeding plumage that were stunningly beautiful, while the landscape was very industrial and without any consideration on aesthetics. During my month-long stay there, my curiosity and interest in shorebirds developed into a deeper sense of concern, which is a source of motivation to this day to research about the shorebirds in East Asia.

Before I could start tracking birds in the East Asian–Australasian Flyway, a harness had to be developed and tested for attaching tags onto Knots; also, I needed to come up with a field set-up to measure exploratory tendency of knots in Australia. I would like to thank Anne and Maarten who took care of the birds, helped with tagging Knots with (dummy) satellite trackers, thought along with the design and built the set-up. I also thank Jorge, who was working in the aviaries in the same period, for his help, company and sharing his knowledge on shorebirds. From working with them I gained a lot of experience in handling birds and keeping them in captivity, which prepared me well to the task of keeping birds in captivity in Australia.

For some years I did live like a migratory bird. I went to Northwest Australia four times to attach satellite tags onto the birds. I am very grateful to Chris' meticulous organization and leadership in the many bird catching sessions, and even letting us temporarily transform his house and garden into an aviary and experimental facility to keep the Great Knots and conduct the trials to measure their exploratory tendencies. Under the gentle guidance of Lee I gradually learnt all the ins and outs of tagging shorebirds. Lee's positivity and level-headedness has helped to overcome numerous challenges that arose from keeping the birds, adopting the trial set-up to Australian conditions, and tagging the birds. After the satellite tagging fieldwork, Chris continued keeping an eye on the tagged birds throughout the whole non-breeding period and collecting and organizing the resighting data, which I am very grateful for. I thank Kerry, Helen MacArthur, Maurice, Liz, Grace, Helen Fong, Ivan, Yvonne, Jesse, Katherine, the BBO wardens Nigel, John, Emilia, Ric, Hazel and many others who helped with catching, keeping and tagging the birds and looked for them in the bay afterwards.

In the seven years that I worked in China during the spring migration season, I met many enthusiastic and incredibly supportive people. I thank Chen Ying for letting me join part of her survey in 2013 so I could visit more shorebird stopping sites. I broadened my view on how sites differ, and also realised how widespread some of the threats to shorebirds in the Yellow Sea were. I also had the fortune to work with David Melville, who shared his immense knowledge on shorebirds in this flyway and his precise attitude in fieldwork. It was in Nanpu where I first met Hebo Peng, who eventually became my 'partner-in-crime' in the exciting quest of following shorebirds on-ground. The fieldwork was very fast-paced and full of unknowns: one of our fieldwork 'routines' was checking the satellite tracking data on where the birds were, deciding on our next destination, immediately looking up transport options and buying tickets to get to that place

the next day. At each new site we had to solve numerous logistical issues. Together we went to places no one else has surveyed, we made new discoveries, we saved each other a few times. Thank you, Hebo, for being extremely flexible, resourceful and responsive, making all these possible. I thank Calvin, Kerry, Isabel, Chen Xue, Yueheng, Zhang Ping, Entao, Xuebing, Yuanyuan, Xu Minchen, etc. for joining our super intense surveys in 2015–2018. I also thank Shanque for his hospitality when we first visited Lianyungang, Jonathan Martinez sharing his knowledge on shorebird sites in southern China, and Lei Ming, Bingrun (Drew), Mu Tong, Lao Bai, Shoudong and Tan Kun for the time in the field together. I thank Vivian Fu for her help with many aspects of our project over the years. And fieldwork in China would not be possible without the support of Prof. Zhengwang Zhang and Prof. Zhijun Ma. I also thank Prof. Ma for having me in his lab at Fudan University.

Apart from the intense travelling across the world, the majority of the time in the PhD was being stationary, processing and analyzing data and writing. Time in the office at NIOZ was great with so many close colleagues, many of whom I also met after work e.g. at the beach or the pub. I thank my office-mates Thomas O., Roos and Pascalle for creating a productive work environment. I thank Allert, Geert and Roeland for organizing the C-Move, Jeroen H. and Mark for organizing the Machine Learning discussion group, and the organisers of the COS seminars and literature discussions where I learnt a lot. I thank Job for helping with equipment and sharing his bird knowledge, and Sander for having an answer to everything. I am thankful that I could participate in the Dutch course that NIOZ organized, where I learnt from our great teacher Antje with the nice fellow classmates Julia, Helge, Chiu, Annika and others, and learning Dutch enables me to enjoy my life in the Netherlands more. I am grateful to the advice, discussions, help and company from Tamar, Jan, Matthijs, Thomas Lameris, Jeroen R., Anieke, Roeland, Martin, Eva, Emma, Eelke, Lise, Loran, Luc, Geert, Piet, Petra, Paolo, Valérie, Tom, Misha, Tanya, David and many more. The scientific and non-scientific discussions during coffee and lunch breaks with the many colleagues in COS (and sometimes with colleagues outside COS) kept the workdays enjoyable and stimulating. I hope we will have another coffee break altogether after the last one on 13 March 2020! The last year of my PhD I was working at home: I thank Selin, Susanne and Clea, my bootcamp buddies for keeping me fit and happy, together also with Nino they were my 'family' during the lockdown. Replacing the NIOZ coffee breaks, I had relaxing walks with my neighbours: Zeynep, Diana, Alejandro, Jaime, Misha, Mark, Carlijn and more.

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how can I write better, sentence by sentence, demystifying the English language. From the many insightful comments she made on all the chapters in this thesis, I significantly improved my critical thinking and writing.

During the PhD I was fortunate to be living on the island of Texel having beautiful nature right at my doorstep, and also surrounded by great friends. The many dinners, drinks, walks in nature, swimming in the sea, hanging out on the beach and little adventures with Suus, Irene, Andres, Selin, Kiki, Zeynep, Michele, etc. were great memories, thank you all for being there. Eldar and Julia, thank you for the lovely dinners and movie nights. Misha and Lena, thank you for the many enjoyable outings around the island, yoga sessions, teas and dinners. I thank also Andre, Hai, Hebo and Shoudong in the 'overkant' (=other side, i.e. Den Helder) for our delicious (big) meals. Kees introduced me to the classical concerts in the church of Den Hoorn which became one of my favourite activities on Texel. The group dinners that Kees initiated (later came Threes as a co-host), always with good food and company, made the dark winters bearable and lively. The cozy evenings in warmer days sitting by the fire with Kees, Piet, Susanne, etc. were magical. Thank you, Kees, for all these great memories, and also for sharing your immense knowledge on gulls, birds and many aspects of marine life.

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