1 Introduction
Chapter 1
Project background

The Netherlands is a densely populated and industrialized country. As a result of human activities such as industry, transportation and agriculture, many soils in this country are contaminated (MNP, 2006). Apart from clearly defined sites where pollution is above legislative levels for soil cleanup, many sites in the country are polluted with a mixture of contaminants below such levels (so called diffuse pollution). The Dutch government wanted to know what effect this diffuse pollution has on ecosystems and therefore started the Stimulation Program ‘System-oriented Ecotoxicological Research’ (SSEO) in 1998, through The Netherlands Organization for Scientific Research (NWO).

Within this program several research projects were initiated that studied the effects of contaminants on different organism groups ranging form bacteria to vertebrates at three selected sites (Zorn, 2004; Vijver, 2005; Notten, 2005; Hobbelen, 2005; Kools, 2006; van der Welle, 2007; Wijnhoven, 2007). The project underlying this thesis was one of them and aimed to determine the effects of mixtures of contaminants on the population dynamics of the Black-tailed Godwit (‘grutto’ in Dutch). The numbers of Black-tailed Godwits are declining in The Netherlands and the species is classified as vulnerable on the IUCN and the Dutch Red list (see below). As effects on individuals do not necessarily translate directly to populations, impacts of pollutants should be studied at the level of populations (Stark & Banks, 2000).

The following research question was formulated:

“What are the population level effects of diffuse pollution, in the form of heavy metals, on Black-tailed Godwits breeding on contaminated soils in The Netherlands?”

Performing studies on the impact of diffuse pollutants poses several problems. These problems are summarized by van Straalen & van Gestel, (2008): (i) absence of gradients and peak concentrations, as the pollutants are spread out spatially and are not emitted from one point, (ii) absence of good reference sites, (iii) low to moderate concentrations, which may cause small effects that are difficult to measure in the field, (iv) large spatial heterogeneity, which necessitates large sample sizes, (v) mixtures of chemicals from different sources, with possibly interacting effects on biota and (vi) legacies from the past, so that the reference situation is unknown, or local populations may have adapted to the contaminant levels. These authors therefore recommend that effects of diffuse pollution should be analysed by simultaneously considering all possible variables using multivariate models, to be able to separate effects from contaminants from natural variation and other stress factors. However, to do this successfully, a large number of independent study sites is imperative. In species higher up in the food chain such as the Black-tailed Godwit, this is a major problem, because of the large spatial and time scales needed. The
given timeframe of this project only allowed for two sites to be studied. The research described in this thesis was carried out at the contaminated site polder Blokland, and at a non-contaminated reference site, polder Zeevang. The contaminated site lies in “de Ronde Venen”, one of the three study sites of the SSEO program. After drainage and peat subsidence, municipal waste from Amsterdam and Utrecht was deposited at this site since the 16th century until 1950, to elevate the land and improve the soil structure and fertility. As a consequence, the top layer of the soil is heterogeneously contaminated with organic pollutants and heavy metals (Lexmond et al. 1987). A more detailed description of the two study sites is given in Chapter 2. Being able to compare only two sites, it was difficult to determine the effects of heavy metal pollution on vital rates (demographic parameters determining population growth rate). However, recent data on vital rates were needed for a better understanding of the population decline of this species. Therefore, a second aim of this project was to collect data on reproduction and survival of Black-tailed Godwits, to compare these to data from literature and to develop a population model to diagnose the population dynamics of the species. In this way, we hoped to identify which demographic parameters have declined in the Black-tailed Godwit population, and to determine to which parameters the population growth rate is most sensitive.

**Study species**

Around 40% of the continental European population of Black-tailed Godwits *Limosa limosa* ssp *limosa* breeds in the Netherlands (BirdLife International, 2004), giving this country a high responsibility in its conservation. Though numbers are declining all over western Europe, threats resulting from habitat deterioration are particularly strong in The Netherlands, being densely populated and one of the leading countries in agricultural intensification (Donald et al. 2001). Moreover, the area of grassland has decreased in most European countries in the period 1960-1990, which was most prominent in the Netherlands: 35.6-29.4% of the available habitat was lost (Young et al. 2005). Also predation rates of nests and chicks have increased (Schekkerman et al. 2009), which amplified recent population declines. Other possible threats to Black-tailed Godwits in The Netherlands are habitat fragmentation, disturbance by traffic and recreation, and pollution.

Not only extrinsic, but also intrinsic factors predispose the Black-tailed Godwit to negative population trends in the light of recent human-induced pressures. Black-tailed Godwits, as other waders, breed on the ground, a trait identified by Van Turnhout et al. (2010) as a factor correlating with population declines in Dutch breeding birds. In addition, it is a long-distance migrant, wintering in western Africa. Bohning-Gaese & Bauer (1996) showed for a site in central Europe that populations of both farmland birds and long-distance migrants have declined, in contrast with
more resident species groups and species from other habitats. Moreover, being a habitat specialist, restricted to wet agricultural grasslands and similar natural habitats, the Black-tailed Godwit has little options left when this habitat deteriorates or disappears (Julliard et al. 2004; Jiguet et al. 2007). Finally, it is a long-lived species (maximum age recorded in literature is 30 years, Zwarts et al. 2009), with long pre-adult stage (age at first reproduction usually 2 years, Cramp & Simmons, 1983) and low reproduction rates (one brood per breeding season, with a maximum of four eggs, Cramp & Simmons, 1983), which hinders rapid adaptation to changing environments (Jiguet et al. 2007).

Its slow life history strategy also makes the species especially vulnerable to chronic contaminant exposure (table 1, Rowe, 2008). In long-lived species chronic exposure may result in high body burdens through accumulation of the contaminant, which may cause direct effects in adults, such as increased mortality and/or decreased fertility. Alternatively, or additionally, high concentrations of contaminants may be transferred to vulnerable offspring. As the number of offspring in these species is relatively low, this may seriously impair reproductive output. Finally, the long generation times may cause delayed expression of effects of contaminants on the population level, while at the same time delaying recovery rates of populations after removing the contaminant from the environment.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Contaminant effects that suboptimize strategy</th>
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<tr>
<td>Large per capita parental investment in offspring</td>
<td>Maternal transfer of high concentrations of contaminants to offspring</td>
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<tr>
<td>Delayed maturation</td>
<td>Mortality before reproduction</td>
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<td></td>
<td>Chronic accumulation of contaminants that may be transferred to offspring upon maturation</td>
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<td>Reduced size at maturity reducing offspring quantity or quality</td>
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<td>Iteroparity</td>
<td>Mortality before achieving total potential life long reproductive events</td>
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<td>Long embryonic/preparturition/preweaning period</td>
<td>Chronic exposure of offspring to female-derived contaminants (yolk, placenta, milk)</td>
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<td>Long cohort turnover time</td>
<td>Delayed expression of fitness effects at the population level</td>
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<td>Delayed recovery of populations following abatement of fitness effects</td>
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Table 1. Reproductive life history traits associated with long-lived animals and associated potential effects on fitness and population dynamics as a result of chronic contaminant exposure (Rowe, 2008).
Chapter 1

**Thesis outline**

In **Chapter 2**, concentrations of **heavy metals in soil, earthworms and godwit eggs and feathers** in the polluted and the reference site are compared to see whether elevated concentrations in the soil are transferred to adult godwits via earthworms, their main food item. This could have effects on vital rates of the Black-tailed Godwit population in the polluted site.

In **Chapter 3**, the **reproductive output** of Black-tailed Godwits in the two main study areas is investigated. The timing of reproduction is related to nest success and chick survival and the resulting reproductive output. Possible proximate causes for this relation are discussed. The reproductive output is compared to the minimum reproductive output required for the populations to remain stable and to historical values from literature.

In **Chapter 4**, I focus on **adult survival** in Black-tailed godwits at the two study sites. Adult godwits are captured on the nest, colour ringed and resighted during three years in four different study sites in the Netherlands. Apparent adult survival is estimated with the use of program MARK and compared to historical survival estimates from literature. As permanent emigration cannot be distinguished from mortality in calculations of local survival, a measure for breeding site fidelity in the two main study sites is also calculated, to see if this can help explain differences in apparent survival.

In **Chapter 5**, a visual diagnostic tool is constructed using **matrix models**, to determine under which conditions meadow bird populations are declining, increasing or stable, to be able to estimate missing demographic parameters and to determine the sensitivity of the population growth rate to changes in demographic parameters, despite a value missing.

In **Chapter 6**, literature data on adult and juvenile survival in five meadow waders (Oystercatcher *Haematopus ostralegus*, Lapwing *Vanellus vanellus*, Black-tailed godwit, Curlew *Numenius arquata* and Redshank *Tringa totanus*) are reviewed and a statistical **meta analysis** is performed on reproductive parameters collected from different years and sites in Europe, to determine whether survival or reproduction or both have declined in the species concerned.

Finally, the results are collated and discussed in **Chapter 7**, the **general discussion**, by performing an elasticity analysis with a matrix model based on the vital rates estimated at the study sites and by determining which part of the Dutch Black-tailed Godwit population is at risk from heavy metal pollution. Future risks of heavy metal pollution in The Netherlands are discussed and recommendations for conservation of the species are given.
References


Chapter 1