Examination for conformity and validity of the Wetland bird Survey data sets for 1981-1983 and 1995-2001 on part of the Upper Severn flood plain at Alberbury, Shropshire and their application for the conservation management of wintering waterbirds.

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A Thesis produced in part fulfilment of the assessment requirements of the degree of Master of Science (Environmental Science) of the University of Wolverhampton.

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Declaration

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Abstract

Historically part of the upper river Severn floodplain has been an important area for wintering waterbirds. Direct counts were made along transects using look and see methodology during the winters of 1995-2001 and the results were compared to those of 1981-1983. The aims of the study were: (i) to identify the quality and value of the best site for eight selected waterbird species in three taxonomic guilds of a floodplain ecosystem of the region by comparison of recent and historical datasets. (ii) Identify selected species preferred environmental conditions by assessment of species responses to three environmental stochastic perturbations namely, temperature, wind and flood pulses.

Most species tolerated low temperatures and high wind forces for short durations and foraged in shallowly flooded heterogeneous topography that formed diverse habitats at varying depths. Interspecifically preferred foraging depths were determined by morphological characteristics that reduced interspecific competition. Datasets revealed that the site is important for wintering waterbirds because under preferred conditions county high counts of dabbling ducks, notably Eurasian wigeon, Eurasian teal and Northern pintail are annual events and it is the only Shropshire site for wintering Whooper swans.

Examination for conformity and validity of the Wetland Bird Survey data sets for 1995-2001 on part of the Upper Severn flood plain at Alberbury, Shropshire and their application for the conservation management of *wintering* waterbirds.

Chapter 1

Introduction

Population monitoring provides data to detect conservation problems and may indicate solutions (Thomas 1996).

The Loton Loop site was selected: (i) to re-assess the value of the area for wintering waterbirds; (ii) because historically it has attracted large numbers of wintering waterbirds (Tucker 1994); (iii) following the first systematic survey of wildfowl and waders on the Severn-Vyrnwy Confluence ecosystem, shown in appendix 14, map 2, during 1981-1983, the Royal Society for the Protection of Birds concluded that the area was important due to species richness and abundances (Crosby 1983); (iv) because of occurrence of regular flood incidents (Tucker 1994;) and (v) because of participation in the national Wetland Bird Survey (WeBS) scheme.

The objectives were to: (1) re-assess the importance of the sampling universe, the Loton Loop, shown on appendix 13, map 1, for wintering waterbirds by comparing the WeBS and the 1981-1983 survey datasets by determination and examination of the: (i) annual population trends; (ii) seasonal population trends; (iii) correspondence between species seasonal trends and trends of environmental processes and (2) identify statistical relationships between avian seasonal dynamics and environmental processes.

To re-assess the wintering avian importance of the area, it was decided to re-survey the area along the original transects. From January to March 1995 a pilot survey was undertaken, at approximately two weekly intervals, using the original three transects, A, C and E, shown in Appendix 14, map 2. The results encouraged survey continuance along transect C, shown in appendix 15, map 3, and reduced transects A and E; the season was eventually extended to September-April. This thesis is in relation to the Loton Loop, Alberbury, Shropshire, transect C, which was compared to the summed data of transects A, C and E of the 1981-1983 survey.

Chapter 2

Literature review

UK Wildfowl and Wader Counts 1981-1983 (Salmon 1981 and 1983), Wetland Bird Survey (WeBS) 1995-2001 and Wildfowl and Wader counts on the Vyrnwy Confluence (Crosby1983) datasets provided national and local information in relation to waterbird populations. Eight target species of waterbirds in three taxonomic groups were selected as being representative of the ecosystem (Brown, Mehlman and Stevens 1995).

A survey is a sample subset, of unknown proportion, of the total population (Thomas 1996) of an unknown size, counted along a transect located in a sampling universe that is representative of the site (James, McCulloch and Wiedenfeld 1996). Birds were sampled by the "look and see" methodology" along prescribed transects (Bibby, Burgess and Hill 1992), which is subject to precision, measurement error and bias that was minimized by agreed protocol compliance (Thomas 1996). Transect length and duration of surveys were representative of the sampling universe (James, McCulloch and Wiedenfeld 1996) to determine directional trends (Mac Nally 1997) and for inter-survey comparability. Large-scale surveys can mask local trends (Coulter and Frederick 1997).

Dynamics of waterbird and biota populations were subject to environmental stochastic perturbations (Goss-Custard and Dit Durrell 1990; Rehfisch, Insley and Swann 2003). Under various environmental conditions, birds aggregate within the site (Lawton 1994). Monitoring strategy was the longitudinal time series paradigm (Mac Nally 1997).

Examination of data sets revealed: (i) population annual and seasonal trends (Green in Maddy and Brew 1995); (ii) species trend dynamics and environmental stochastic perturbations investigated to identify synchronous relationships (Greenwood and Baillie 1991; Lawton 1994) and causative factors that drove trends (James, McCulloch and Wiedenfeld 1996); (iii) comparative interspecific mobility assessed in relation to environmental stochasticity (Lawton 1994); (iv) numbers and fluctuations in relation to body size (Lawton 1994) and (iv) detection of sink populations and fate assessment when separated from the core area of the conspecific population (Lawton 1994). Avian trends are compared to national trends (Mac Nally 1997).

Time series trends were measured on arithmetical and logarithmic (base 10) scales (Thomas 1996). Data sets were de-trended to reveal any relationships between species and abiotic environmental variables, which were statistically tested by analysis of variance (ANOVA) (Green in Maddy and Brew 1995; Thomas 1996). Robust statistical methods (Pallant 2002) with few assumptions were used for violation avoidance (James, McCulloch and Wiedenfeld 1996). Graphs, statistical tests and maps were used for temporal comparison (James, McCulloch and Wiedenfeld 1996). Duration of surveys were representative, thus not misleading (James, McCulloch and Wiedenfeld 1996).

The patterns of abundances reflect niche requirements, environmental suitability, processes of temporal variation, and deterministic processes that characterize species requirements (Brown, Mehlan and Stevens 1995). Temporal abundance patterns over generations illustrate local population dynamics (Brown, Mehlman and Stevens 1995).

Flocking is attributable to group benefit and not due to environmental conditions alone (Brown, Mehlman and Stevens 1995). A site is characterized by the environmental variables and local density, varying over time resulting in intrinsic population dynamics (Brown, Mehlman and Stevens 1995).

Environmental perturbations (Power et al. 1995) interact with population regulation processes (Goss-Custard and Dit Durrell 1990) to reset population levels (Power et al. 1995). Perturbations influence energy expenditure and food accessibility (Rehfisch, Insley and Swann 2003). Preferred foraging depths are determined by avian morphological characteristics (Colwell and Taft 2000). Substrate condition influences food supply (Ntiamoa-Baidu et al.

1998). A permanent central wetland area is required (Paittison and Marion 2002) and a continuum of wetland habitats (Parkinson, Mac Nally and Quinn 2002) to sustain waterbird and other biota populations.

Chapter 3

The Sites

The site was the Loton Loop, Alberbury, Shropshire, shown in Appendix 13, map 1, which datasets have revealed was the most important of the three sub-sites of the 1981-1983 survey of the Severn-Vyrnwy Confluence sampling universe, shown in appendix 14, map 2. The latter, part of the upper Severn flood plain ecosystem, formerly part of the post glacial Lake Severn (Toghill 1990) was in two geographical parts: (1) the Loton Loop and (2) to the west and north of the river Severn.

The Severn-Vyrnwy Confluence site extended to approximately 900 ha. and was divided into two parts, north and south of the river Severn. From the northern and southern extremities of both parts of the site, altitudes declined towards centres (Ordnance Survey maps, Severn-Trent aerial survey 1977); micro undulations were frequent. Heterogeneous topography amplitude was 54-62 m MAOD. Parts of the Loton Loop and the Confluence are designated water based prime sites for nature conservation (Environment Agency 1998; Tucker 1994).

The landscape comprised fields of 0.4-12 ha., most fields remained unaltered between surveys (Ordnance Surveys maps, Severn-Trent aerial survey 1977). Field boundaries were mainly hawthorn *Crataegus monogyna* hedgerows with mature pedunculate oak *Quercus robur* and ash *Fraxinus excelsior*. Parts of the banks of the river Severn were lined with willow Salix species that naturally regenerated. There were several ephemeral pools.

The substrate was heterogeneous, much of the Conway Soil Association and also an admixture of permeable humus, silt-loam over impermeable boulder clay (pers. obs. 1995). The pH estimated amplitude was 5.9-6.5. There were two main habitats: (i) agricultural, that consisted of ryegrass *Lolium perenne* leys MG7 (Rodwell 1992) and arable cropping of spring cereals and maize and (ii) a poplar plantation.

Features specific to the Loton Loop were: (i) substrate included occasional pockets of peat (Powell pers. comm. 2002); (ii) habitats included approximately 38 ha of hygrophilous Yorkshire fog-tufted hair-grass *Holcus lanatus-Deschampsia cespitosa* grassland MG9 (Rodwell 1992); there were extensive areas of overgrown hawthorn bushes in pastures near the river Severn indicative of extensive agricultural management; (iii) arable cropping included sugar beet and (iv) there were several plantations, notably willow carr.

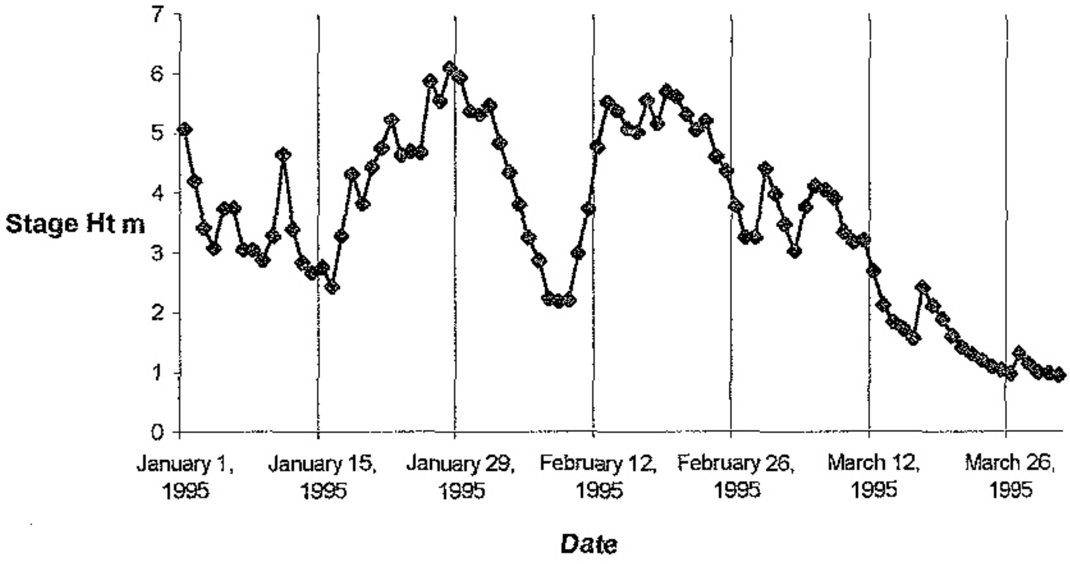
There were four sources of stormwater: (i) river Vyrnwy with the source 37 km westerly; (ii) river Severn, the source was Plynlimon Fawr, source 64 km south westerly; (iii) The Weir, Strine, Nesscliffe brooks, Newcut and numerous ditches, as shown in Appendix 19, map 7; (iv) the mean annual rainfall (613 mm) measured at Monkmoor, Shrewsbury, grid reference SJ517136 (Environment Agency 2000).

Water stage heights were recorded at the Environment Agency's nearest permanent archival hydrometric station, Crew Green, site reference 2175, National Grid Reference SJ32961581, approximately 2.5 km upstream from start of transect C, shown in appendix 13, map 1. Crew Green is an open channel site and water stage heights were registered on a drum chart recorder daily at 0900 hours (Environment Agency 2000); the datum was 54.00 m MAOD (Environment Agency datasets 2001 and 2002).

Water stage heights rose slowly in the river Severn and when the channel was full, the Severn-Vyrnwy Confluence flood storage basin filled swiftly (Environment Agency, Midlands Region 2000). The Severn-Vyrnwy Confluence site was subject to regular September-April seasonal flooding incidents (Tucker 1994; Environment Agency water stage height datasets 1981-1983 and 1995-2001). The Loton Loop has flooded in every month between 1953-2002, but not annually (Powell pers. comm. 1995). Flooding incidents frequently occurred in two stages: (i) river Vyrnwy stormwater, typically peat coloured. (ii) a supplementary flood, river Severn stormwater, (Pannett 2002; Payne pers. comm. 2002). Water stage height datasets revealed frequent supplementary flood incidents, less severe flood pulses occurred as the original floods declined, as shown on graph 1, thus flood *incidents were prolonged* (Environment Agency datasets 2001 and 2002). Residual floods were frequent, attributable to heterogeneous ground level back falls.

Saturated substrate, usually from early autumn, remains wet winter long, consequently further moisture absorption capacity is nominal and residual *flooding can be prolonged (pers. obs.* 1995-2001). Over time, flood incidents have: (i) eroded a proportion of the humus layer from arable fields and (ii) deposited silt, an allogenic process, for example over the fields and in terrace *formation flanking the river Severn.*

Graph 1
Water Stage Heights on the River Severn at Crew Green January-March 1995



Flood plain hydrology has been modified (Kingsford and Norman 2002) since *circa* 1785 due to drainage operations (Tucker 1994) including: (i) construction of argaes, embankments, shown in appendix 19, map 7, to provide limited flood protection to adjacent farmland (Environment Agency

1998). The first argae was built *circa* 1785 under the Enclosure Act, 1785 (Tucker 1994); (ii) construction of Newcut and ditches, installation of sub-surface land drains and mole ploughing of land; (iii) sluices, shown in appendix 19, map 7, restricted ingress of water from main river channels into ditches, thereby reducing flooding likelihood. Thus, anthropogenic improvements have diminished flood pulse incident probability, frequency, intensity and duration with consequential biota reduction, an ecological cost (Kingsford 2000).

Stormwater was enriched by agricultural contaminants, including fertilizer, herbicides, pesticides, biocides, silage effluent, faeces and lead shot (pers. obs. 1995-2001) resulting in eutrophic water. Chemical, biological, nutrient and aesthetic analysis results of General Quality Assessment of river water were generally good (Environment Agency 1998). The chemical quality of water required supporting riparian ecosystems, assessed as part of the River Quality Objectives, at the Weir Brook-Severn sampling point was a "marginal fail" and under the River Ecosystem Classification Scheme the location was so classified (Environment Agency 1998).

Wildfowl were shot over the Loton Loop during 1981-2001 (Leighton pers. comm. 2002) and in the locality (pers. obs. 2000-2001). Both main rivers were fished but disturbance was minimal (pers. obs. 2001). Public minor rights of way, shown in appendix 18, map 6, were infrequently used (pers.obs. 1995-2001).

In summary, functioning of the ecosystem, characterized by frequent flooding, has been modified by hydrological modification and agricultural intensification (Environment Agency 1998; Tucker 1994). Some preservation of the Confluence area has been achieved since the 1950's by: (i) agricultural holdings occupation remaining with the same families (Powell pers. comm. 2001); (ii) minimum disturbance, except organised wildfowl shoots and (iii) relative geographical isolation.

Chapter 4

Study Design

Objectives

Study design includes: (i) a statement of objectives; (ii) an hypothesis; (iii) sampling strategy (Greenwood and Baillie 1991) (iv) named variables that are capable of analysis and computed statistics to answer specific questions (Thomas 1996).

The objectives were: (i) to assess the importance of the sampling universe, the Loton Loop, shown in appendix 13, map 1, for wintering waterbirds; (ii) to detect annual population trends in the Wildfowl and Wader Counts of 1981-1983, the Wetland Bird Survey (WeBS) of 1995-2001 and inter-survey period; (iii) comparison of annual population trends between the two surveys and the inter-survey period; (iv) assessment of the net quantitative annual population trends by comparison of site to national trends (Brown, Mehlman and Stevens 1995); (v) detection of seasonal population trends; (vi) identification of relationships between avian seasonal population trend dynamics and trends of environmental processes, temperature, wind forces and water stage heights (Brown, Mehlman and Stevens 1995; Power et al. 1995).

Hypotheses

The null hypotheses:

(i) if, on the sites, waterbird abundances were not less due to declining European temperatures, then the null hypothesis was not rejected in favour of the alternative hypothesis. The alternative hypothesis: if, on the sites, waterbird abundances were greater due to diminishing European temperatures, then the null hypothesis was rejected in favour of the alternative hypothesis.

(ii) if, on the sites, waterbird abundances were not less when local temperatures were below 0^{o} C compared to temperatures above 0^{o} C, then the null hypothesis was not rejected. The alternative hypothesis: if waterbird abundances were greater when to local temperatures were below 0^{o} C compared to temperatures above 0^{o}

C, then the null hypothesis was rejected in favour of the alternative hypothesis.

(iii) if, on the sites, waterbird abundances were not less during calm weather compared to when the wind was blowing, then the null hypothesis was not rejected. The alternative hypothesis: waterbird abundances were greater during windy periods compared to calm periods, then the null hypothesis was rejected in favour of the alternative hypothesis.

(iv) if, on the sites, waterbirds abundances were not less during non-flood events compared to flood incidents, then the null hypothesis was not rejected. The alternative hypothesis: if waterbird abundances were greater during flood events compared to non-flood events, then the null hypothesis was rejected in favour of the alternative hypothesis.

Monitoring

Wildfowl and Wader Counts were undertaken by the RSPB for two "bird years" from September to March 1981-1983 at approximately fortnightly intervals from November to February and monthly for the remaining period along three transects, A, C and E; A and E were extended for the 1982-1983 survey (Crosby 1983), as shown in appendix 14, map 2; site data is in table 1.

Table 1

Severn-Vyrnwy confluence site data of the 1982-1983 surveys

Transect	Central national grid reference	Altitude MAOD	Transect length km	Sub-site area, ha
A	SJ348174	61.5	10.5	325
C	SJ353164	57.5	3.6	250
E	SJ339185	57.5	8.5	325

Of the 21 survey dates, 13 were used for this study, shown in appendix 2. Coverage improved during 1982-1983 (Crosby 1983) when transects A and E were extended, methodology improved and labour ranged between 2-5 persons per survey (Crosby 1983). Surveyors recorded flooding extent *en route*, shown on maps and were qualitatively described and were shown on maps for three dates (Crosby 1983). Data for the three transects was summed (Crosby 1983), thus inter-transect comparability is not directly possible. Summed data for each "bird year" was shown on a map in the area of occurrence (Crosby 1983). Recorded species are shown in appendix 4.

In compliance with a recommendation of Tucker (1994), it was agreed to survey wintering waterbirds along the extended transects of 1982-1983 to obtain current data for assessment of the site's present value. A pilot survey was undertaken between January-March 1995 at approximately two weekly intervals.

During January-March 1995, 12 birdwatchers in five teams, with experienced team leaders, surveyed the transects. Transect commencement times were similar. The results were encouraging because: (i) during flood incidents the site held the greatest numbers of Eurasian wigeon Anas penelope, Eurasian teal Anas crecca and Northern pintail Anas acuta in the county and (ii) it was the only Shropshire site to have Tundra swan Cygnus columbianus and Whooper swan Cygnus cygnus during the period. In consequence, the second recommendation of Tucker (1994) was adopted, to undertake annual surveys.

To identify relationships between avian trend dynamics and environmental processes (James, McCulloch and Wiedenfeld 1996) the "longitudinal" monitoring strategy was chosen in preference to the classical control and experimental paradigm (Mac Nally 1997). The former method involved comparison of historical 1981-1983 dataset with WeBS dataset (Mac Nally 1997). Reasons for longitudinal method selection were: (i) there was minimal change in habitats; (ii) independent variables were separately measurable and (iii) the classical method was inappropriate due to the inability to manage environmental processes on experimental sub-sites, lack of suitable control sites and insufficient labour.

Methodology

Standard WeBS "look-see" methodology (Bibby, Burgess and Hill 1992; Greenwood and Baillie 1991) was used to minimize bias and attain constant precision and included: (i) sampling strategy to undertake surveys: (a) along three transects, A, C and E, shown in appendix 14, map 2; part lengths of transects, A and E, were severed where birds were few; (b) on WeBS prescribed dates, approximately monthly (Waters et al. 1996); (ii) uniform effort and coverage for survey durations (Buckland et al. 1993; Bibby, Burgess and Hill 1992; James, McCulloch and Wiedenfeld 1996); (iii) knowledge of species (Greenwood *in* Sutherland 1996); (iv) relatively constant inter-personnel skills (Thomas 1996); (v) teams of experienced observers surveying transects, usually during the morning. This minimized risk of double counting which was further reduced by recording directions and numbers of flying birds onto other transects. Hence numbers recorded were likely to be minima present for most species; maxima of rare species, particularly Whooper swan *Cygnus cygnus* were known from previous counts; thus transects were independent (Mac Nally 1997); (vi) surveyors' transects were rotated to minimize systematic error (Buckland et al. 1993); (vii) site knowledge; (viii) record of date, time, meteorological conditions, water stage height in relation to the river Severn bank top and extent of flooding (Bibby, Burgess and Hill 1992); (ix) during floods, surveys could only be conducted from accessible positions because most transects were impassable. Furthermore, there was the Health and Safety factor, namely the danger of a rapidly rising flood surrounding observers. (ix) Count data was entered onto data sets each month (Field and Gregory 1999) and at the end of each bird year a full data set was sent to surveyors and completed recording forms were sent to the Wildfowl and Wetlands Trust for entry into the national data set.

Table 2
Severn-Vyrnwy confluence site data of the 1995-2001 surveys

Transect	Central national grid reference	Altitude MAOD	Transect length km	Sub-site area, ha
A	SJ354170	58.5	7.5	225
C	SJ353164	57.5	3.6	250
E	SJ345178	56.5	2.5	125

Environmental processes

Daily temperature and wind force data was obtained from the Met Office, Shawbury, Shropshire. Water stage height data was obtained from the Environment Agency. The datasets are extensive and are obtainable from the author.

Water stage heights were only available for Montford Bridge, Grid reference SJ 41191445 for 1981-1983 (Environment Agency 2000), so the Crew Green water stage heights were computed by regression using Montford Bridge and Crew Green 1995 water stage heights as the independent variable and dependent variable respectively, as shown on graph 2 and the results are in table 3. The coefficient of determination showed that 98.9% of variation of a Crew Green value was attributable to the corresponding Montford Bridge value. The 1981-1983 Crew Green water stage heights were computed by applying the 1981-1983 Montford Bridge water stage heights to the following regression formula:

Crew Green water stage
height (m) = (slope x Montford Bridge water stage height) (m) + intercept

= (1.258 x Montford Bridge water stage height) (m) --0.694

Graph 2

Regression of water stage heights in metres at Crew Green and Montford Bridge 1995

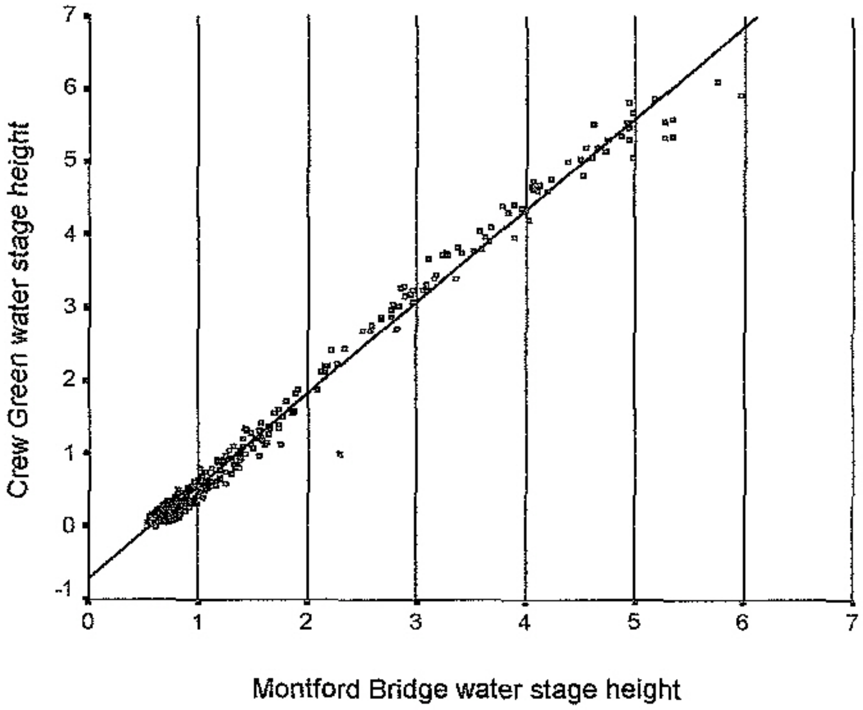


Table 3

Regression analysis results of Montford Bridge and Crew Green water stage heights 1995

AVOVA significance	Slope	Intercept	r^2	Hypothesis
<0.001	1.258	-0.694	0.989	H_1

The northern end of transect E was primarily affected by flood incidents from the river Vyrnwy. Flood incidents of both main rivers have closely related temporal scales (Ing and Pannat pers. comm. 2002). As the 1981-1983 surveys transect data was summed, it is not feasible to ascribe separately analysis avian and water stage height altitude classes to part of transect E.

Stage heights have been added to the datum of 54.0 MAOD, 0 m stage height, the sum being the altitude above national datum at Newlyn, Cornwall. To interpret seasonal population trends, water stage heights were divided into four altitude classes, shown on table 4 and in appendix 23, namely: (i) "below bank tops": of the river Severn and internal ditches; (ii) "internal low flood": over banks of internal ditches, shown in appendix 16, map 4; (iii) "medium flood": over internal ditch banks and the eastern banks of the river Severn, shown in appendix 17, map 5, and (iv) "high flood": over all banks of the river Severn. Altitude classes were highly variable and were amalgamated into two water stage height classifications: (a) below bank tops for the 3-day term per month and (b) one or more of the flood altitude classes over bank tops for all or part of the 3-day term per month.

Table 4

Water stage height altitude classes

Stage height class	Stage height level m	Stage height altitude m MAOD
Below bank tops	0 - 1.9	54 - 55.9
Internal low flood	2 - 3.9	56 - 57.9
Medium flood	4 - 4.9	58 - 58.9
High flood	5 and above	59 and above

Target Species

From recorded taxa, shown in appendices 4 and 5, eight target species of three functional guilds (Roshier, Robertson and Kingsford 2002), swans, dabbling ducks and waders, shown in table 5, were selected as being representative of wintering waterbirds of the Confluence (Brown, Mehlman and Stevens 1995) for reasons of migration, residents and feeding habits, including foraging depths and diet.

Table 5

Target waterbird species

English name	Latin name	Guild class
Mute Swan	*Cygnus olor*	swan
Whooper Swan	*Cygnus cygnus*	swan
Eurasian Wigeon	*Anas penelope*	dabbling duck
Common Teal	*Anas crecca*	dabbling duck
Mallard	*Anas platyrhynchos*	dabbling duck
Northern Pintail	*Anas acuta*	dabbling duck
Northern Lapwing	*Vanellus vanellus*	wader
Eurasian Curlew	*Numenius arquata*	wader

Data properties

To achieve the objectives, a prerequisite was the acquisition of good quality data possessing three attributes. (1) conformity: the dependent variable must be free from contamination from confounding variables (Pallant 2001). (2) reliability: attained by compliance with WeBS methodology attested by empirical evidence on the time series graphs when similar numbers of the same species under similar environmental conditions were recorded, thus the probability of random error was minimized (Pallant 2001). (3) validity, of three types: (a) "content validity": transect lengths were of a scale to be representative of the sampling universe (James, McCulloch and Wiedenfeld 1996). (b) "criterion validity": the quantum of the dependent variable was representative of the independent variables. (c) "construct validity": the relationship between the dependent and the independent variables to facilitate examination of the hypothesis (Pallant 2001). The 1982-1983 survey indicated compliance with this protocol, which was tested by a pilot survey for WeBS (Bibby, Burgess and Hill 1992).

Statistical analysis

Statistical analysis was undertaken in three parts:

(1) preparation of target species 1981-1983 survey, WeBS transect C datasets and running medians were computed and joined on species time plots to determine population trends (Green *in* Maddy and Brew 1995): (i) annually; the respective datasets are shown in appendices 6 and 7. (ii) seasonally; the respective datasets are shown in appendices 8 and 9.

(iii) 1981-1983 and WeBS datasets of seasonal environmental processes were prepared by computation of running medians for: (a) 11-day term per month temperature trends; (b) 4-day term per month wind force trends and (c) 3-day term per month water stage height trends. Numbers of days term trend per month comprised days prior to and including the survey date. Due to relative high mobility of birds, the various temporal response scales were judged appropriate to quantitatively compare classifications of environmental processes with species abundance classes.

(2) time series analysis of: (i) annual population trends (Mac Nally 1997) were assessed from time plots as increasing, decreasing or stationary and cycles were identified (Diggle 1992). The inter-survey period was assessed by comparison of the trends and data for 1983 and 1995 (Mac Nally 1997). (ii) site annual population trends were compared to national population trends to assess the net magnitude of population variation (Mac Nally 1997). (iii) site seasonal population trends were compared to national population trends to assess the net magnitude of population variation (Mac Nally 1997). (iv) comparison of species population seasonal trends with the day term per *month trends of environmental* processes to identify the degree of trends correspondence and association (Mac Nally 1997).

Running medians for each month were subtracted from raw datasets of species seasonal populations and day term per month trend of environmental processes to de-trend the datasets, the differences being deviations from the *medians, residuals (Green in Maddy and Brew 1995) which were used to* compute the association between each species and each environmental process. Values surrounding running medians were noise and obscured the *trend (Diggle 1992). Skewness properties of species trends are described.*

Linear regression

(3) The hypotheses were statistically tested by linear regression. Residuals of each environmental process day term per month trend were the independent variable and species residuals were the dependent variable. The alpha level *of significance was $P<0.05$ for rejection of the null hypothesis in favour of the* alternative hypothesis (Greenwood and Baillie 1991); conversely, when $P>0.05$ the null hypothesis was not rejected in favour of the alternative *hypothesis (Mac Nally 1997). When the probability was marginally greater* than 5%, just insignificant, regression was re-tested after removal of any atypical outlier due to sensitivity of regression to outliers (Pallant 2000).

Chapter 5

Time series analysis of species seasonal population trends and European mean temperature trends 1981-1983 and Wetland Bird Survey

The purpose of time series analysis of species seasonal population trends and European mean temperature trends is to detect: (i) associations between species seasonal population dynamics on the Confluence and on transect C and European temperatures during the summer-autumn migration to the UK and (ii) noise. Temperature is considered to be the main environmental factor of influence due to its affect on species physiological conditions and food supplies (Elkins 1988; Sparks in Sparks et al. 2002). During the winter all migrants' breeding and summering habitats are frozen and are inhospitable.

Mean maximum and minimum monthly temperatures for August-January were used as recorded by European meteorological stations at De Bilt, Holland, Oslo, Norway and Reykjavik, Iceland, which are near species main migration departure locations to the UK (Wernham et al. 2002). From temperature datasets of 1981-1983 and WeBS, shown in appendices 10 and 11 respectively, monthly medians were computed to determine European stations' temperature trends, which were compared to Confluence, transect C and UK species seasonal population trends to identify associations. Migration periods were interspecifically variable (Bairlein, Elkins and Evans *in* Wernham et al. 2002).

European Temperatures

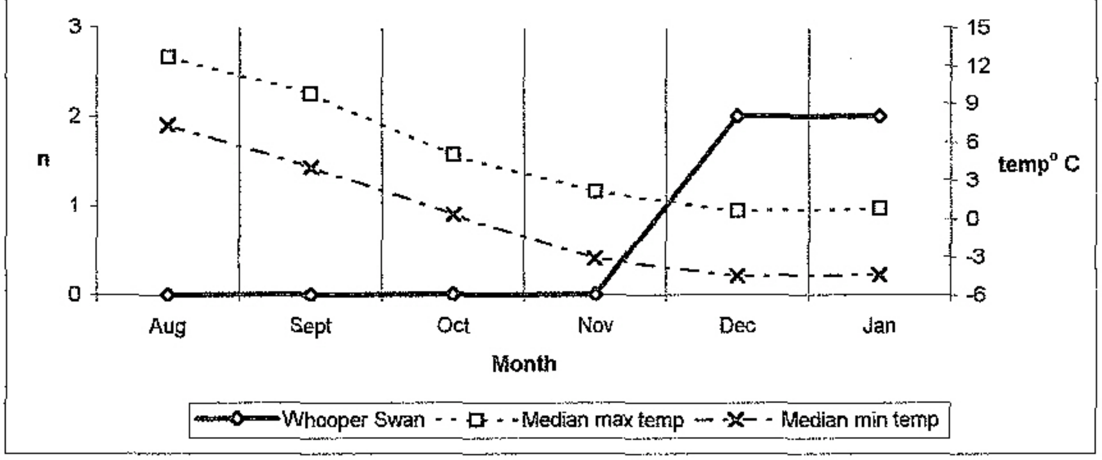
1981-1983 and WeBS August-January mean maximum and mean minimum temperature trends were broadly parallel and declined seasonally, as shown on the species account graphs. Minimum temperature trends are stated in species accounts due to their migration stimulus (Sparks in Sparks et al. 2002). For ease of presentation, WeBS European temperature tables are in appendix 12 tables series A, and the following footnote is applicable to 1981-1983 species seasonal population and temperature tables:

a: above trend b: sub-trend

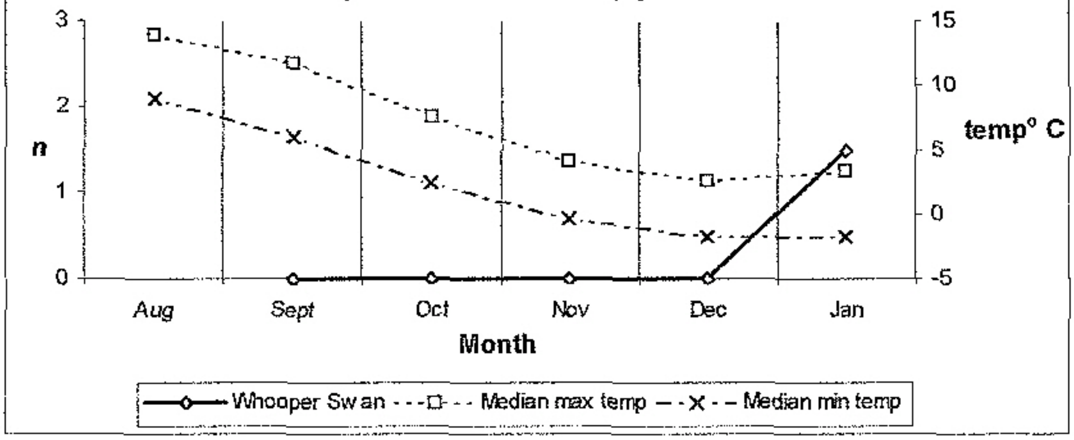
Whooper Swan *Cygnus cygnus*

The Whooper swan migrates from Iceland during September-October to the UK (Rees et al. *in* Wernham et al. 2002), mainly down to the Dee Estuary-Wash line (Merne *in* Lack, Lack and Spencer 1986). During 1981-1983 and WeBS, Reykjavik September-October temperature trends declined 3.7° C and 3.6° C respectively and Confluence population trends increased to 2 and *transect C to 1.5 over* November-January and December-January respectively, shown on graphs 3 and 4 respectively. Thus delayed inverse population-temperature associations existed. Confluence arrivals were *outside the migration period, thus outliers did not further elucidate association* formation.

Graph 3
Whooper swan Confluence seasonal population trend and mean temperature trends at Reykjavik, Iceland 1981-1983

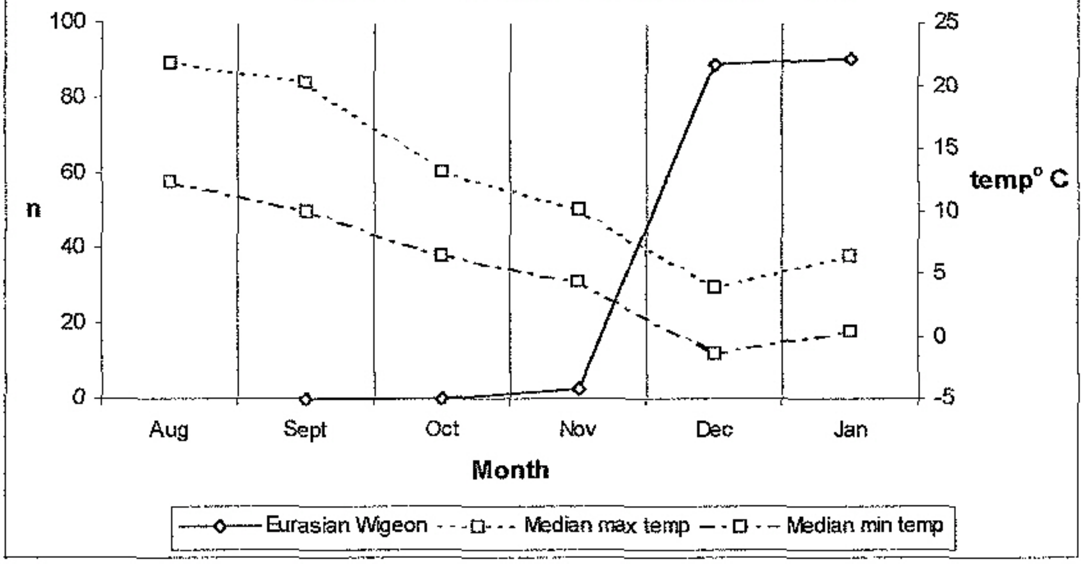


Graph 4
Whooper Swan transect C seasonal population trend and mean *temperature trends at Reykjavik WeBS*

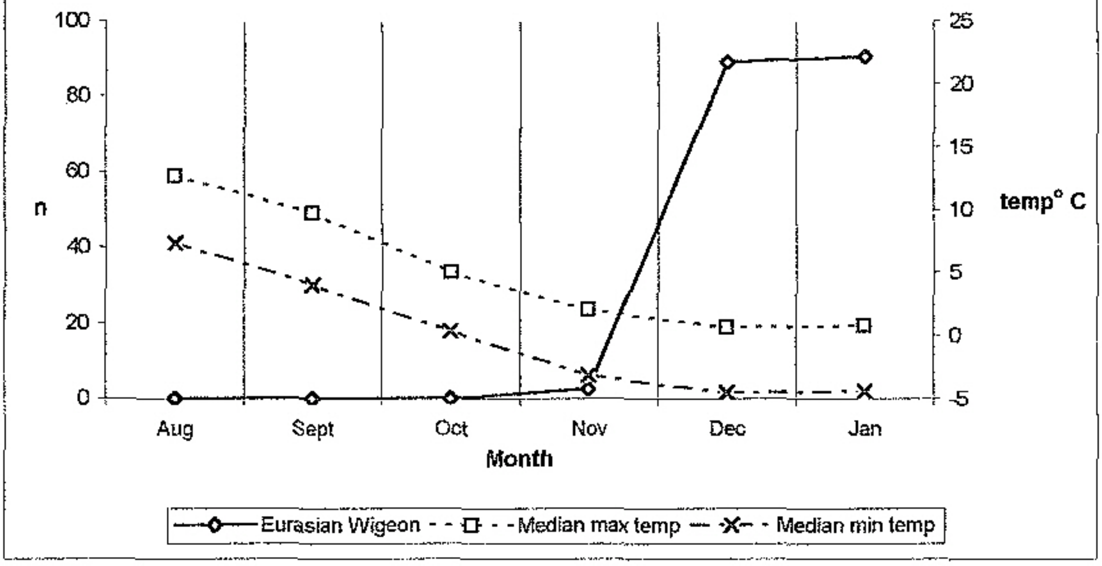


Eurasian Wigeon *Anas penelope*

Eurasian wigeon migrate from northern Europe and Iceland during September-November (Mitchell *in* Wernham et al. 2002). 1981-1983 August-November temperature trends declined 8.1 C ° and 10.5 C ° at De Bilt and Reykjavik respectively and Confluence population trend increased to 90.5 over October-January, shown in graphs 5 and 6.



Graph 5
Eurasian Wigeon Confluence seasonal population trend and mean temperature trends at De Bilt, Holland 1981-1983



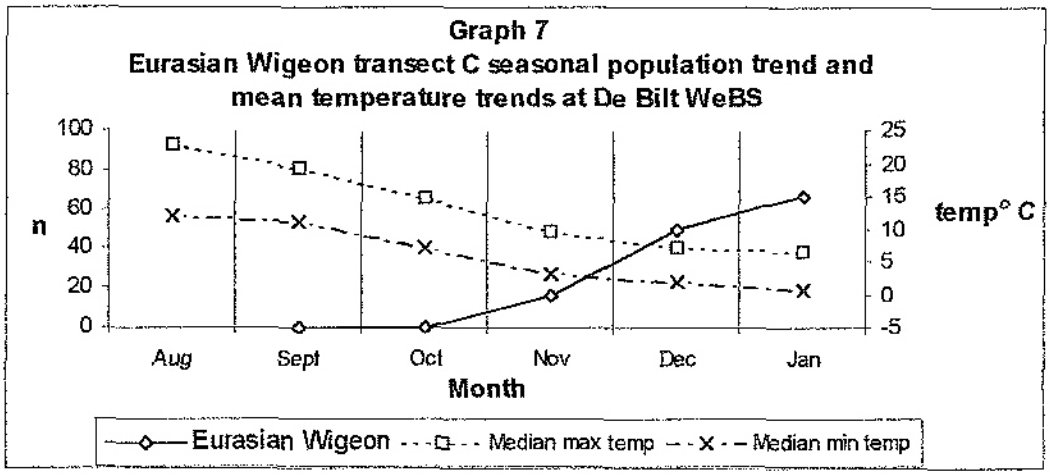
Graph 6
Eurasian Wigeon Confluence seasonal population trend and mean temperature trends at Reykjavik, Iceland 1981-1983

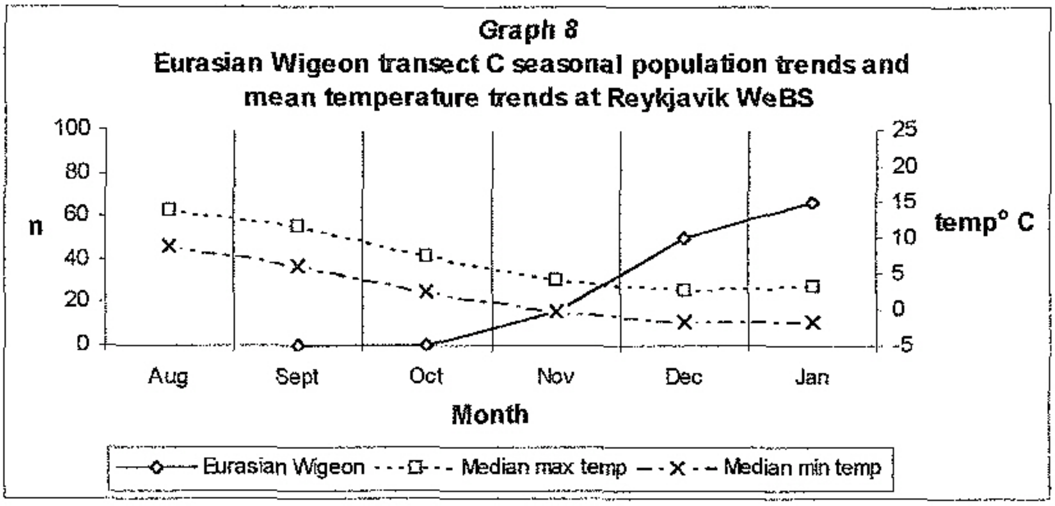
Outliers corresponded in November-January, shown on table 6; the population rose as temperatures declined, notably over November-December.

Table 6
Corresponding outliers of Eurasian Wigeon and mean minimum temperatures Celsius at De Bilt, Holland 1981-1983

Month	Eurasian Wigeon numbers			Temperature C °		
	1981	1982	1983	1981	1982	1983
November	0 b	5 a	_	3.2	5.4	_
December	55 b	123 a	_	-3.4	0.7	_
January	_	60 b	121 a	-	-2.4	3.2

WeBS August-November temperature trends declined 8.8 C ° and 9.25 C ° at De Bilt and Reykjavik respectively and transect C population trend increased to 66.5 over November-January, shown in graphs 7 and 8 for the corresponding stations.





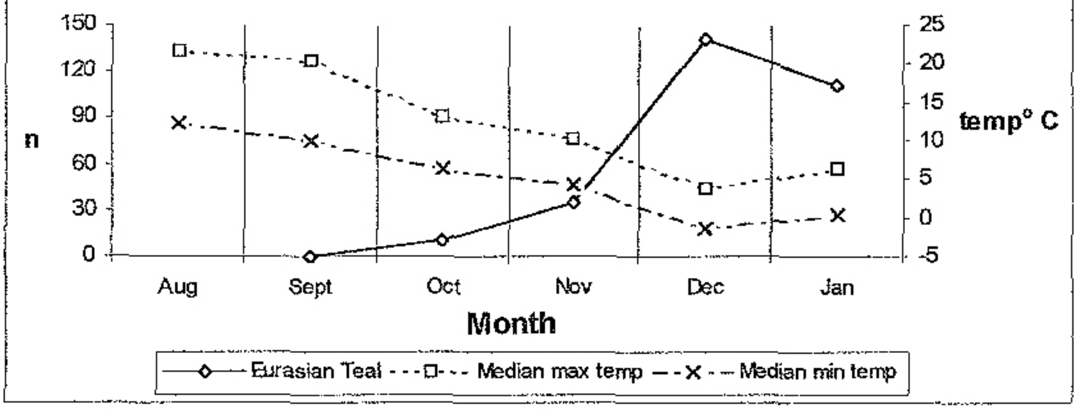
November-January above trend corresponding outliers demonstrated greater populations were associated with higher temperatures, exceptions were reverse corresponding outliers, for example January 1995, shown in tables 1A *and 2A respectively.* Delayed inverse larger population-higher temperature decline associations existed.

Eurasian Teal Anas crecca

Eurasian teal migrate from northern Europe and Iceland during July-November (Ogilvie *in* Wernham et al. 2002). 1981-1983 August-November *temperature trends diminished 8.1° and 10.5° C at De Bilt and Reykjavik* respectively while Confluence population trend increased to 141 over October-December, shown in corresponding graphs 9 and 10

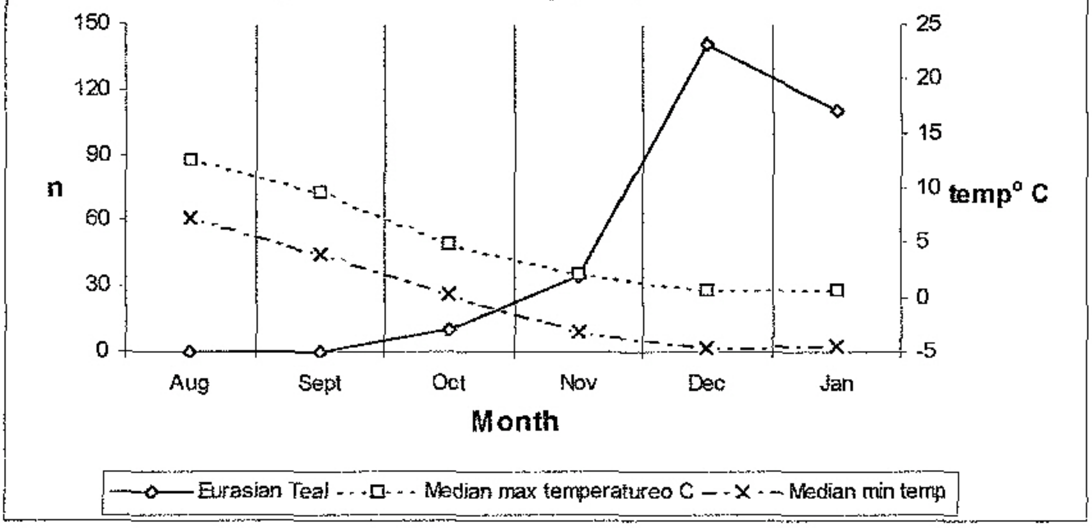
Graph 9

Eurasian Teal Confluence seasonal population trend and mean temperature trends at De Bilt, Holland 1981-1983



Graph 10

Eurasian Teal Confluence seasonal population trend and mean temperature trends at Reykjavik, Iceland 1981-1983



Corresponding outliers occurred during October-January, shown on table 7.

Table 7

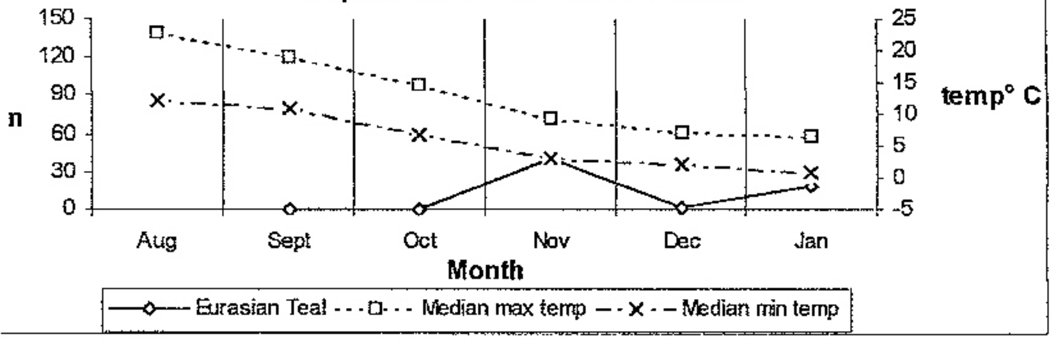
Corresponding outliers of Eurasian teal and mean minimum temperatures Celsius at De Bilt, Holland 1981-1983

Month	Eurasian Teal numbers			Temperature C °		
	1981	1982	1983	1981	1982	1983
October	1 b	19 a	_	4.8 b	7.9 a	_
November	4 b	65 a	_	3.2 b	5.4 a	_
December	54 b	228 a	_	-3.4 b	0.7 a	_
January	_	15 b	207 a	_	-2.4 b	3.2 a

During WeBS as August-November temperature trend declined 8.8° and 9.25°C at De Bilt and Reykjavik respectively and transect C population trend increased to 40 over October-November, shown in corresponding graphs 11 and 12.

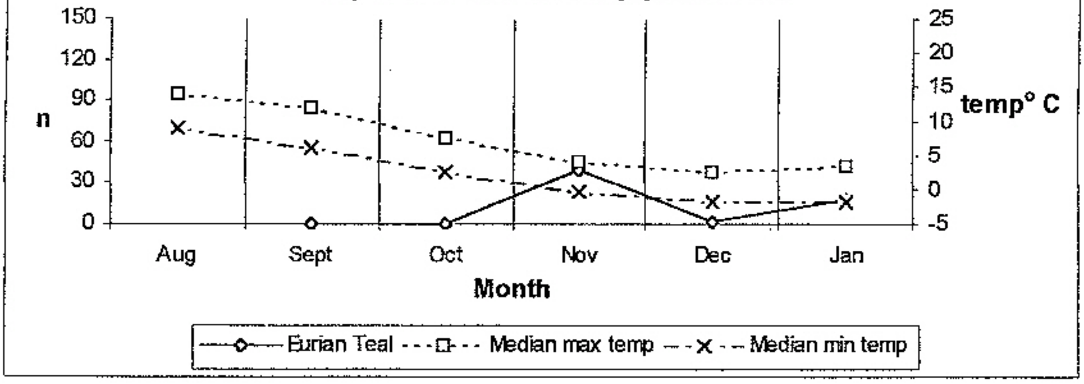
Graph 11

Eurasian Teal transect C seasonal population trend and mean temperature trends at De Bilt WeBS



Graph 12

Eurasian Teal transect C seasonal population trend and mean temperature trends at Reykjavik WeBS

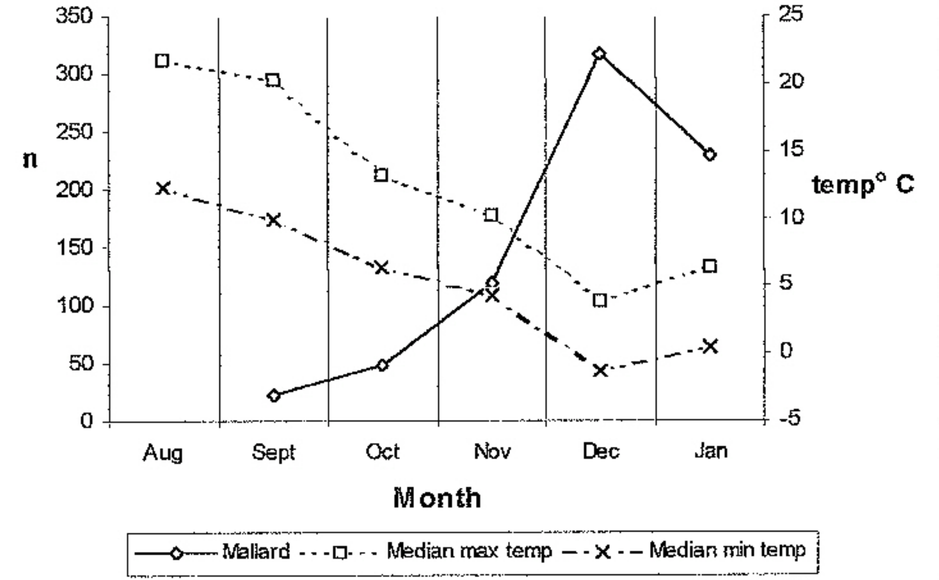


Above trend corresponding outliers revealed that greater numbers occurred over October-January, shown on table 3A but exceptions were reverse corresponding outliers were at lower temperatures, for example November 1999 and January 1995, shown in table 4A. Delayed inverse population-temperature associations existed.

Mallard ***Anas platyrhynchos***

Mallard migrate from north and east Europe to south and west Europe during autumn (Mitchell, King and Cook *in* Wernham et al. 2002). August-December temperature trend diminished 10° C at De Bilt and Confluence population trend numbers increased to 317.5 during September-December and overall rose to January, shown in graph 13.

Graph 13
Mallard Confluence seasonal population trend and mean temperature trends at De Bilt, Holland 1981-1983



Corresponding outliers occurred in December and January, shown in table 8; contrastingly sub-trend reverse corresponding population outliers occurred at higher temperatures, shown in table 9.

Table 8

Corresponding outliers of Mallard and mean minimum temperatures at De Bilt, Holland 1981-1983

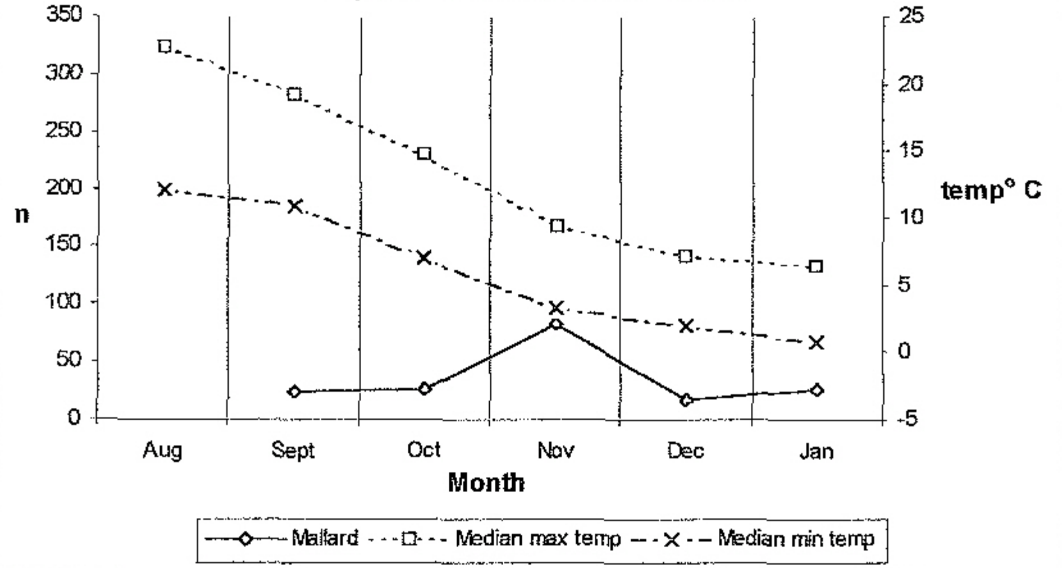
Month	*Mallard Teal numbers*			*Temperature C °*		
	1981	1982	1983	1981	1982	1983
December	229 b	406 a	–	-3.4 b	0.7 a	
January	–	37 b	420 a	–	-2.4 b	3.2 a

Table 9

Reverse corresponding outliers of Mallard and mean minimum temperatures at De Bilt, Holland 1981-1983

Month	Mallard numbers			Temperature C °		
	1981	1982	1983	1981	1982	1983
September	23 m	–	–	9.7 b	–	–
October	51 a	44 b	–	4.8 b	7.9 a	–
November	128 a	109 b	–	3.2 b	5.4 a	–

During WeBS August-December temperatures decreased 10° C at De Bilt and transect C population trend increased to 84 over September-November, shown in graph 14.

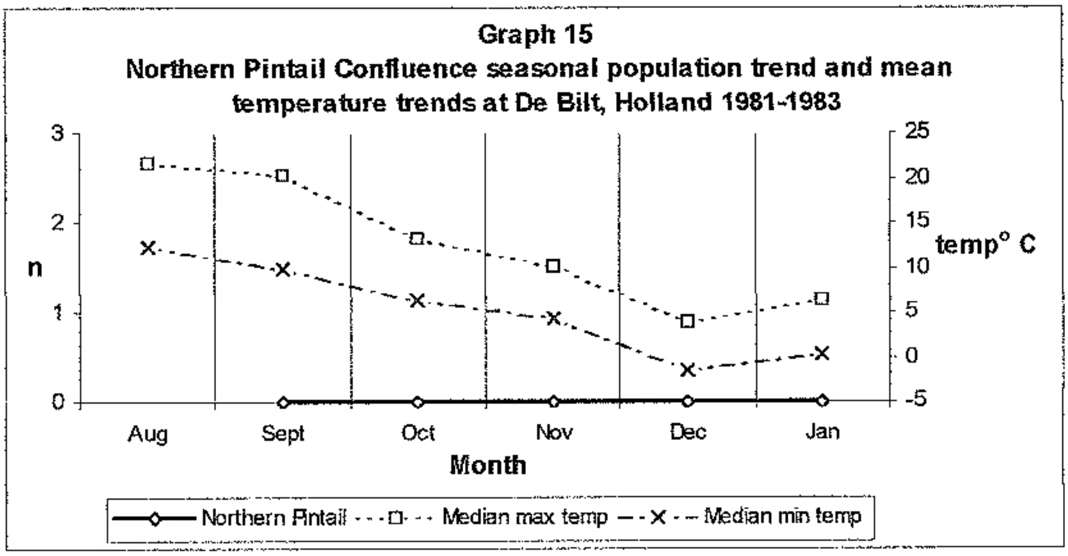


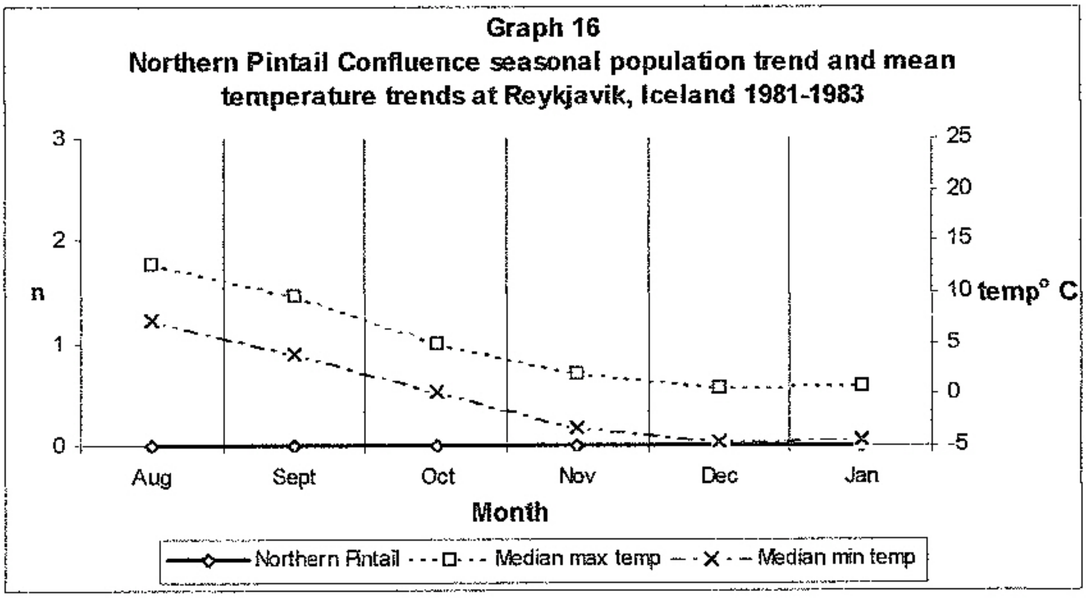
Graph 14
Mallard transect C seasonal population trend and mean temperature trends at De Bilt WeBS

Above trend corresponding outliers occurred during September-January, shown on table 5A, but exceptions were reverse corresponding outliers, for example November 1998, table 6A. Delayed inverse population-temperature decline associations existed.

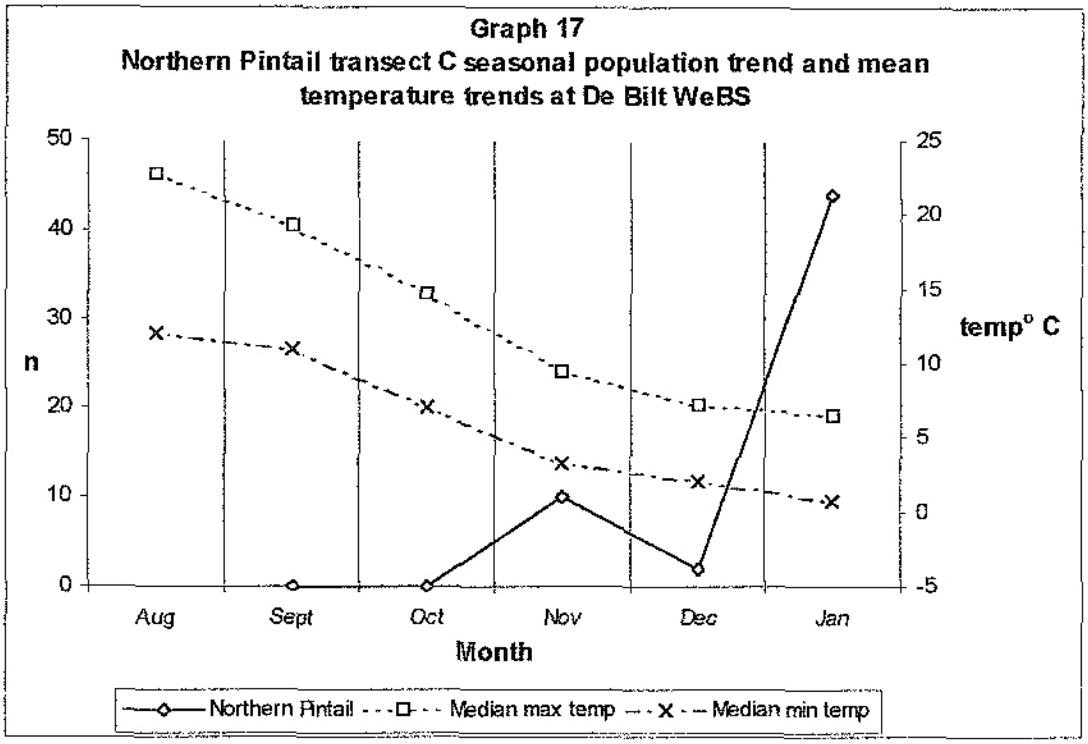
Northern Pintail *Anas acuta*

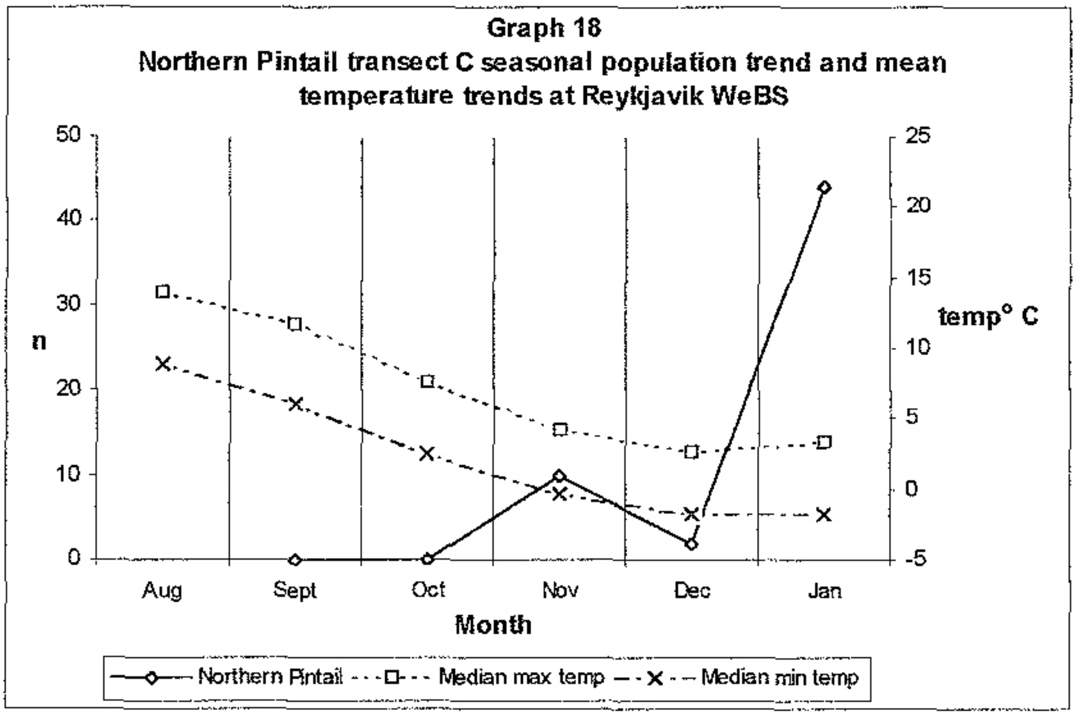
Northern pintail migrate from Scandinavia, Russia and Iceland during September-November (Ogilvie *in* Wernham et al. 2002). 1981-1983 August-November temperature trends declined 8.1° and 10.5° C at de Bilt and Reykjavik respectively and Confluence population trend remained stationary zero over September-January, shown in graphs 15 and 16.


Graph 15
Northern Pintail Confluence seasonal population trend and mean temperature trends at De Bilt, Holland 1981-1983


Graph 16
Northern Pintail Confluence seasonal population trend and mean temperature trends at Reykjavik, Iceland 1981-1983

During WeBS August-November temperature trend declined 8.1° and 9.25° C at De Bilt and Reykjavik respectively and transect C population trend rose to 10, shown in graphs 17 and 18.



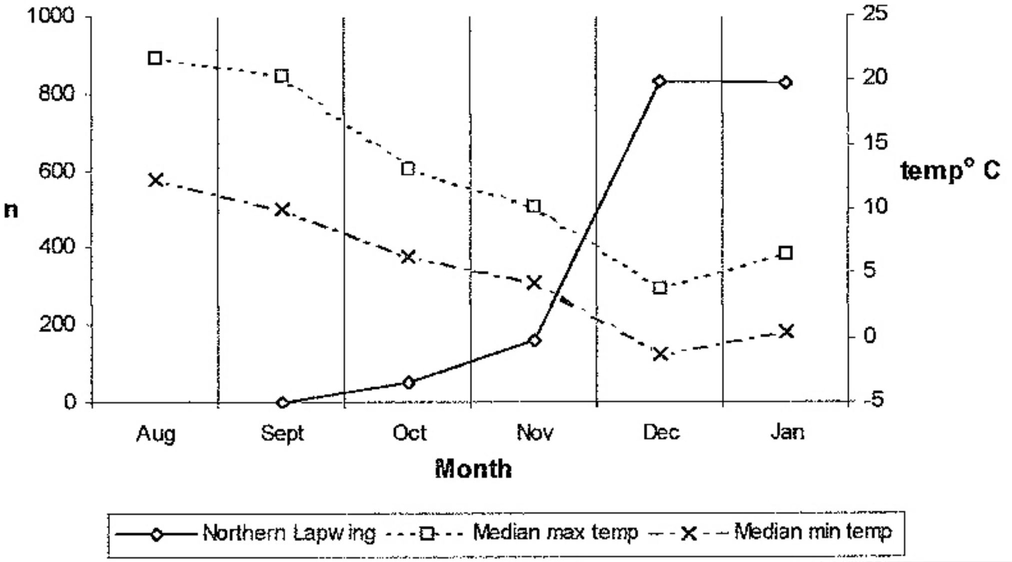


Above trend corresponding outliers occurred during October-January, shown on table 7A, were higher than those of reverse correspondence with notable exceptions of November and December 1997, shown on table 8A. During 1981-1983, due to absence, there was no association; over WeBS an inverse population-temperature association existed.

Northern Lapwing *Vanellus vanellus*

Northern lapwing migrate from western Europe during September-November (Appleton *in* Wernham 2002). 1981-1983 De Bilt August-November temperature trend diminished 8.1° C and Confluence population trend increased to 829 over September-December, shown in graph 19.

Graph 19
Northern Lapwing Confluence seasonal population trend and mean temperature trends at De Bilt, Holland 1981-1983



Above trend corresponding outlier of December, table 10, were higher than those of reverse correspondence, table 11.

Table 10

Corresponding outliers of Northern Lapwing and mean minimum temperatures Celsius at De Bilt, Holland 1981-1983

Month	Northern Lapwing numbers			Temperature C °		
	1981	1982	1983	1981	1982	1983
December	200 b	1458 a	–	0.6 b	4.6 a	–

Table 11

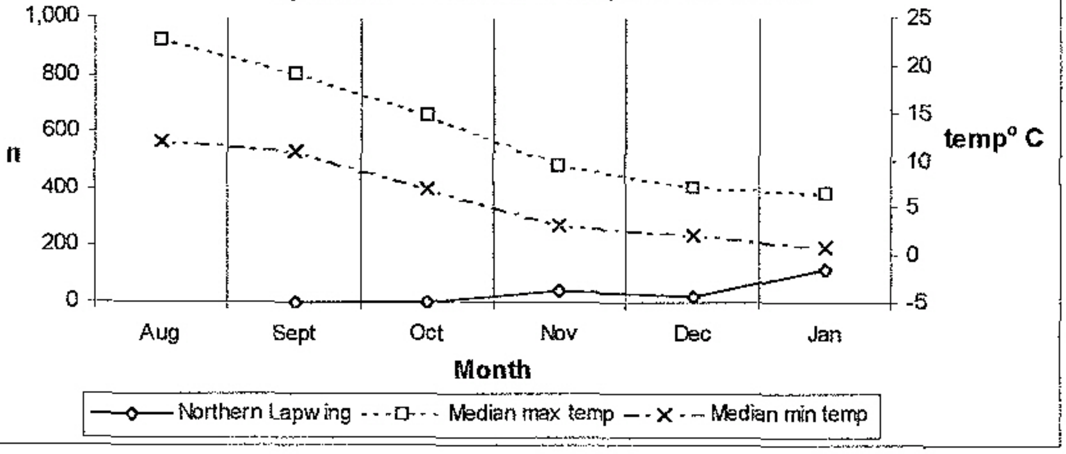
Reverse corresponding outliers of Northern Lapwing and mean minimum temperatures Celsius at De Bilt, Holland 1981-1983

Month	Northern Lapwing numbers			Temperature C °		
	1981	1982	1983	1981	1982	1983
October	73 a	32 b	–	-2 b	2.6 a	–
November	150 b	167 a	–	-3 a	-3.3 b	–
January	–	693 b	1458 a	_ -4 a	-4.9 b	

During WeBS De Bilt August-November temperature trends decreased 8.8° C and lapwing overall population trend increased to 40 during September-November and the September-January trend dynamically increased to 116, shown in graphs 20 and 21.

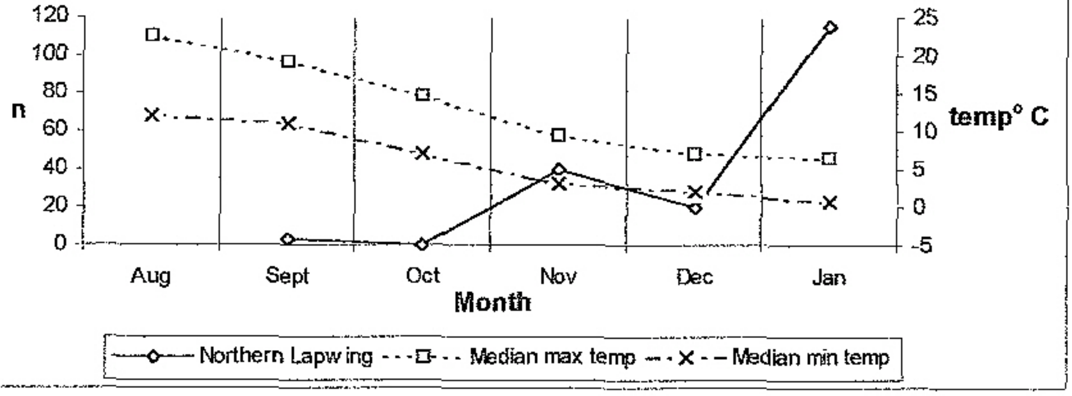
Graph 20

Northern Lapwing transect C seasonal population trend and mean temperature trends at De Bilt, Holland WeBS



Graph 21

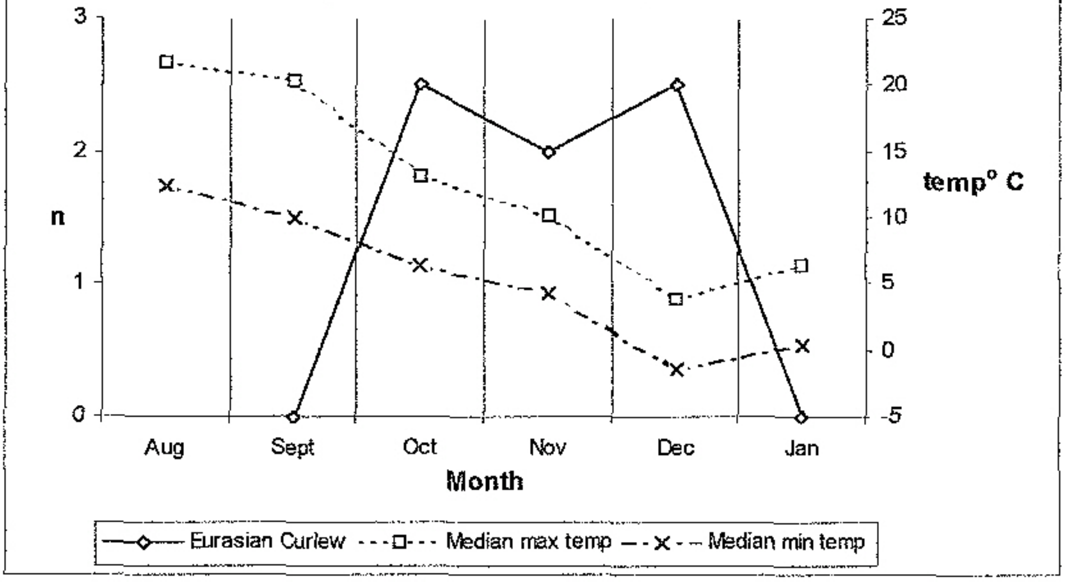
Northern Lapwing transect C seasonal population trend and mean temperature trends at De Bilt, Holland WeBS



Above trend corresponding outliers' temperatures of October-January were higher compared to sub-trend outliers, except September 1999, shown on table 9A, and those of reverse correspondence, except September 2000, shown on table 10A. Delayed inverse population-temperature associations existed.

Eurasian Curlew Numenius arquata

Eurasian curlew migrate from northern Europe during July-September (Bainbridge *in* Wernham et al. 2002). 1981-1983 De Bilt August-October *temperature trend declined* 6° C *and Confluence population rose to 2.5 over* September-October, shown on graph 22.



Graph 22
Eurasian Curlew Confluence seasonal population trend and mean temperature trends at De Bilt, Holland 1981-1983

Above trend corresponding outliers' temperatures of October-December, shown on table 12, were higher than those of reverse correspondence sub-trend temperatures, except for example September 1981, shown on table 13.

Table 12

Corresponding outliers of Eurasian Curlew and minimum temperatures Celsius at De Bilt 1981-1983

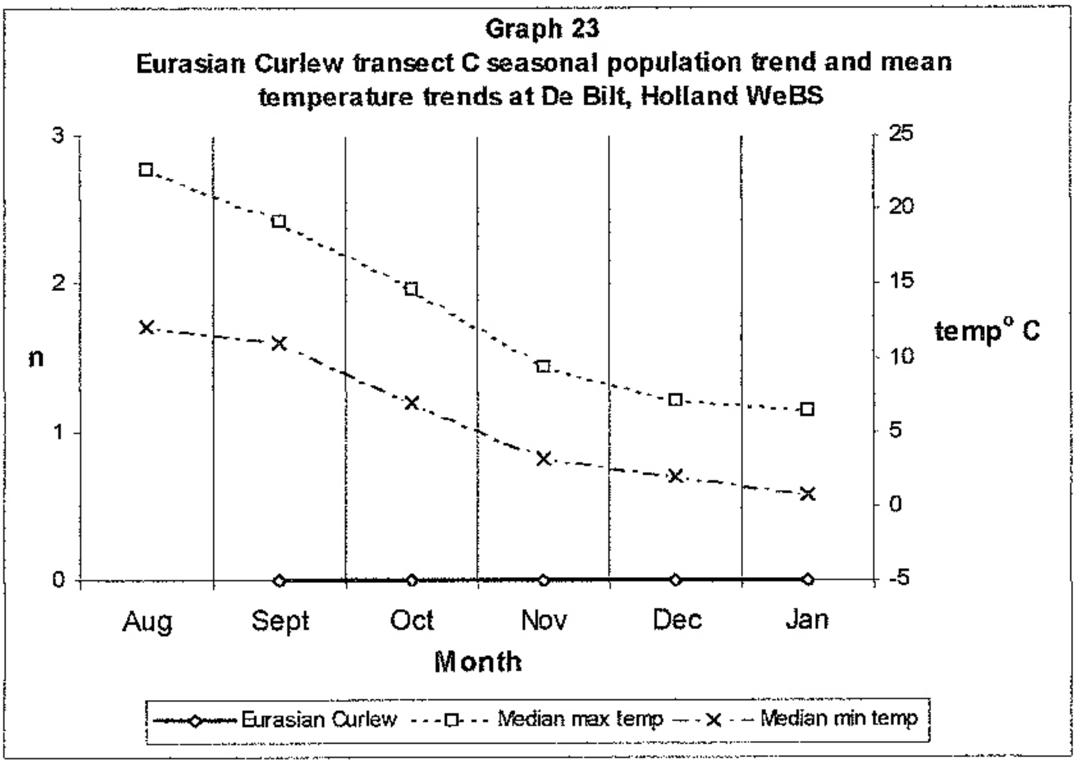
Month	Eurasian Curlew numbers			Temperature C °		
	1981	1982	1983	1981	1982	1983
October	0 b	5 a	_	4.8 b	7.9 a	_
November	0 b	4 a	_	3.2 b	5.4 a	_
December	0 b	5 a	_	-3.4 b	0.7 a	_

Table 13

Reverse corresponding outliers of Eurasian Curlew and minimum temperatures Celsius at De Bilt 1981-1983

Month	Eurasian Curlew populations			Temperature C °		
	1981	1982	1983	1981	1982	1983
September	0 m	_	_	9.7 b	_	—
January	_	0 m	0 m	_	-2.4 b	3.2 a

During WeBS August-October De Bilt temperature trend declined 5.05° C and the population trend remained stationary zero, shown in graph 23.



The species single above trend outlier, October 1999, in the migration period of influence was in reverse correspondence to temperature, shown on table 11A. The only above trend outlier in reverse correspondence was in January 1996, outside the period of influence, shown on table 12A.

1981-1983 delayed inverse population-temperature decline association existed. There was no association during WeBS. Due to the high proportion of zeros over September-January, interpretation must be cautious.

Summary

Table 14

Summary of species increases during summer-autumn migration periods 1981-1983 and WeBS

Species	1981-1983		WeBS	
	UK population trend fold increase	Confluence population trend fold increase	UK population trend fold increase	Transect C population trend fold increase
Whooper Swan	92.8	2	81.6	1.5
Eurasian Wigeon	7.9 7.9	90.5 90.5	5.46 5.46	16 16
Eurasian Teal	2.41 2.41	141 141	2.1 2.1	40 40
Mallard	1.11	13.8	1.21	3.5
Northern Pintail	42.5 42.5	0 0	3.54 3.54	10 10
Northern Lapwing	1.05 to February peak data December-February only	829 to December peak	3.68	38.7
Eurasian Curlew	1.25 to February peak data December-February only	1.8 February peak	September peak	0

In summary: (i) delayed inverse species populations-temperature associations existed during the surveys with exceptions during 1981-1983 for Northern pintail and WeBS for Eurasian curlew; (ii) UK and local fold increases were computed for the same months, except lapwing and curlew UK trends are based on December-February restricted data, and are presented in table 14 and were similar for Eurasian wigeon, mallard and Northern pintail and (iii) species UK and local dissimilar trends folds were attributable to different representations in geographical distributions.

Chapter 6
Statistical analysis of species seasonal population residuals and European mean minimum temperature residuals per month

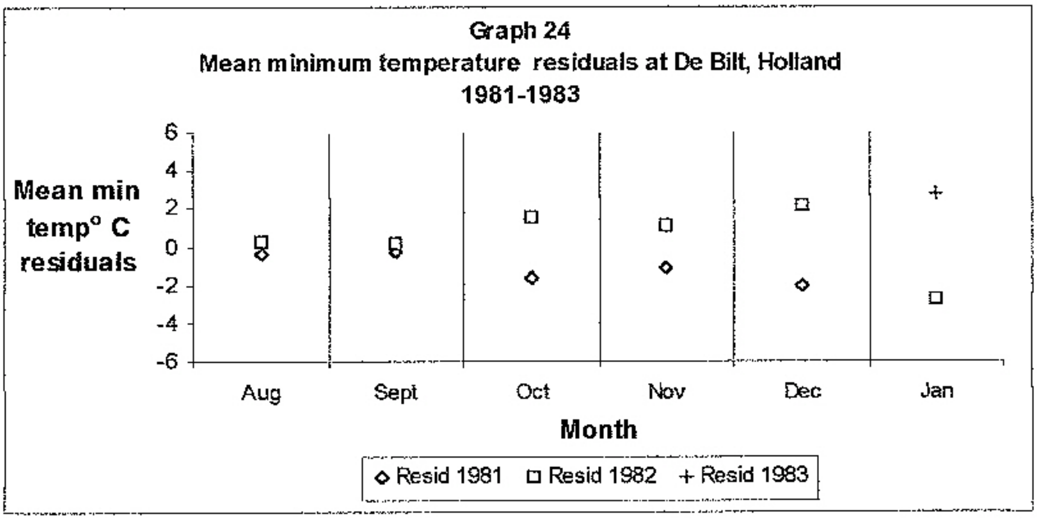
The target species, except resident Mute swan, emigrate from Europe to the UK to avoid winter starvation (Bairlein, Elkins and Evans *in* Wernham et al. 2002). Most species emigrate during August-October but departure dates vary interspecifically (Bairlein, Elkins and Evans *in* Wernham et al. 2002). The considered causal factor of departure is declining temperature (Bairlein, Elkins and Evans *in* Wernham et al. 2002). Mean minimum temperatures per month August-January from three European meteorological stations were used for regression computations.

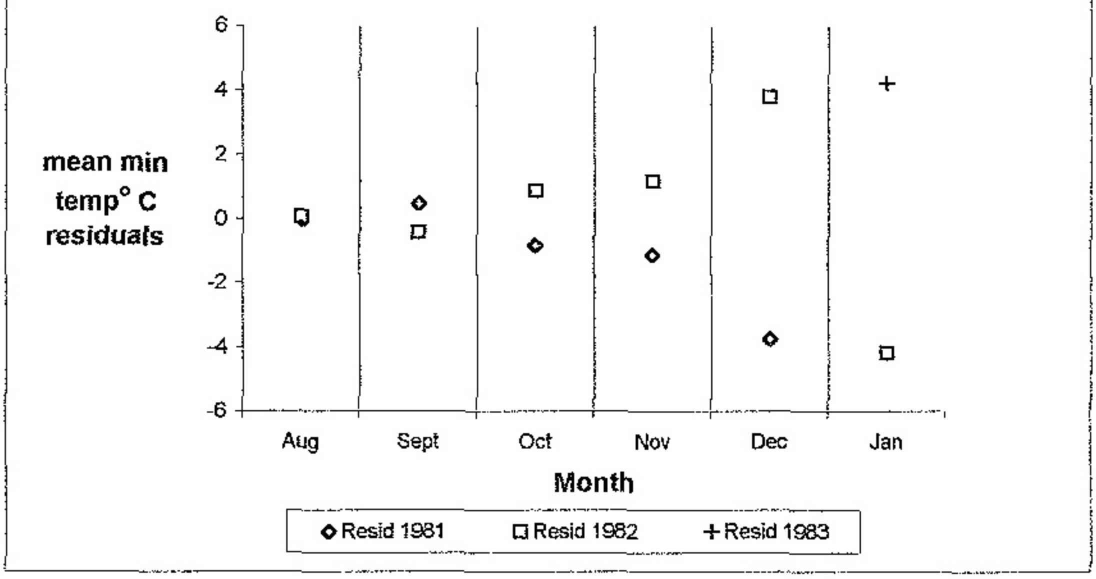
Hypothesis

The null hypotheses: if, on the sites, waterbird abundances were not less due to declining European temperatures, then the null hypothesis was not rejected in favour of the alternative hypothesis. The alternative hypothesis: if, on the sites, waterbird abundances were greater due to diminishing European temperatures, then the null hypothesis was rejected in favour of the alternative hypothesis.

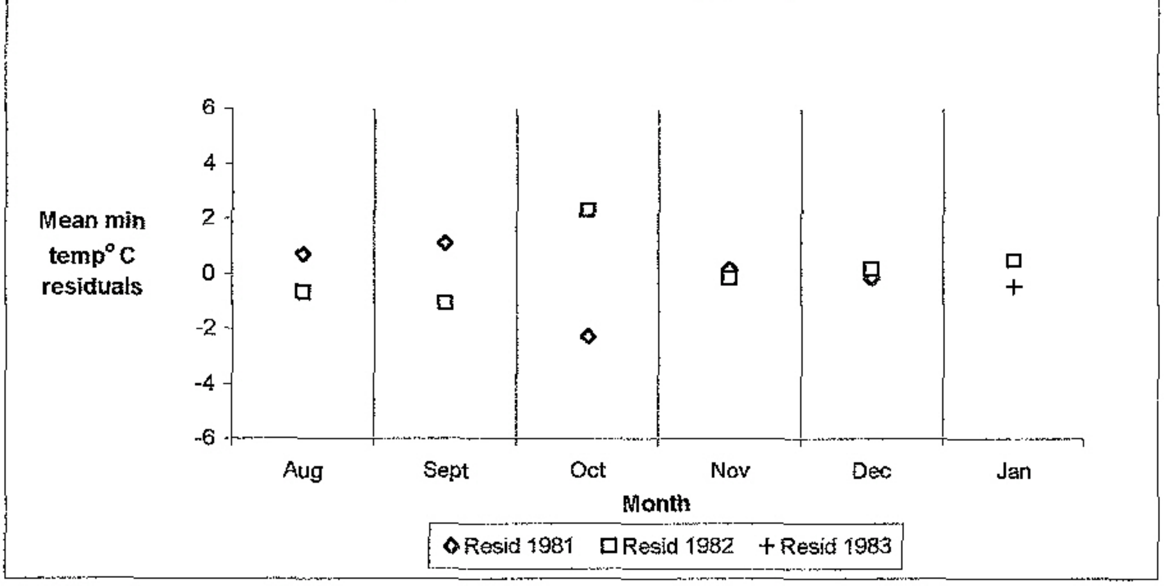
European temperature residuals

August-January temperature residuals for 1981-1983 in appendix 10 and in graphs 24, 25 and 26 and for WeBS in appendix 11 in graphs 27, 28 and 29 correspondingly at De Bilt, Holland, Oslo, Norway and Reykjavik, Iceland.





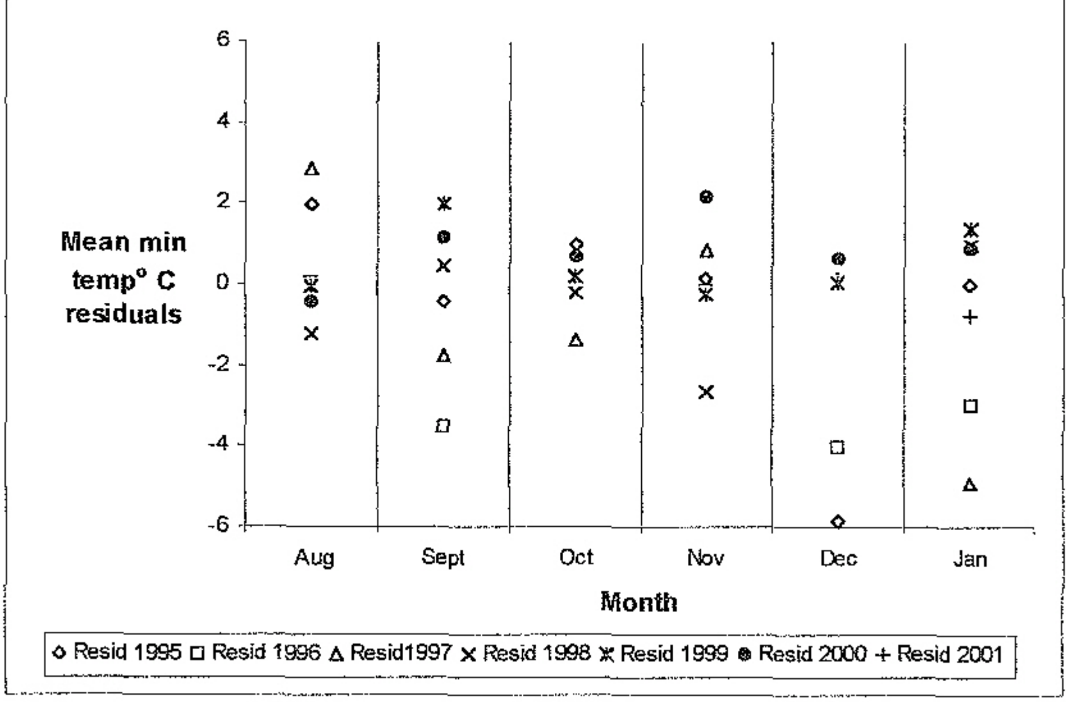
Graph 25
Mean minimum temperature residuals at Oslo, Norway 1981-1983



Graph 26
Mean minimum temperature residuals at Reykjavik, Iceland 1981-1983

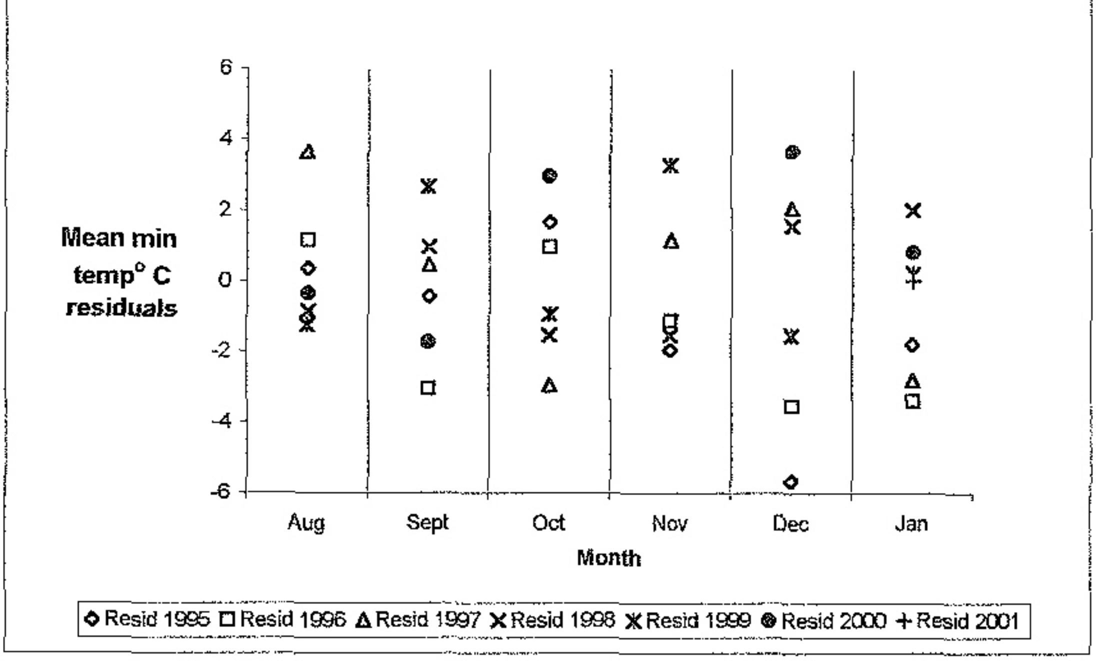
Graph 27

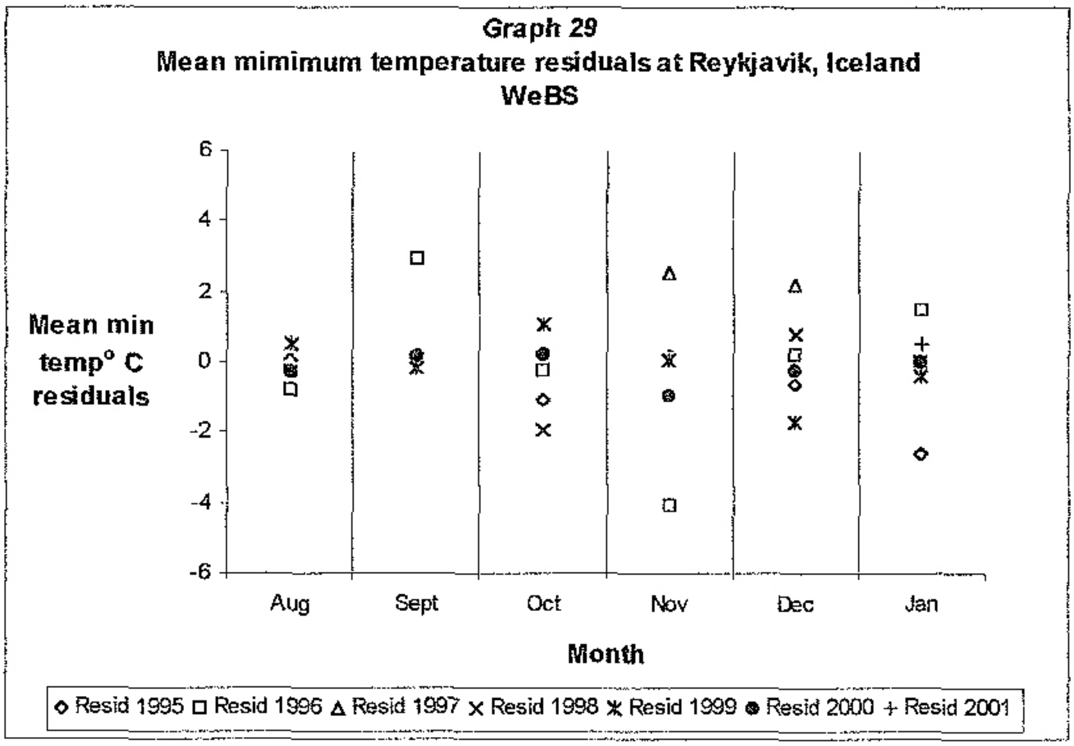
Mean minimum temperatures per month at De Bilt, Holland WeBS



Graph 28

Mean minimum temperature residuals at Oslo, Norway WeBS





Species accounts

Species European migration departure locations at the nearest three meteorological stations are shown in table 15.

Table 15

Species- European meteorological station migration departure locations

Species	Meteorological Station		
	De Bilt	Oslo	Reykjavik
Whooper Swan	N	N	Y
Eurasian Wigeon	Y	N	Y
Eurasian Teal	Y	N	Y
Mallard	Y	N	N
Northern Pintail	Y	N	Y
Northern Lapwing	Y	N	N
Eurasian Curlew	Y	Y	N

Migration departure location N: no; Y: yes

For both surveys the ANOVA probability was non-significant (P> 0.05), thus the null hypothesis was not rejected, with the following De Bilt exceptions:

Eurasian Wigeon *Anas penelope*

1981-1983 survey regression is shown in graph 30. ANOVA probability was highly significant ($P< 0.01$) and the intercept was non-significant ($P> 0.05$), shown in table 16. The null hypothesis was rejected in favour of the alternative hypothesis.

Graph 30

Regression of European Wigeon residuals and mean minimum temperature residuals per month at De Bilt, Holland 1981-1983

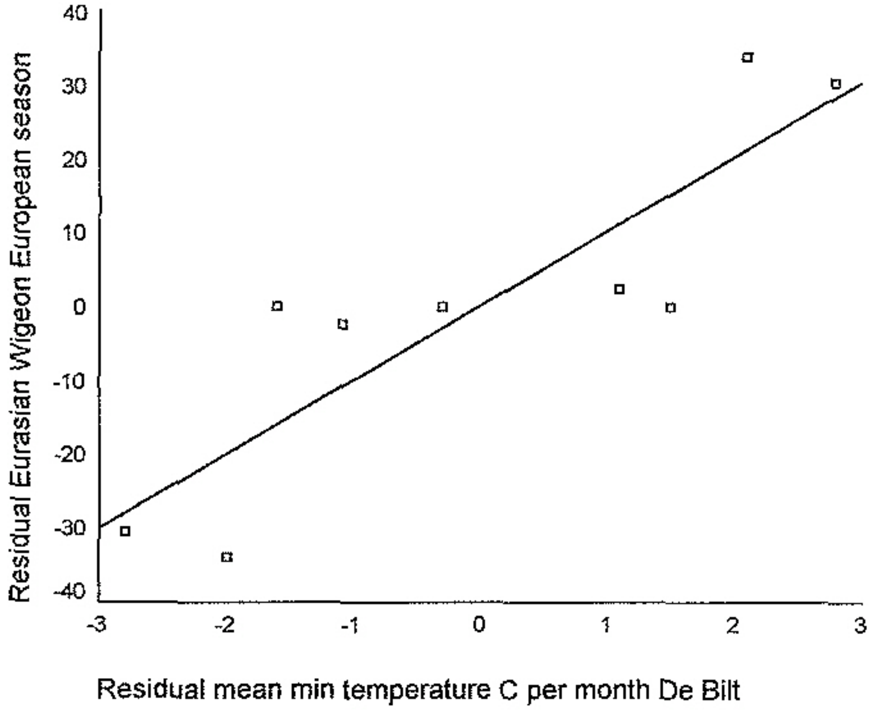


Table 16

Confluence: ANOVA results of Eurasian Wigeon residuals and mean minimum temperature residuals at De Bilt, Holland 1981-1983

Eurasian Wigeon residual removal	AVOVA significance	Slope	*t*-test the slope is zero	Intercept	*t*-test that the intercept is zero	Probability that the intercept is zero	r^2	Hypothesis favoured
None	0.002	10.054	4.688	0.335	0.084	0.936	0.758	H_1

WeBS probability was non-significant. On removal of atypical outlier 1320 the probability declined to 0.068, close to significant ($P < 0.05$) and the intercept was significant (P < 0.05), shown on table 17. The null hypothesis was not rejected.

Table 17

Transect C: ANOVA results of Eurasian Wigeon residuals and mean minimum temperature residuals at De Bilt, Holland WeBS

Eurasian Wigeon residual removal	AVOVA significance	Slope	*t*-test the slope is zero	Intercept	*t*-test that the intercept is zero	Probability that the intercept is zero	r^2	Hypothesis favoured
1320	0.068	13.714	1.925	32.515	2.123	0.046	0.15	H_o

Eurasian Teal *Anas crecca*

1981-1983 survey regression is shown in graph 31. ANOVA probability was very highly significant (P< 0.001) but the intercept was non-significant, shown on table 18. The null hypothesis was rejected in favour of the alternative hypothesis.

Graph 31

Regression of European Teal residuals and mean minimum temperature residuals per month at De Bilt, Holland 1981-1983

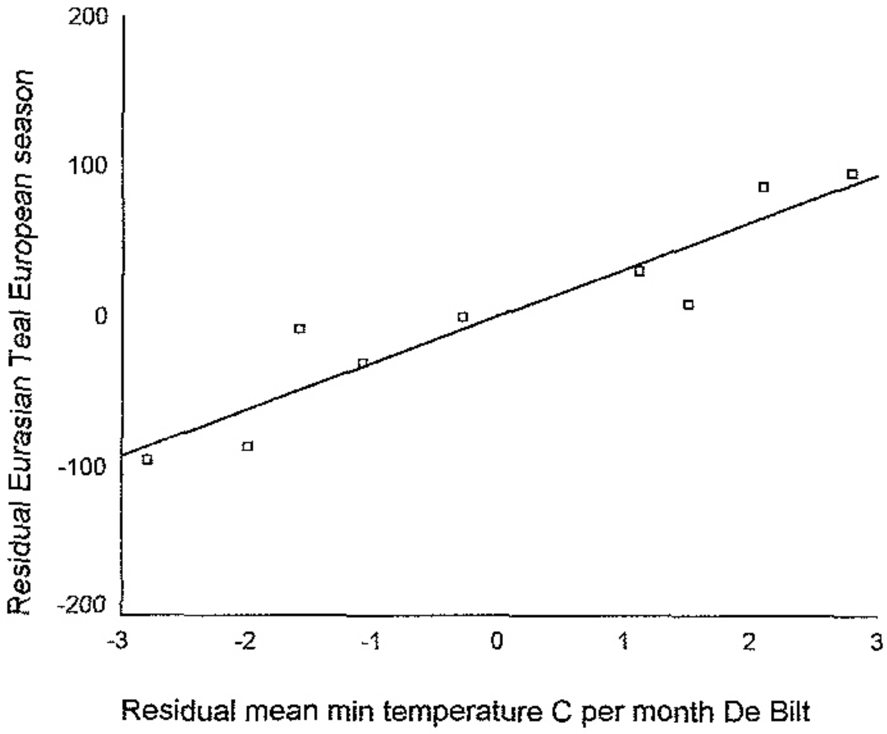


Table 18

Confluence: ANOVA results of Eurasian Teal residuals and mean minimum temperature residuals at De Bilt, Holland 1981-1983

Eurasian Teal residual removal	AVOVA significance	*Slope*	*t-test* the slope is zero	*Intercept*	*t-test* that the intercept is zero	Probability that the intercept is zero	r^2	Hypothesis favoured
None	< 0.001	31.506	7.023	1.05	0.125	0.904	0.876	H_1

Mallard *Anas platyrhynchos*

1981-1983 survey regression is shown in graph 32. ANOVA probability was highly significant ($p < 0.01$) but the intercept was non-significant, shown in table 19. The null hypothesis was rejected in favour of the alternative hypothesis.

Graph 32

Regression of Mallard residuals and mean minimum temperature residuals per month at De Bilt, Holland 1981-1983

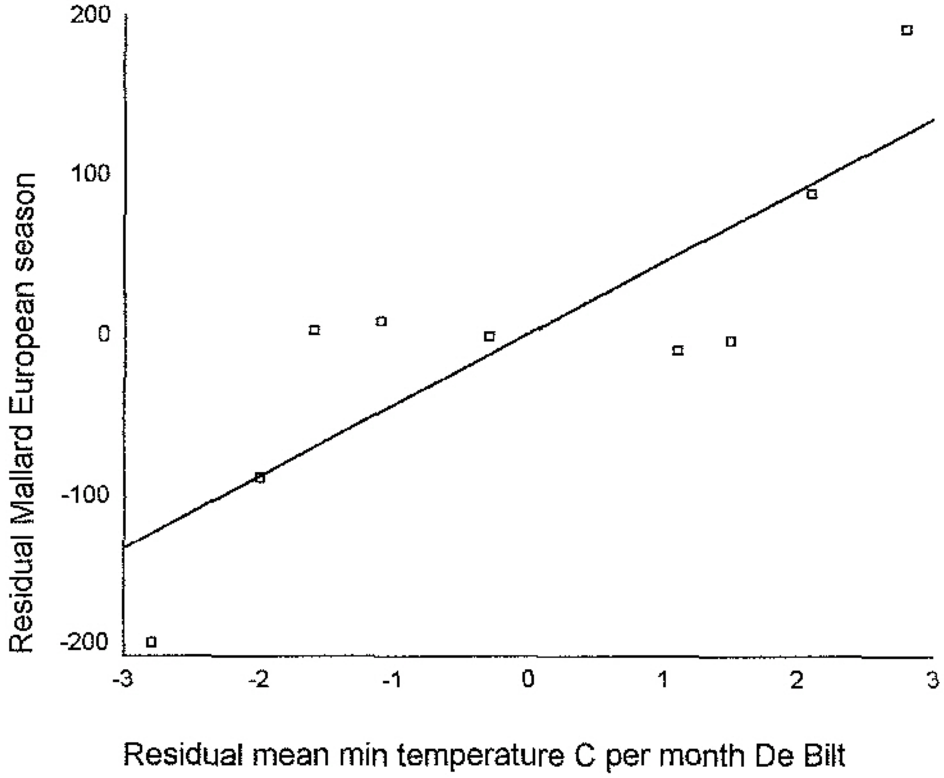


Table 19

Confluence: ANOVA results of Mallard residuals and mean minimum temperature residuals at De Bilt, Holland 1981-1983

Mallard residual removal	*AVOVA* significance	*Slope*	*t-test* the slope is zero	*Intercept*	*t-test* that the intercept is zero	*Probability* that the intercept is zero	r^2	*Hypothesis* favoured
None	0.005	44.697	4.072	1.49	0.073	0.944	0.703	H_1

Northern Pintail ***Anas acuta***

WeBS regression is shown in graph 33. ANOVA probability and intercept were significant, shown on table 20. The null hypothesis was rejected in favour of the alternative hypothesis.

Graph 33

Regression of Northern Pintail residuals and mean minimum temperature residuals per month at De Bilt, Holland WeBS

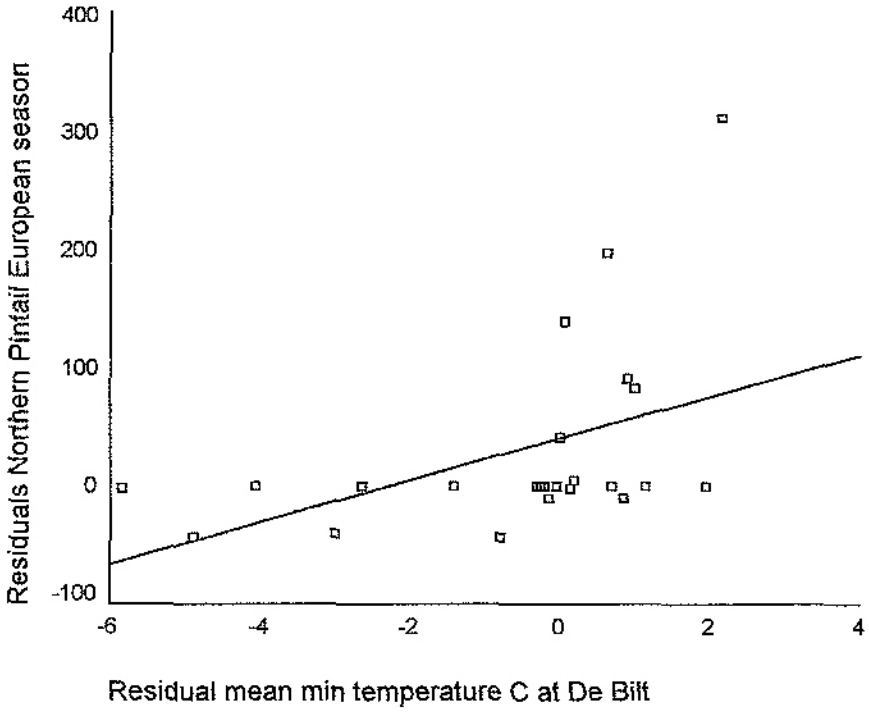


Table 20

Transect C: ANOVA results of Northern Pintail residuals and mean minimum temperature residuals at De Bilt, Holland WeBS

Northern Pintail residual removal	AVOVA significance	Slope	*t*-test the slope is zero	Intercept	*t*-test that the intercept is zero	Probability that the intercept is zero	r^2	Hypothesis favoured
None	0.028	17.761	2.351	39.749	2.495	0.021	0.201	H_1

Northern Lapwing *Vanellus vanellus*

1981-1983 survey regression ANOVA probability was 0.061, close to significant ($P < 0.05$). The null hypothesis was not rejected.

Eurasian Curlew *Numenius arquata*

1981-1983 survey regression is shown in graph 34. ANOVA probability was significant ($P < 0.05$) but the intercept was non-significant, shown on table 21. The null hypothesis was rejected in favour of the alternative hypothesis.

Graph 34

Confluence: regression of Eurasian Curlew residuals and mean minimum temperature residuals per month at De Bilt, Holland 1981-1983

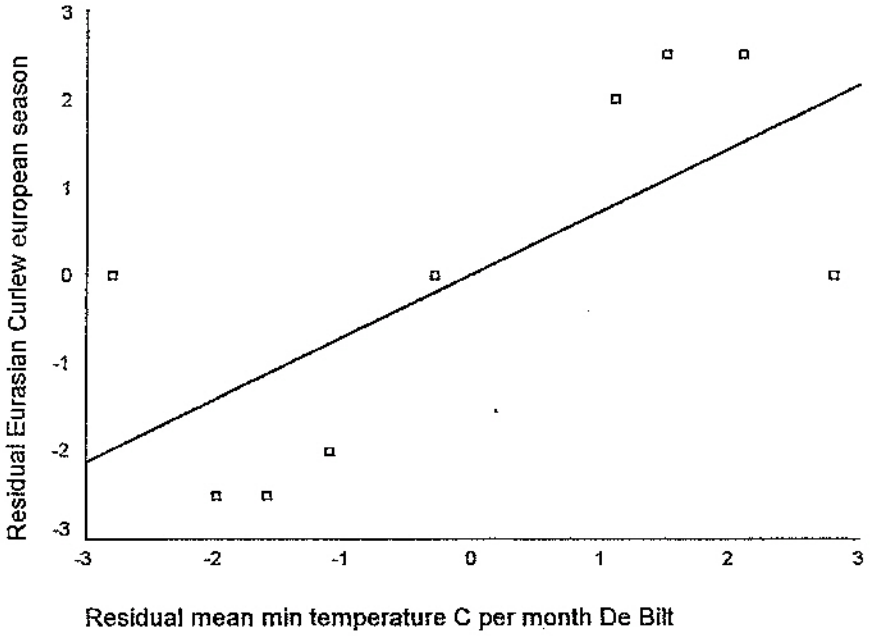


Table 21

Confluence: ANOVA results of Eurasian Curlew residuals and mean minimum temperature residuals at De Bilt, Holland 1981-1983

Eurasian Curlew residual removal	*AVOVA* significance	*Slope*	*t-test* the slope is zero	*Intercept*	*t-test* that the intercept is zero	*Probability* that the intercept is zero	r^2	*Hypothesis* favoured
None	0.037	0.713	2.564	0.024	0.046	0.965	0.484	H_1

Summary

Summarized regression results are in table 22.

Table 22

Summary of regression results of species residuals and mean minimum European meteorological station temperature residuals

Species	European Meteorological Station	1981-1983		WeBS	
		ANOVA probability	Hypothesis favoured	ANOVA probability	Hypothesis favoured
Whooper Swan	Reykjavik	$P > 0.05$	H_o	$P > 0.05$	H_o
European Wigeon	De Bilt	$P < 0.01$	H_1	$P > 0.05$	H_o
European Wigeon	Reykjavik	$P > 0.05$	H_o	$P > 0.05$	H_o
European Teal	De Bilt	$P < 0.001$	H_1	$P > 0.05$	H_o
European Teal	Reykjavik	$P > 0.05$	H_o	$P > 0.05$	H_o
Mallard	De Bilt	$P < 0.01$	H_1	$P > 0.05$	H_o
Northern Pintail	De Bilt	$P > 0.05$	H_o	$P < 0.05$	H_1
Northern Pintail	Reykjavik	$P > 0.05$	H_o	$P > 0.05$	H_o
Northern Lapwing	De Bilt	$P > 0.05$	H_o	$P > 0.05$	H_o
Eurasian Curlew	De Bilt	$P < 0.05$	H_1	$P > 0.05$	H_o
Eurasian Curlew	Oslo	$P > 0.05$	H_o	$P > 0.05$	H_o

Alternative hypothesis was associated with four species of two guilds at De Bilt during 1981-1983. Small datasets may have resulted in type 1 error (Pallant 2002) that could be minimized by increasing alpha power.

WeBS had larger datasets and one alternative hypothesis relationship, Northern pintail at De Bilt. Some non-significant species were virtually absent until January-February, for example Eurasian Curlew.

Chapter 7

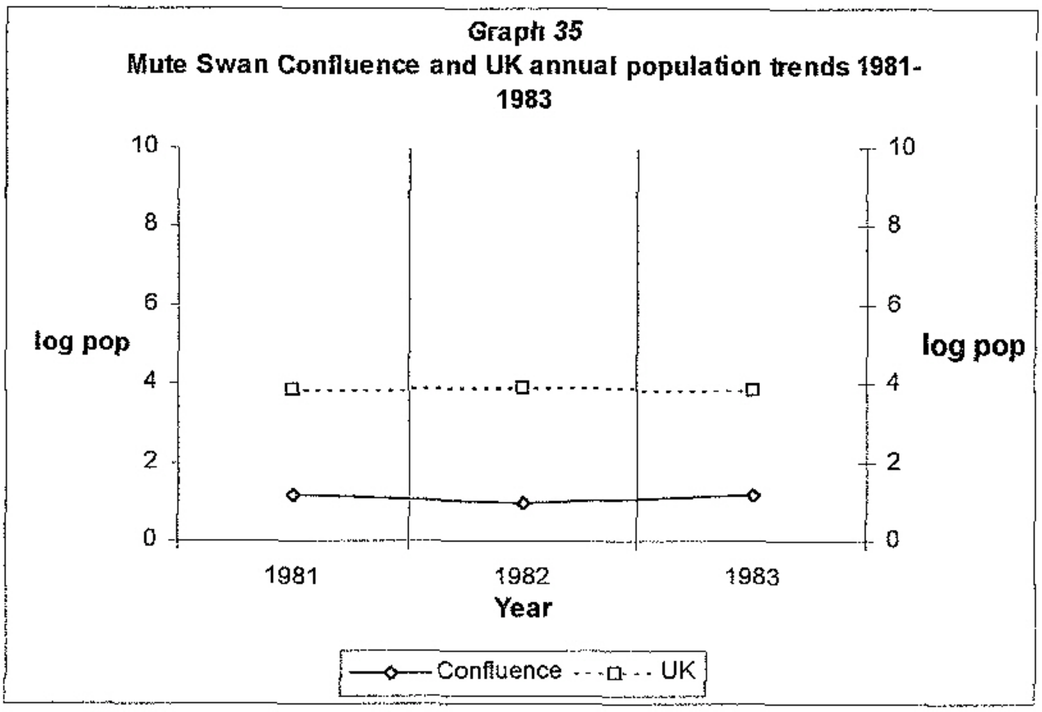
Time series analysis of annual population trends

It is necessary to identify cycles and directions of annual population trends during and between surveys for interpretation of seasonal populations trends in relation to environmental variables (Brown, Mehlman and Stevens 1995). 1981-1983 UK, Confluence and WEBS UK and transect C population trend ranges are compared. Northern lapwing and Eurasian curlew UK data are only available for 1981-1983 December-February, wader priority mid-winter count terms (Salmon 1981 and 1983), and data for both surveys are compared for these species accordingly. Graphs were plotted as logarithmic (base 10) of population trends so that relative changes of large and small populations could be compared directly; the same relative change, for example doubling, would be seen as the same movement whatever the absolute population size. Population directions were compared and the inter-survey population trend was determined from populations at the end and commencement of 1981-1983 and WeBS surveys respectively. Overall population trend directions were computed for the three periods. Trend results are described in logarithmic figures. Population directions were qualitatively assessed for modality and skewness. 1981-1983 and WeBS datasets are in appendices 6 and 7 respectively.

Mute Swan *Cygnus olor*

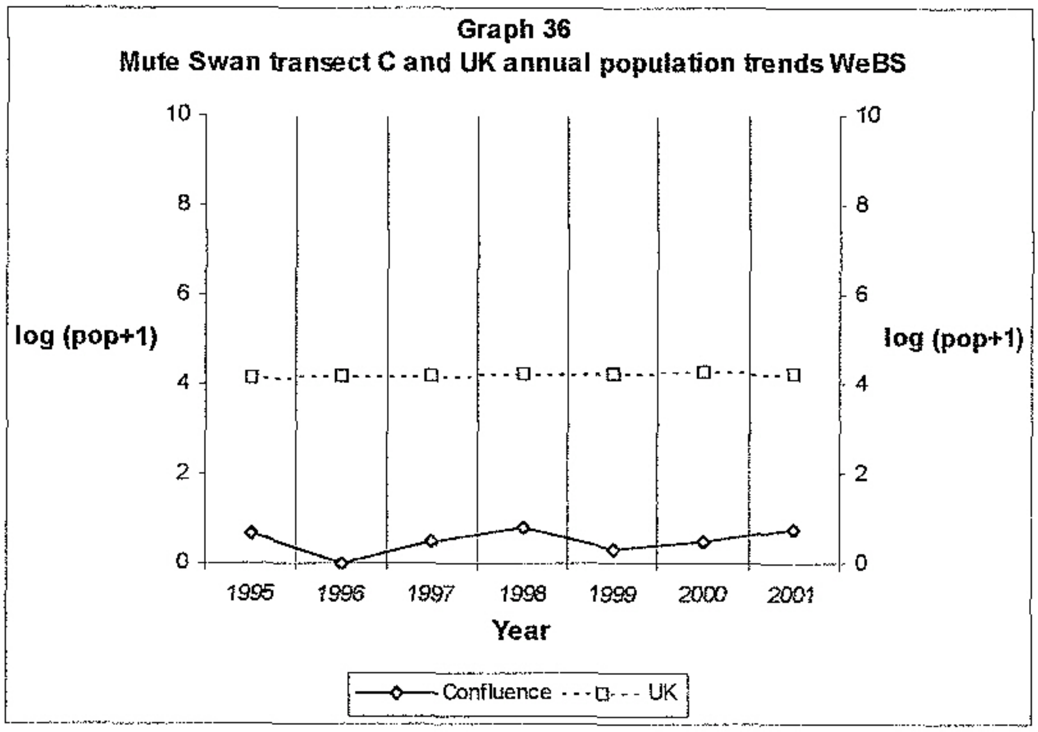
The Mute swan is very resident, often remaining in its natal locality.

1981-1983 UK and Confluence populations decreased 0.02 and were stationary respectively, shown in graph 35. WeBS UK and transect C populations rose 0.09, shown in graph 36. Inter-survey populations declined 0.28 and increased 0.49 respectively.



Graph 35

Mute Swan Confluence and UK annual population trends 1981-1983

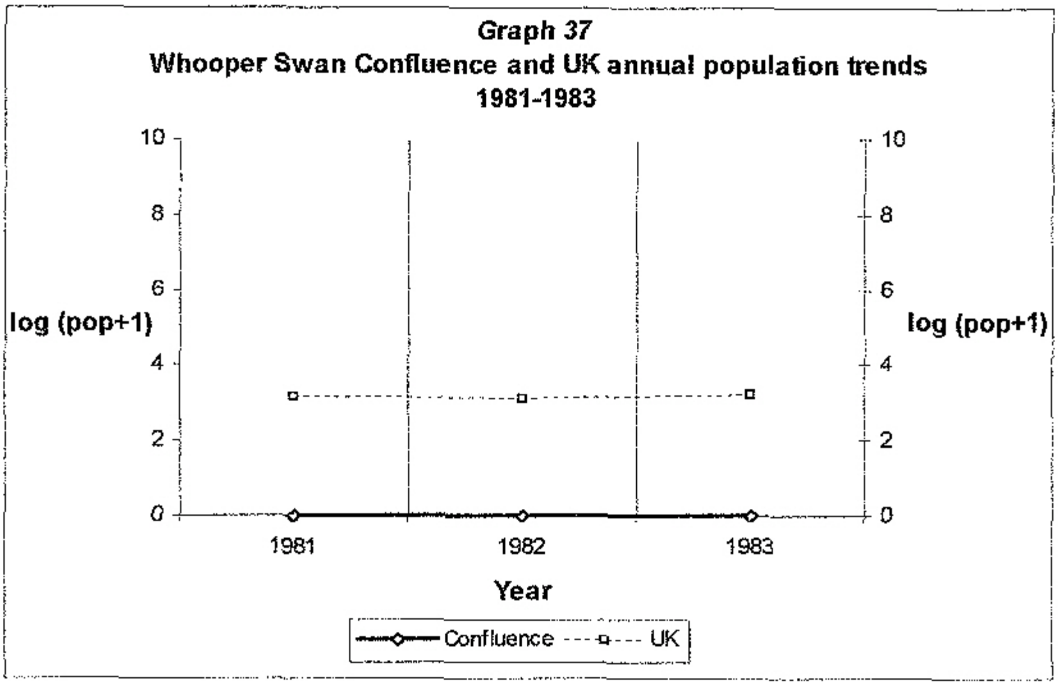


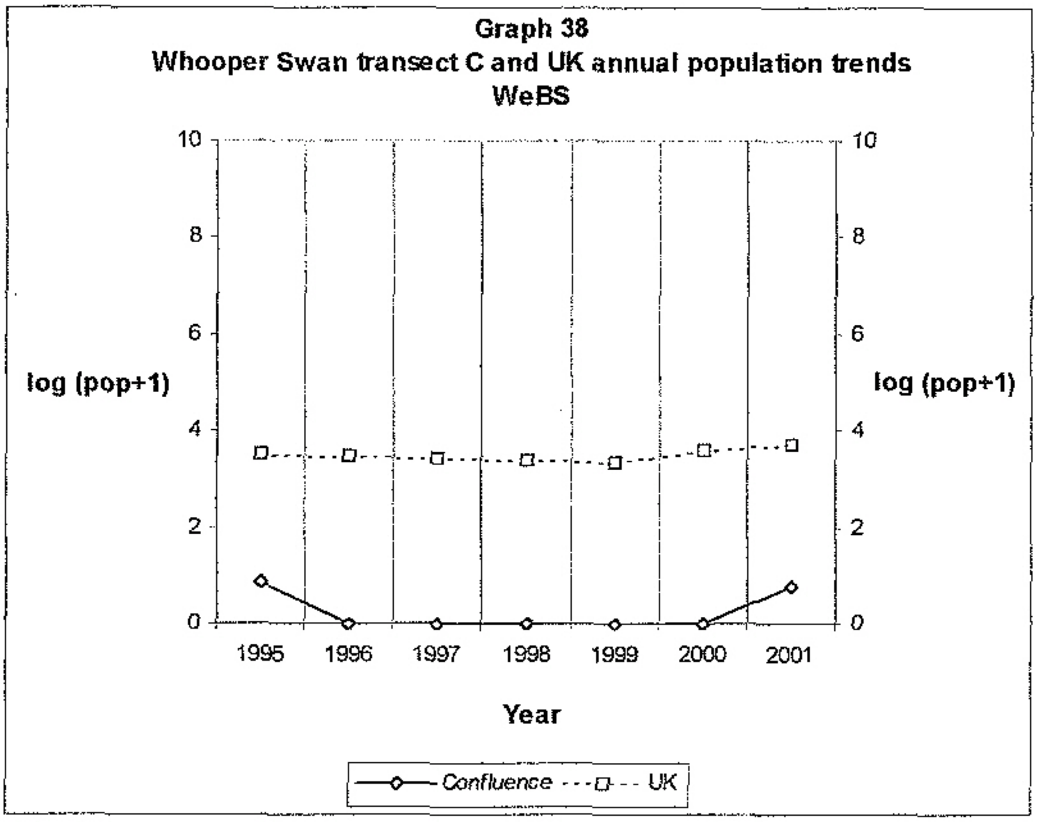
Graph 36

Mute Swan transect C and UK annual population trends WeBS

Whooper Swan ***Cygnus cygnus***

1981-1983 UK and Confluences populations increased 0.06 and were stationary at log (0+1) respectively, shown in graph 37. WeBS UK and transect C populations increased 0.22 and declined 0.1, respectively, shown in graph 38. Inter-survey populations' rose 0.27 and 0.87 respectively.





Eurasian Wigeon *Anas penelope*

1981-1983 UK and Confluence and the UK populations increased by 0.07 and 1.96 respectively, shown on graph 39. WeBS UK and transect C had a possible cycle peaking every three to four years; the populations increased 0.11 and decreased 1.15, shown in graph 40. The inter-survey populations