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Methods of comparing low-tide trends for Wetland Bird Survey count sectors with wider regions: a pilot study for three wader species on the Stour and Orwell Estuaries SPA

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EXECUTIVE SUMMARY

1. Managers of wetland sites can assess the status of a particular count sector on a site counted for the Wetland Bird Survey (WeBS) by comparing the numbers of birds found there, and their population trends, with wider areas. Where trends at a sector differ from those expected from the data for wider areas, and habitat change has also occurred, it may be possible to infer ways to improve the conservation management of the site.

2. WeBS runs two major count schemes covering all estuaries in the UK. The WeBS Core Count Scheme was developed specifically for surveillance of numbers of waterbirds at the site level, and to derive population estimates, and has been in use for over 50 years. The underlying methodology of the Core Count Scheme aims to deal with overcounting resulting from multiple recording of the same individuals. The second scheme, the Low Tide Count Scheme was developed to monitor relative usage of the intertidal habitat within an estuary. Because waterbirds may make use of different parts of an estuary over the same low tide period, avoidance of overcounting is not a primary concern addressed by the methodology of the Low Tide Count Scheme and WeBS does not routinely use low tide count data to derive site totals for waterbirds.

3. Consequently population trend generated from the monthly core counts (CCs) may be expected to differ from the trend generated by summing low tide counts (LTCs) from relevant count sectors. Conclusions about the relative favourability of a count sector may depend, therefore on the methodology used.

4. Previous ornithological reports for the Stour and Orwell SPA have derived estimates of site totals from summed LTCs. Because there has been concern that summing LTCs may have resulted in an unknown and probably changing degree of overcounting, we here test a method of comparing trends obtained from LTCs on individual sectors with trends derived from CCs for wider areas. Although WeBS routinely compares CCs from individual count sectors with population derived from summed CCs, previously no analyses have been done that compare LTCs from individual count sectors with CC totals. In principal, however, there is no obvious argument against putting trends in <u>usage</u> of intertidal areas within estuaries determined by LTCs in the context of the site population derived from CCs.

5. The study compares counts for Knot, Dunlin and Black-tailed Godwit on count sectors of the Stour and Orwell SPA over a 10-year period. These are placed in the context of the data for lower, mid and upper estuary consolidations (for which summed LTCs provide the only available background data), the whole estuary (Stour or Orwell), the Stour and Orwell together, a wider region including the Deben Estuary and Hamford Water, and the Environment Agency's East Anglian region based on CC data.

6. The analysis suggests that conditions across the Stour & Orwell SPA as a whole are favourable to Knot. Indeed Knot have increased on the site and more rapidly so than across East Anglia as a whole. There have been some local declines within the SPA, with decreasing numbers recorded at Bathside Bay and Seafield Bay on the Stour and from sectors close to the Orwell Bridge indicating redistribution within the site but these birds have been absorbed elsewhere. All things being equal one would expect increases across all sectors given the increased numbers on individuals on the SPA and so these local declines may indicate pressures due to habitat change or increased disturbance in these particular areas. However, same redistribution could arise it other areas have become increasingly attractive to this species. This cannot be determined from analysis of trends alone.

7. Although Dunlin numbers are showing a strong decline throughout East Anglia and indeed the UK, believed to be a response to global climate change (with increasing numbers wintering on the Waddensea) this analysis has identified that the steep decline of Dunlin across the SPA exceeds that expected from the wider trend. This indicates that this SPA is becoming increasingly less favourable for this species.

8. The decline in Black-tailed Godwit on the SPA is in stark contrast with almost every other site within the species UK winter range. There has also been a redistribution within the SPA.

9. With only three species analysed, it is difficult to draw conclusions with regard to potential pressures that may be driving changes in bird numbers. It is the identification of similar trends in species with similar ecological requirements that focuses attention on potential pressures. Despite this, it is notable that all three species have shown declines in the upper reaches of the Orwell in the vicinity of the Orwell Bridge

10. The method of using Core Counts, rather than summed LTCs, has successfully identified sectors where trends have differed from those in wider areas. The method can help to determine the effects on key estuarine bird species of management activities, such as dredging and sediment placement, by identifying sectors where population changes have not been in line with those expected. We recommend the use of this method across all species in similar future studies.

1. INTRODUCTION

1.1 Background

The Wetland Bird Survey (WeBS) has a long history of monthly counting of water birds on estuaries and inland waters throughout the UK, and of providing results that provide surveillance of the distribution and population trends of these species on local, regional and national scales (Austin *et al.* 2008). Volunteers, whose efforts are organised centrally by the BTO and locally by WeBS local organisers, carry out most of the counting. WeBS (a partnership between British Trust for Ornithology, Royal Society for the Protection of Birds and Joint Nature Conservation Committee, in association with the Wildfowl & Wetlands Trust) organises two major count schemes, the WeBS Core Count Scheme and WeBS Low-tide Count Scheme.

WeBS Core Counts (CCs) have been used to monitor waterbird numbers in the UK since the 1960s. They are carried out monthly throughout the year, in a synchronous and coordinated manner across each site, and indeed between sites, on pre-set dates chosen with special regard to estuarine sites so as to coincide with spring high-tides occurring during the middle of the day-light hours (to optimise counting conditions and to maximise synchrony with non-estuarine sites). Larger sites are divided into count sectors, which are, again, ideally counted simultaneously, to minimise the risk of ‘overcounting’ that can arise when the same individuals are recorded on multiple count sectors during the same survey period. Although counts frequently target high-tide roosts it is left to the discretion of the local organiser to decide the most appropriate approach to ensure that best possible coverage is obtained whilst minimising the risk of overcounting. The purpose of the Core Count Scheme is primarily to monitor trends in numbers and generate population estimates at site, regional and national levels. These data are those that generally feed into site designation undertaken by JNCC and the country agencies (typically with reference to the five year mean of peak counts), and those used by the WeBS Alerts System to inform surveillance of site, regional and national trends. The division of large sites into sectors has evolved principally in response to the practicality of undertaking counts, the divisions between sectors typically follow distinctive features of the environment. This reflects their principal function, that of providing overall estimates of site numbers. They do, however, provide data on roost sites and, consequently, an analysis of water-bird counts on the individual Core Count sectors can provide information that is both biologically meaningful and valuable for site management.

Unfortunately, the bird numbers recorded from each individual count sector often give rather little information about the value of the intertidal habitat for water birds, and this is especially true for waders because, in most cases, they are absent from their main feeding grounds at the time the counts are made as these areas a largely submerged. Core Count sectors do, however, frequently encompass intertidal areas where information gathered at high tide is still important from the perspective of monitoring wildfowl. For local management and conservation purposes, however, it is often data on intertidal habitat use by waders at the sector level that would be of greatest value.

To address this important gap in information, WeBS instigated in 1992/93 the Low Tide Count Scheme, a rolling programme of low tide counts (LTCs), in which the low-tide distribution of water birds is recorded, by count sector, at a small number of estuaries each winter. Musgrove *et al.* (2003) have described the Low Tide Counts and their operation over the first seven years. LTCs are made four times each winter – monthly between November and February. The aim of the Low Tide Count Scheme is to record the use made by birds of discrete areas within an estuary. While the sector counts across a whole estuary are often made within a single low-tide period, it is often the case that a single bird or group of birds may be counted at more than one count sector; for LTCs, the plan is to quantify all birds using the sector, whether or not they have been recorded earlier in another sector. The rationale for this is that, even if birds use a sector for only a part of the tidal cycle, the sector is still valuable to the birds recorded there. There is no requirement for synchrony as they are not intended to be summed to inform estimates of waterbird numbers at the site level. A corollary of this method is that, where birds have moved between sectors, the sum of the LTCs for a particular estuary may be substantially higher than that obtained using CCs; it is the CCs, however, that are the better measure of the total numbers of birds present on the day of the count (Musgrove 1997).

In summary, WeBS Low-tide Counts are intended to serve a different purpose to WeBS Core Counts. The former counts aim to quantify the feeding distributions within estuaries of waterbirds, particularly waders. The latter counts are intended to quantify the number of waterbirds using a given site and incidentally quantify important roost sites. On a handful of sites LTCs may be used in lieu of CCs but only where the local organiser confirms both that counts have been synchronous across sectors and believes they better estimate the populations at that particular site.

With particular regard to the Stour and Orwell estuaries, the local organisers (M. Wright – Orwell; R.Vonk - Stour) are adamant that low-tide counts should not be used to estimate site totals because of the un-quantifiable degree of overcounting known to occur could give a false impression of favourable status of the estuaries. However, the local organisers do not believe that overcounting is an issue with the roost counts and, furthermore, believe that if there is a bias on these estuaries, then it is towards 'undercounting' i.e. underestimating the number of birds using the estuary as some birds are believed to vacate the site over high tide (M.Wright pers. comm.).

1.2 Analysis of low-tide count data for the Stour and Orwell Estuaries

The Stour and Orwell estuaries in southeast Suffolk and northeast Essex are designated as a Special Protection Area (SPA) under the EC Birds Directive and as a Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act 1981. LTCs have been undertaken on the Stour and Orwell Estuaries in every winter since 2002/03, funded by Harwich Haven Authority and these data have been incorporated into the WeBS database. These data form the basic of previous analyses commissioned by Harwich haven Authority and undertaken by Haskoning UK Ltd. The WeBS database holds data from LTCs for the Orwell back to winter 1994/95 and for the Stour (with gaps) back to winter 1996/97. These additional data were also available for this analysis.

These unique long-term time series of Low Tide Count data make it is possible to assess trends in the bird numbers on each count sector over this period of time. Of particular interest are the species trends for each sector in relation to the trends for the whole estuary and for wider regions. These comparisons reveal whether changes observed within a sector are likely to be confined to that sector or are a reflection of wider trends. If confined to a particular sector, trends may show the effects of local habitat change or disturbance and in some cases reflect management decisions made by Harwich Haven Authority or another responsible body.

In planning an analysis of species trends by count sector, the question arises of which set of counts to use when comparing LTCs within a sector to wider areas: the options are to use the summed LTCs for the wider areas, or to use the summed CCs. A conceptual difficulty with using summed LTCs is that, although such a figure is easy to calculate, the methodology does not specifically seek to minimise the risk of overcounting as it does with CCs. Consequently, site estimates derived from summed CCs are invariably preferred (Musgrove 1997).

Practical differences between these approaches arise when a species shows differences in population trend between the summed LTCs and the Core Counts. Overall trends for Knot ***Calidris canutus***, Dunlin ***C. alpina*** and Black-tailed Godwit ***Limosa limosa*** on the Stour and Orwell Estuaries separately, using summed LTCs and summed CCs, are compared in Figs 1 & 2. For Dunlin on the Stour, Core Counts show a progressive decline, whereas the summed LTCs show a shallow increasing trend (Fig 1b); for other species and estuaries, the differences between the two trends are less systematic.

Such differences can arise from two, non-exclusive reasons. Firstly, it could be due to a trend of increasing overcounting in the LTCs. Secondly, it could be due to a trend of increasing undercounting in the CCs. Neither possibility can be completely excluded as in order to quantify either overcounting or undercounting we would require a long time series of detailed and labour intensive observations of individually identifiable (typically colour-ringed) birds and such data do not exist. However, in the case of Dunlin on the Stour, overcounting from summed LTCs is the more likely explanation as Dunlin is a declining species on estuaries throughout the UK (Maclean ***et al.***

2008) and the Stour is unlikely to be an exception. The degree of overcounting or undercounting can be expected to differ between species because some species are naturally more mobile than others and not all species are equally sensitive to disturbance. Thus a species such as Knot, which is particularly sensitive to disturbance, has particularly strong flocking behaviour and are very mobile, moving around considerably both within and between estuaries, has probably always suffered from a high degree of overcounting. On the other hand Dunlin move around in smaller flocks, are more site faithful and perhaps more tolerant of disturbance leaving more scope for increased disturbance to have an affect on the degree of overcounting.

Given the uncertainty, it is essential that analyses should be conducted and interpretation be made in such a way that inappropriate conclusions are not drawn from the results.

(a)

Knot

(b)

Dunlin

(c)

Black-
tailed
Godwit

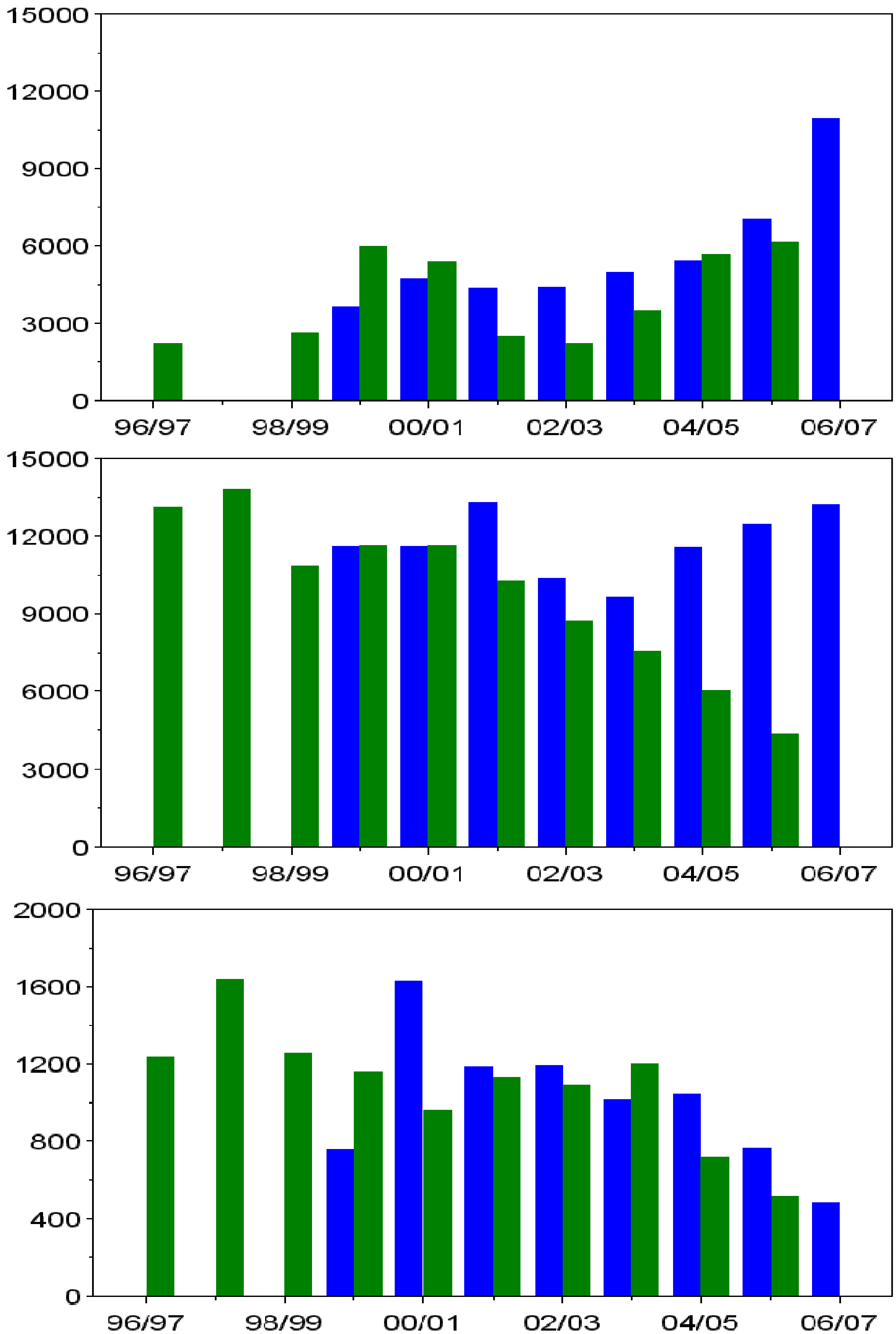


Figure 1. Five-year trends for (a) Knot *Calidris canutus*, (b) Dunlin *C. alpina* and (c) Black-tailed Godwit *Limosa limosa* on the Stour Estuary, using the Core Count data (green) and the summed Low Tide Counts (blue), taking the mean across the four months November–February.

(a)

Knot

(b)

Dunlin

(c)

Black-tailed Godwit

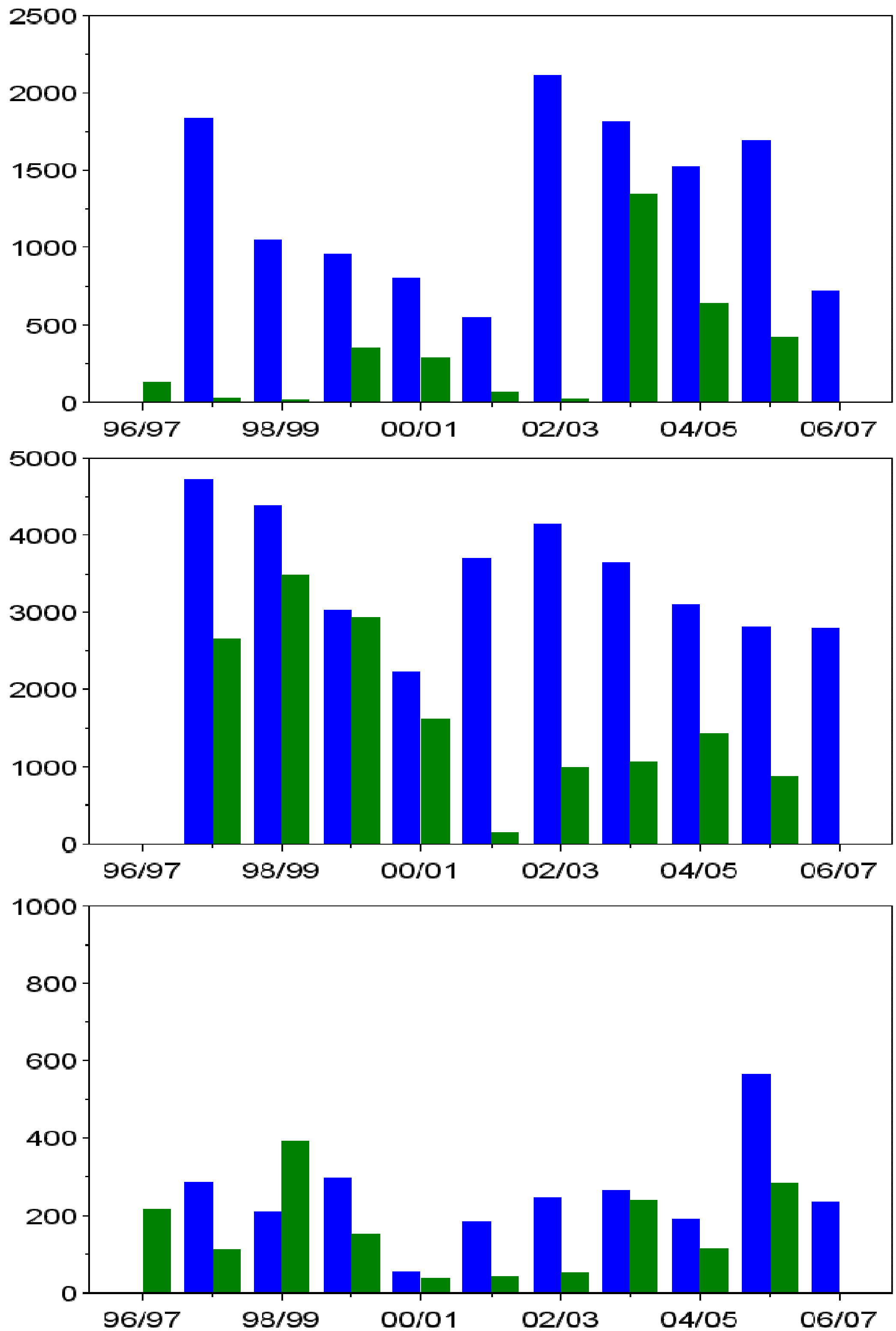


Figure 2. Trends for (a) Knot *Calidris canutus*, (b) Dunlin *C. alpina* and (c) Black-tailed Godwit *Limosa limosa* on the Orwell Estuary, using the Core Count data (green) and the summed Low Tide Counts (blue), taking the mean across the four months November–February.

There are no issues surrounding interpretation of trends in LTCs on individual Low Tide Count sectors as double counting is not an issue within sectors. Issues associated with double counting only become important when counts are amalgamated for multiple sectors consolidations. Thus, increases, long-term stability or declines at the sector level can be considered to represent the usage of that sector to the birds, be it in relation to changes in suitability, changes due to changes in the birds' behaviour in response to disturbance, changes reflecting broad scale population trends or some combination of these.

However, except for in a very crude manner, trends in usage of a given sector, when viewed in isolation, does not provide an insight into whether or not conditions on that sector are favourable. They may simply reflect the availability of birds to occupy that sector as population numbers or winter distributions fluctuate at country-wide or regional scale. To determine this, it is necessary to put the trends observed on each sector into a wider context, typically the whole site or some regional combination of sites. It may be that numbers of birds on a sector are increasing but this increase is less than that across the site as a whole, or a site-wide decrease may be more marked on a particular sector, either observation suggesting that conditions for the birds on that sector are, compared to the site as a whole relatively unfavourable. In contrast, numbers of birds on a sector may be increasing more rapidly or declining less rapidly than the site as a whole, either observation suggesting conditions on the sector are relatively favourable. Thus, in order to understand whether sector level trends are favourable, it is therefore necessary to amalgamate counts to quantify bird numbers at the broader scale and this is where issues can arise because values for amalgamated counts should represent the number of individual birds on the site but not be a function of the birds' behaviour.

Given the primary purpose and methodology used, WeBS Core Counts would be considered the more appropriate of the two schemes for defining overall site populations (Musgrove 1997). However previous reports by Haskoning UK Ltd have relied on amalgamated LTCs both to quantify to numbers of birds occupying the whole estuary(s) but also on consolidations of individual sectors within spatially discreet areas of each estuary (Upper, Mid and Lower estuary consolidations). It is therefore important to consider whether this may have compromised interpretation.

We would expect that the methodology used here to characterise trends in bird usage of individual count sectors would lead to similar conclusions to those reported previously (Anon 2009). We would also expect to draw similar conclusions on trends in bird usage of the Upper, Mid and Lower consolidations of each estuary, although recognising the potential problems of overcounting influencing these trends. Where conclusions may differ is when comparisons between sectors or consolidations are compared with those for the whole site or combination of sites.

1.3 Objectives

The aim of the present report is to investigate whether it is appropriate to undertake statistical trend analysis of the low-water count data for the Stour and Orwell Estuaries using high-water count totals to determine proportional use of the count sectors over time. This follows a preliminary investigation of the two methods (Anon 2009). Trends in low-water bird numbers for the Stour and Orwell Estuaries are discussed by sector in a local, regional and national context. Initially, this approach covers only Knot *Calidris canutus*, Dunlin *C. alpina* and Black-tailed Godwit *Limosa limosa*.

The report includes an assessment of whether the method can help to determine the effects of dredging and sediment placement on key estuarine bird species.

2 METHODS

2.1 Study sites and their water bird data

The Stour and Orwell Estuaries, though adjacent and forming a single SPA, are separate WeBS sites, each with a long history of Core Counts and a recent series of LTCs. Presently the Stour has 40 Low Tide Count, counts sectors (Fig 3) and the Orwell 41 (Fig 4), nine of which are the product of recent splitting of earlier count sectors.

Core counts for individual sectors are summed for each monthly count to give the overall site total. During this process it is necessary to assess the completeness of the overall count, because not necessarily all sectors are counted on all occasions. Completeness is assessed in a species-specific manner, because the lack of data from a given sector would not be expected to affect the overall total for all species to the same degree, and using algorithms that allow for both seasonal and long-term trends in site usage. A consolidated count for a site composed of multiple sectors is considered complete when the sectors that were counted would have been expected to have held at least 75% of the site total for that month and year for the species in question.

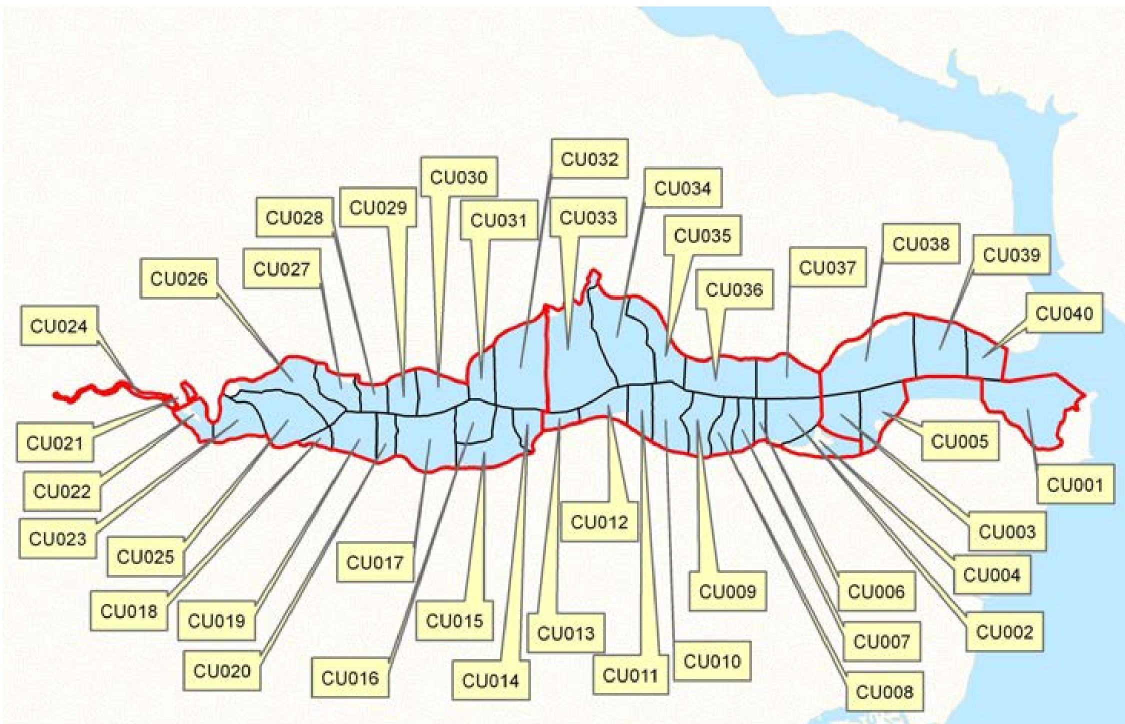
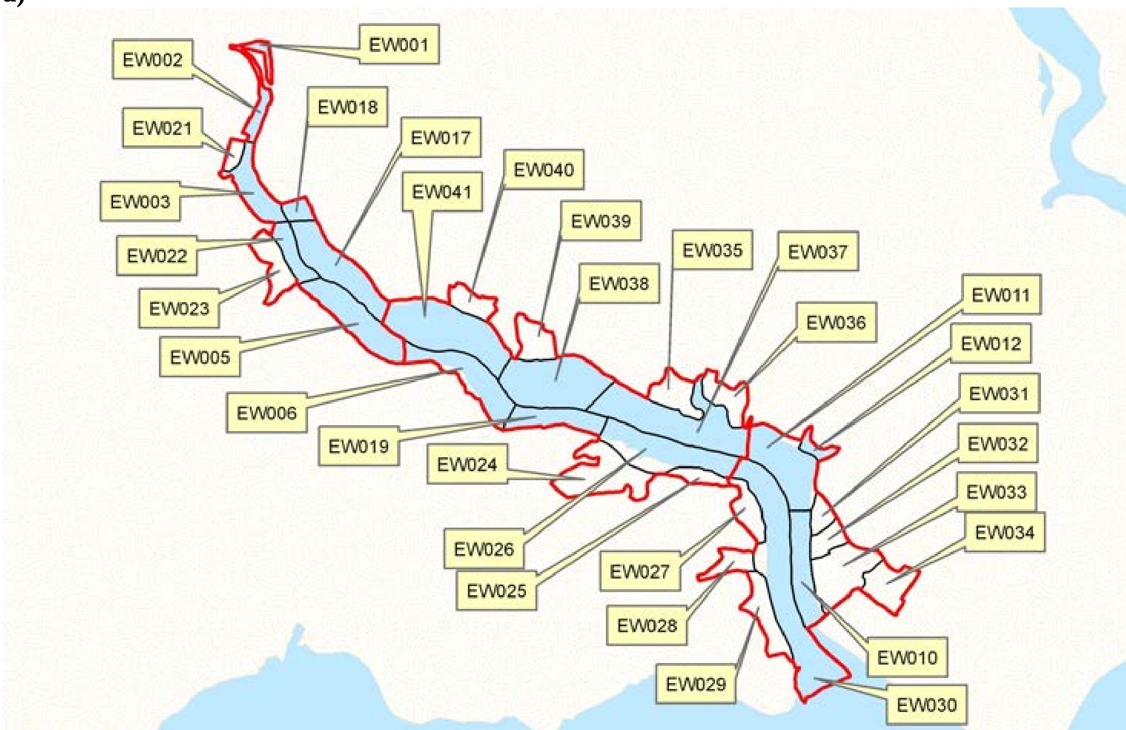


Figure 3. The Stour Estuary, along the Suffolk/Essex border, with its 40 count sectors. The red lines mark the division of the estuary into upper, mid and lower consolidations.

A

a)



b)

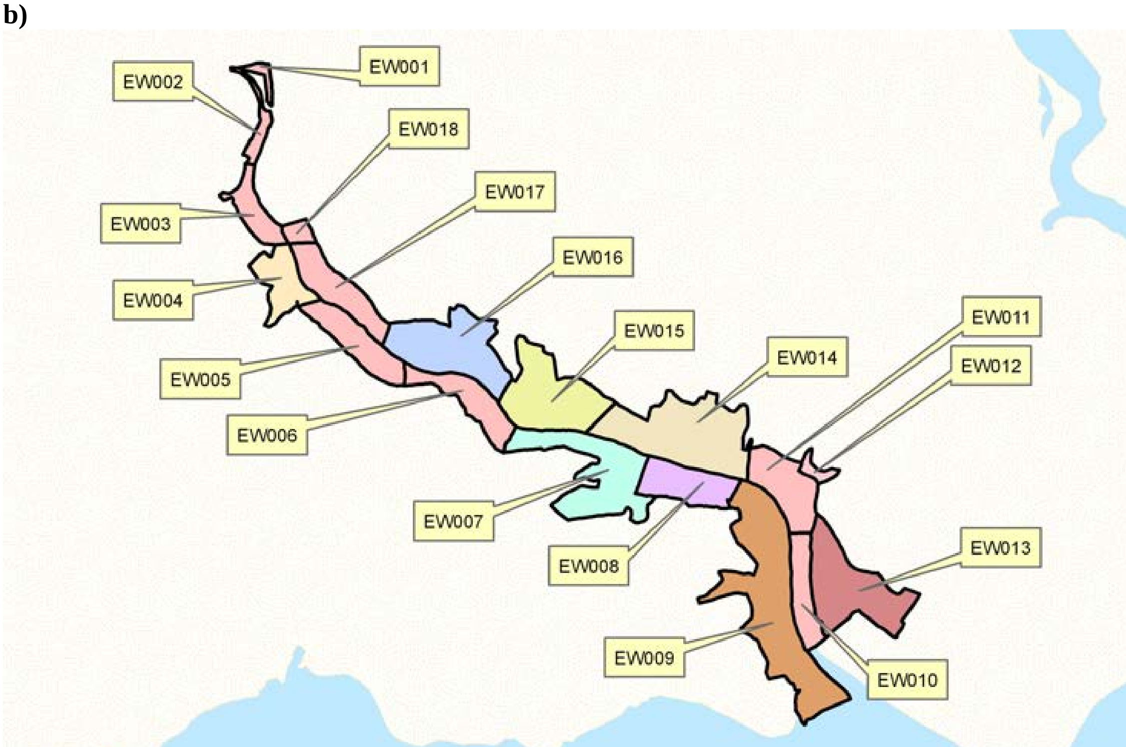


Figure 4. The Orwell Estuary, in southeast Suffolk, with **a)** its current 41 count sectors (red lines mark the division of the estuary into upper, mid and lower consolidations), and **b)** those in use prior to 2000 (those unchanged in pink).

Low-tide counts (LTCs) for each sector are independent, and may include individual birds also recorded on other sectors in the same monthly count. Summed LTCs to derive values for consolidations of sectors in the upper, mid and lower part of each estuary. For reasons of consistency with earlier reports (e.g. Anon 2009), the amalgamated counts for these consolidations are also analysed in the same manner as counts for individual sectors. However, it should be noted that there is a logical inconsistency in avoiding summed LTCs across the whole site as a site estimate against which to compare trends from individual sectors, and then using summed LTCs for upper, mid and lower estuary consolidations as if they were equivalent to a count from a single sector.

In this report, counts are analysed only for Knot, Dunlin and Black-tailed Godwit. These are considered as useful example species because they show marked and differing patterns of occurrence within the study area. It should be noted, however, that it is often during the comparison of trends for a wide range of species that consistent patterns between species with common aspects to their ecological requirements focus attention on particular aspects of environmental change that may be driving those trends.

2.2 Smoothed trends and percentage change by count sector

The methodology used to produce summarised trends at site, regional and national levels, as reported by WeBS Alerts (Maclean & Austin 2008), can be usefully extended to generate trend figures for smaller areas of interest such as WeBS count sectors or appropriately grouped consolidations of count sectors. The sector level analysis described below here has been developed as the standard used by BTO to investigate and report on trends on count sectors. This methodology has been variously used to investigate declines in diving duck numbers on Lough Neagh and Beg (Maclean *et al*. 2006), inform wildfowling consent decisions for the Humber SPA by Natural England (Austin *et al* 2008), inform the Thames Estuary 2100 flood management assessment being undertaken by the Environment Agency (Wright *et al.* 2008) and has been incorporated as the favoured approach for analysis of sector level trends outlined in Natural England's forthcoming guidance notes for assessment of wildfowling consents.

It is important to recognise, however, that the numbers of birds underlying the trends observed on individual sectors are generally much lower than those underlying the site trends reported by the WeBS Alerts which are, by definition, at least equal to the national qualifying threshold. Trends for individual sectors should not be over interpreted, therefore, and the sample sizes of birds should always be taken into account. For example, a 50% decline from 30 birds to 15 birds would give much less cause for concern than a 50% decline from 1,000 to 500 birds – the latter being much more likely to reflect a real and substantial loss of birds from an area than the former. While bearing this in mind, a consistent pattern of decline across multiple species, even when the numbers involved for some of them are comparatively low, is strongly indicative of adverse factors affecting the sector in question and the particular suite of species showing a decline in numbers can guide us in where to look for problems; for example, the suite of species in decline might represent those known to be particularly sensitive to disturbance, or those with similar ecological requirements. Although longer time series of data are available, numbers of birds using a particular count sector or consolidation are quantified using the five-year mean of peak counts. Based on the most recent five years, this statistic is that used for quantifying waterbird numbers on protected sites by JNCC and the country agencies, that used for standard WeBS reporting (e.g. Austin *et al.* 2008) and that used for the most recent ornithological monitoring report for the Stour and Orwell Estuaries Special Protection Area (Anon 2009).

The trends in winter LTCs by sector that are presented in this report were calculated in the following way. For each sector, species and winter, the mean of the four monthly counts was taken, using the latest available validated WeBS data (to winter 2006/07 inclusive). Then, following (Atkinson *et al.* 2000, 2006), the mean values for the relevant species were smoothed using Generalized Additive Models (GAMs). The smoothing ensures that year-specific factors, such as poor conditions on the breeding grounds or particularly harsh weather on the wintering grounds that cause exceptional values that are not related to changes in the quality of the estuary itself, do not dominate the trend, and that the underlying longer-term trends are more clearly evident. Percentage change has been calculated for the most recent five and 10-year periods by comparing the smoothed estimates for 2006/07 with those for 2001/02 and 1996/97 respectively. WeBS does not have the necessary data collated at the sector level to support analysis of longer time-series.

By analogy with the WeBS Alerts system, declines of at least 25% but below 50% are flagged as moderate declines, and declines of 50% or greater are flagged as rapid declines (we do not use the specific term 'Alerts' because declines reported at the sector level do not constitute a formal WeBS Alert). The corresponding percentage changes required to return the numbers to their former level following a decline are similarly termed moderate (at least 33% but below 100%) and rapid (100% or greater) increases.

2.3 Placing the smoothed indices into context

Once the smoothed sector indices have been produced, they have been placed in the context of the site trends. The latest WeBS methodology (Banks & Austin 2004) as used to compare site trends with regional and national trends (Maclean & Austin 2008) is extended here to compare counts sector trends with site trends.

In essence, the four LTCs for each sector, species and winter are expressed as proportions of the total Core Counts for wider areas. Geographical scales considered are the count sector itself, the lower, mid and upper estuary sector consolidations (based on summed LTCs), the whole estuary (Stour or Orwell as appropriate), the Stour and Orwell combined, and these estuaries together with the adjacent sites of Deben Estuary and Hamford Water (these being areas to which some birds feeding on the Stour and Orwell may commute to roost at high tide). The larger combined area is abbreviated as SODHW. The mean of the four proportions for each sector, species and winter has been plotted, together with its 95% confidence interval, to show the trend for each sector and species. It is recognised that the sum of the proportions of sectors of a site is unlikely to equate to 100% because LTCs are being compared to Core Counts. However, this in no way undermines the interpretation of the changes in proportions undertaken in the context of this report. The only assumption being made here is that the true (but unknown) total of each species occupying the site(s) at low tide remains stable in relation to the true site(s) total at high tide (as estimated from Core Counts), i.e. there has been no long-term trend for increasing immigration or emigration between high and low tide to estuaries further afield than SODHW. The reasoning behind considering comparisons between the count sector and site, two sites and four sites is to investigate whether or not there has been an increasing trend for birds to move outside of the immediate estuary to roost. Similar comparative plots between sectors and the alternative amalgamations would indicate that there has been little change in the proportion of a given species leaving the site at high tide whereas, if the comparative plots diverged over time then this would suggest that the number of a given species leaving the site had changed over time – something that would need to be acknowledged in any subsequent interpretation.

If trends for a given species on a given count sector follow those of the species across the site as a whole, then the proportional contribution of numbers on the site would remain constant. Any significant deviation from this gradient of zero would indicate that the populations on the relevant count sector were doing either better or less well than would be expected from the site trend. Consequently:

- where a decline on a sector reflects a decline across the site as a whole it is unlikely that the observed site trends is being driven by factors affecting that sector. If this is true of the majority of sectors, then this may indicate that the observed site decline in the species in question is due to factors external to the site and are thus not due to site management issues *per se*. Furthermore, there is not evidence that the sector is becoming any more or less favourable for the species in question;
- where a decline on a sector is more substantial than that across the site as a whole, this may suggest that factors affecting that sector could be contributing to the overall decline. Furthermore, it indicates that the sector has become relatively less favourable for the species in question;
- where a decline on a sector is less than the decline across the site as a whole, this suggests that relatively favourable conditions on that sector are helping to buffer the wider decline;

- where an increase on a sector is less steep than that across the site as a whole, this suggests that the sector is already at carrying capacity for the species in question or, if historically it supported greater numbers, that the quality of the sector for that species has diminished;
- where an increase on a sector is greater than that across the whole site, this suggests that trends on that sector are driving the increase across the site or that the sector in question is relatively attractive compared to the site as a whole when increased numbers arrive at the site due to external factors.

The comparisons between sectors and site are derived from a logistic regression model with a binomial error term. The resulting plots depict the percentage contribution of the sector to the site as a whole and the associated confidence limits represent both variation in this proportion between months in a given year and the underlying sample size (e.g. we would be more confident of our estimate that a sector contributed 10% of the site total if 100 birds out of 1000 on the site were counted there than we would be if this was 10 out of 100). This is based on the period November to February (months when counts are available from both LTCs and Core Counts) and restricted to those occasions where Core Counts consolidated across the site as a whole had been assessed as complete – following standard WeBS protocol as described above.

The various site consolidations are compared with regional and countrywide trends in order to put site trends into a wider context. The regional comparison is with the Environment Agency's East Anglian Region, as used for WeBS Alerts reporting. This approach is especially important where there has been a strong national or regional trend. Consequently:

- where there has been an apparent redistribution of a species within the Stour and Orwell SPA (i.e. declines on some sectors appear to be balanced by increases on other sectors), but the proportional contribution of the Stour and Orwell to increasing regional numbers is declining, then this implies that those sectors on the Stour or Orwell with static or declining numbers are actually of concern because we would expect them to be increasing in parallel with the other sectors. Thus, in such cases, the apparent redistribution within the SPA is misleading and the species in question may be facing problems on those sectors not supporting an increase in numbers;
- where a species is in regional decline we would expect declines on at least some of the sectors of the Stour and Orwell SPA, regardless of whether birds are being affected by adverse factors locally. Thus, we would expect those sectors of least suitable habitat to a given species to be the first to show a decline in numbers.

2.4 Interpretation under scenarios of overcounting and undercounting

Having acknowledged that the relative methodologies of Low Tide Counts and Core Counts may have been affected by overcounting and undercounting respectively, how this will affect the interpretation of trends must be considered.

As stated earlier, these issues only arise when counts from individual sectors are amalgamated. At the individual sector level the trends represent bird usage and one aspect of the this usage may indeed be as a refuge from disturbance events elsewhere on the site and as such makes that sector important to the birds.

It is when counts from individual count sectors are amalgamated that over- and undercounting may bias subsequent interpretation.

When LTCs are amalgamated, for example to quantify bird numbers on the upper, mid and lower estuaries, then overcounting becomes problematic because it cannot be quantified. Where overcounting occurs the amalgamated counts will be inflated. Consequently:

- if the degree of overcounting is increasing through time the trend for that amalgamated sector relative to an unbiased reference population will be overly favourable;
- if the degree of overcounting is stable through time the trend for that amalgamated sector relative to an unbiased reference population will be representative and;
- if the degree of overcounting is decreasing through time the trend for that amalgamated sector relative to an unbiased reference population will be overly unfavourable:

When counts are amalgamated to give a value for the reference population (site or combination of sites) using LTCs or Core counts where overcounting occurs the amalgamated counts will be inflated. Consequently:

- if the degree of overcounting is increasing through time then trend for any single sector relative to the reference population will be overly unfavourable;
- if the degree of overcounting is stable through time then the trend for any single sector relative to the reference population will be representative;
- if the degree of overcounting is decreasing through time then the trend for any single sector relative to the reference population will be overly favourable;

When counts are amalgamated to give a value for the reference population (site or combination of sites) using LTCs or Core counts where undercounting occurs the amalgamated counts will be deflated. Consequently:

- If the degree of undercounting is increasing through time then the trend for any single sector relative to the reference population will be overly favourable;
- if the degree of undercounting is stable through time then the trend for any single sector relative to the reference population will be representative;
- if the degree of undercounting is decreasing through time then the trend for any single sector relative to the reference population will be overly unfavourable;

In the case of CCs, undercounting of the site may occur because birds are roosting on habitat that is not been visited by counters or birds may be leaving the site altogether. In the case of LTCs undercounting can be ruled out as all intertidal areas on the sites are visited and by definition, birds feeding other than on the Stour and Orwell Loe Tide Count sectors are not part of the focus population. Both CCs and LTCs could be subject to overcounting however the comparison of trends between site estimates based on the Low Tide and Core Count data imply that if overcounting is occurring with the CCs then this must be to a lesser degree than with the LTCs. This leaves the following possibilities:

- If both the LTCs and the Core counts were subject to the same degree of overcounting, then there would be little advantage in using one over the other when amalgamating counts to quantify the reference population. Both would suffer equal bias of interpretation.

- If the degree of overcounting is less for Core counts than it is for LTCs then the amalgamation of Core counts would provide a more representative reference population and resulting bias in interpretation would be reduced.

- If there is a degree of undercounting for the Core counts then the amalgamated Core counts may be no more representative of the reference population than the amalgamated LTCs. It would not be possible to determine which would be the most suitable. If there has been a increasing degree of undercounting through time then the trend in the reference population will be represented as less favourable than true trend. Consequently, favourable comparisons of a single sector to the reference population will be optimistic and unfavourable trends will be conservative.

It can therefore be argued that the CCs provides the better option for deriving the reference population as the comparisons will be either less bias than those derived from LTCs or more conservative when raising cause for concern. The latter is important when dealing with trends at the sector level rather than whole sites as numbers of birds are lower and can be expected to be affected to a greater degree by random fluctuation as birds move around within the site from one survey session to the next. Although beneficial changes may be over emphasised it is generally declines in favourability that attract conservation concern under statutory requirements and so it is important not to misinterpret trends in such a way that false concerns are raised.

3 RESULTS

3.1 Population changes by count sector

The magnitude and statistical significance of the population changes recorded for the three study species in each count sector over the recent five- and 10-year periods are shown, for the Stour and Orwell separately, in Tables 1 & 2.

Sectors are grouped by their estuary and consolidation sub-area. As well as the 81 individual count sectors, trends are also presented for the upper, mid and lower consolidations of each estuary. Trends for these amalgamated groups of sectors are picked out in the table by yellow shading.

Cells for sectors and species showing major increases or decreases are coloured. Red indicates a rapid decrease, amber a moderate decrease, pale green a moderate increase and dark green a rapid increase. Cells are not coloured for changes of between –25% and +33%.
Empty cells are those where the species was not recorded or in insufficient numbers to generate a meaningful trend.

Comparing colours across rows and columns of the tables thus gives a visual impression of similarities or differences in magnitudes and directions of change across sectors and species. For example, Knot on the Stour and on the mid Orwell sectors predominantly show increase, whereas declines predominate in the sectors on the upper Orwell. Black-tailed Godwits show rapid decline on most of the sectors they use on the Stour, but on the Orwell they were more stable and have increased substantially in the mid and upper estuary during the recent five-year period. Results by species are discussed more fully in the species sections of the Discussion.

There are few discrepancies between time periods, for particular sectors or consolidations and species; unexpected results can arise, however, when one or more of the four winters that are relevant to the starts and ends of the periods are either high or low with respect to the overall trend.

Among these three species there are no cases where trends are uniform across sectors. To some extent this is because the three species were chosen because they show interesting and different patterns. Repeating the analysis across a broader range of species might reveal similarities across species of similar ecology and so focus attention on particular potential pressures to which particular ecology traits may expose the vulnerabilities of similar species.

The same data are mapped in Figs 5–13, where the locations of the sectors are shown and their spatial relationships can be seen more clearly. Figs 5–7 show the results by estuary consolidation sub-area, and Figs 8–13 the more-detailed data for each count sector.

The full details of year-to-year changes is shown in the Appendix tables, where the annual counts and smoothed trend for each count sector appear in the left-hand graphs. Counts sectors where no species had a mean of peak counts above 20 have not been included because meaningful interpretation of trends based on so few birds are not possible.

Section	Sector	Knot		Dunlin		Black-tailed Godwit	
		5-yr	10-yr	5-yr	10-yr	5-yr	10-yr
Lower	CU001	-40%	-52%	-19%	-11%		
Lower	CU003			-42%	-36%		
Lower	CU005			-72%	-72%		
Lower	CU038	-46%	-46%	-60%	-65%		
Lower	CU039	130%	164%	4%	3%	-93%	-89%
Lower	CU040			-86%	-87%		
Lower	**Total**	57%	49%	-28%	-28%	-58%	-64%
Mid	CU002			-56%	-58%		
Mid	CU004						
Mid	CU006			-57%	-58%		
Mid	CU007			0%	-25%	-10%	-61%
Mid	CU008			-11%	-24%	-13%	-67%
Mid	CU009	1220%	1168%	-25%	-25%	-25%	-69%
Mid	CU010	353%	648%	16%	-9%		
Mid	CU011	1083%	-36%	-49%	-42%		
Mid	CU012			25%	-9%		
Mid	CU013						
Mid	CU033	542%	1173%	18%	-7%	-56%	-69%
Mid	CU034	178%	446%	92%	46%		
Mid	CU035	109%	156%	69%	35%		
Mid	CU036			21%	-15%		
Mid	CU037			-34%	-25%		
Mid	**Total**	306%	527%	13%	-2%	-17%	-58%
Upper	CU014			69%	13%		
Upper	CU015	-5%	196%	-40%	-45%	-55%	-69%
Upper	CU016	56%	276%	116%	65%	-46%	-79%
Upper	CU017	199%	51%	19%	-30%	-63%	-78%
Upper	CU018	6533%	3631%	40%	-5%	80%	77%
Upper	CU019	7%	279%	-18%	-39%	-77%	-78%
Upper	CU020	6%	13%	51%	46%	-66%	-78%
Upper	CU021			-80%	-97%		
Upper	CU022			-54%	-72%	125%	-28%
Upper	CU023	-32%	85%	-65%	-76%	87%	-49%
Upper	CU024						
Upper	CU025	-63%	-29%	-76%	-71%	-42%	-87%
Upper	CU026	340%	307%	59%	66%	-72%	-77%
Upper	CU027	68%	192%	-50%	-31%	-84%	-78%
Upper	CU028			54%	14%	19%	-11%
Upper	CU029			50%	-20%	-14%	-78%
Upper	CU030			85%	-28%	-38%	-91%
Upper	CU031	-44%	-57%	86%	-13%	0%	-63%
Upper	CU032	844%	580%	75%	-38%	-10%	-71%
Upper	**Total**	37%	140%	-1%	-27%	-43%	-73%

Table 1. Table of population trends on the Stour, by assessment period and count sector.

Section	Sector	Knot		Dunlin		Black-tailed Godwit	
		5-yr	10-yr	5-yr	10-yr	5-yr	10-yr
Lower	EW009			-10%	-77%		
Lower	EW010			-91%	-96%		
Lower	EW011			-6%	-65%		
Lower	EW012						
Lower	EW013						
Lower	EW027						
Lower	EW028						
Lower	EW029						
Lower	EW030			-20%	-91%		
Lower	EW031	293%	57%	-97%	-100%		
Lower	EW032						
Lower	EW033			-100%	-100%		
Lower	EW034						
Lower	**Total**	425%	500%	7%	-56%	12%	211%
Mid	EW006	-39%	240%	-52%	-76%	243%	41%
Mid	EW007			-13%	-80%		
Mid	EW008	116%	1500%	-13%	-79%		
Mid	EW014	81%	23%	-23%	-74%		
Mid	EW015	134%	804%	-5%	-74%		
Mid	EW016	139%	1361%	8%	-75%	220%	-30%
Mid	EW019			10%	-90%		
Mid	EW020			-11%	-82%	185%	-16%
Mid	EW024						
Mid	EW025						
Mid	EW026	443%	-7%	122%	-77%	220%	-45%
Mid	EW035						
Mid	EW036						
Mid	EW037	59%	-57%	-41%	-93%	458%	29%
Mid	EW038	40%	-38%	-49%	-95%		
Mid	EW039						
Mid	EW040						
Mid	EW041	52%	-48%	-51%	-95%	295%	-9%
Mid	**Total**	129%	-13%	6%	-60%	405%	113%
Upper	EW001						
Upper	EW002						
Upper	EW003	-73%	-89%	-82%	-98%		
Upper	EW004	136%	1200%	17%	-75%		
Upper	EW005	-5%	-27%	-28%	-78%	64%	-20%
Upper	EW017	-22%	-39%	-69%	-90%	97%	42%
Upper	EW018	-82%	-75%	-89%	-93%	-42%	0%
Upper	EW021						
Upper	EW022	-75%	-86%	-62%	-95%		
Upper	EW023						
Upper	**Total**	-25%	-39%	-61%	-86%	53%	-15%

Table 2. Table of population trends on the Orwell, by assessment period and count sector.

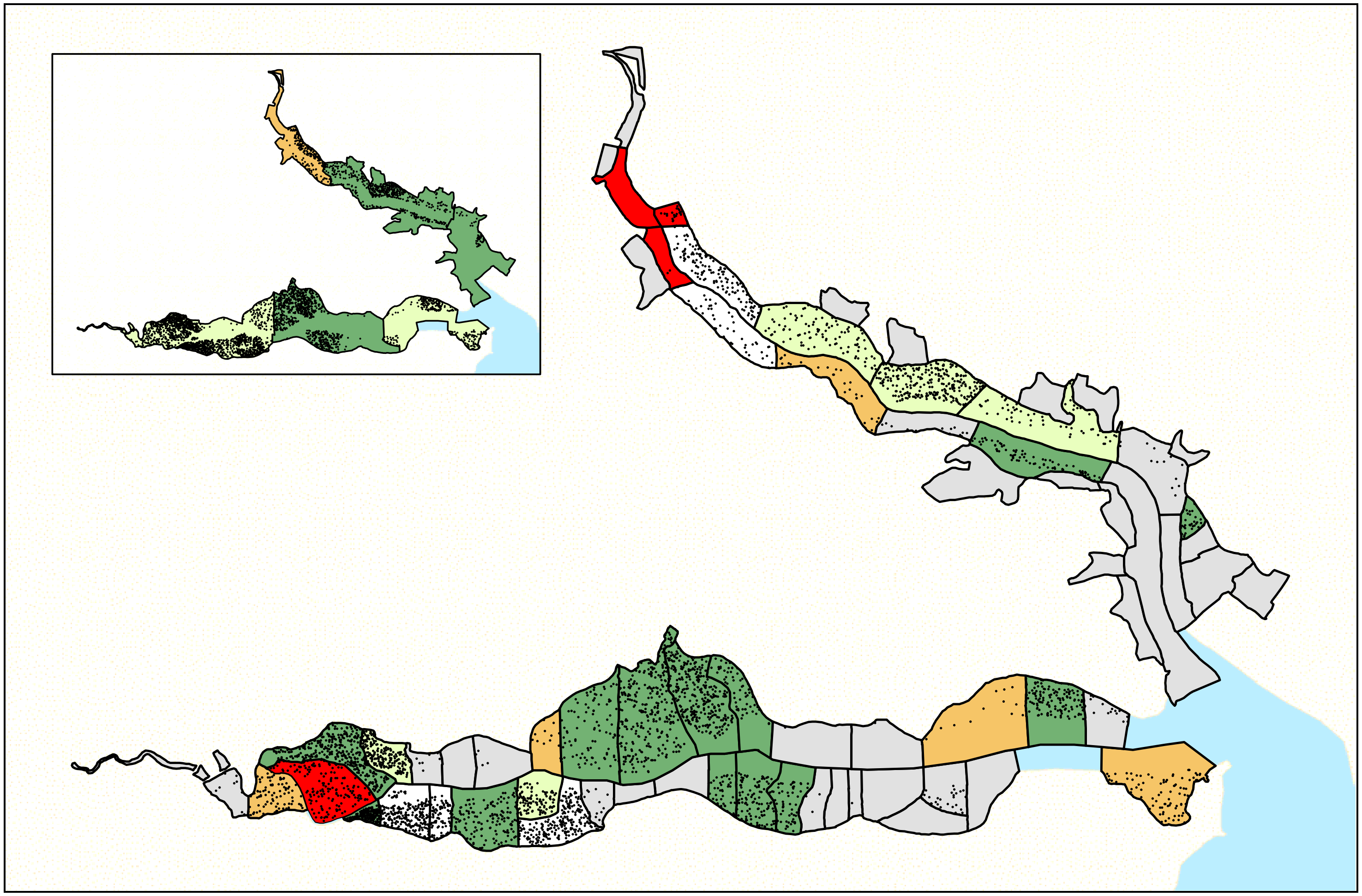


Figure 5. Knot 5-yr trends on the Stour and Orwell Estuaries. Main figure: individual count sectors; Inset: lower, mid and upper estuary sector consolidations. Red: >50% decline; Orange:25%-50% decline: white: decline <25% or increase <33% (i.e. “no substantial change”); pale green: increase 33%-100%; dark green: increase >100%; grey: insufficient birds for meaningful trend analysis. Dots show the most recent five-year mean distribution of birds by sector, with each dot representing five birds.

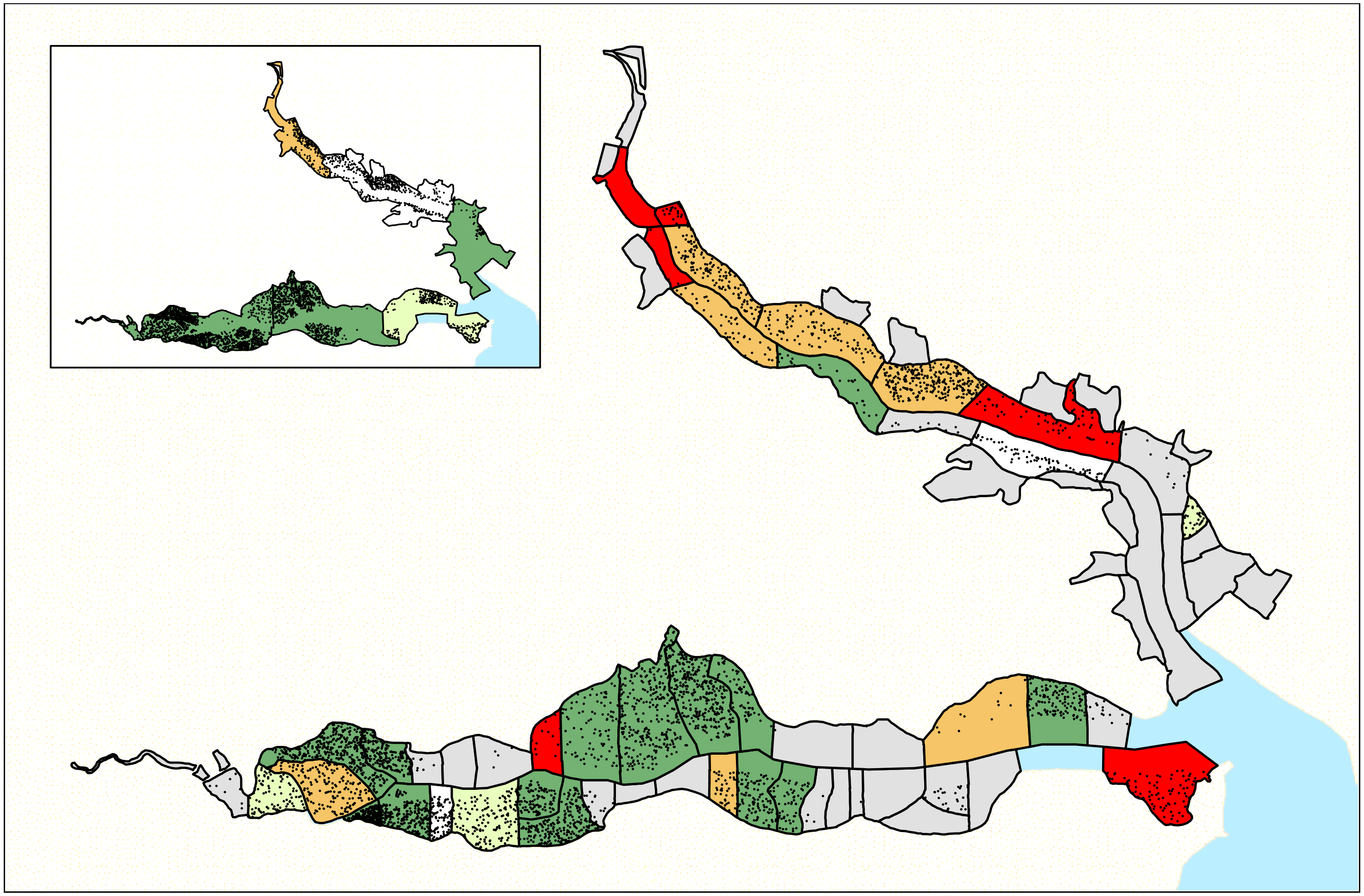


Figure 6. Knot 10-yr trends on the Stour and Orwell Estuaries. Main figure: individual count sectors; Inset: lower, mid and upper estuary sector consolidations. Red: >50% decline; Orange:25%-50% decline: white: decline <25% or increase <33% (i.e. “no substantial change”); pale green: increase 33%-100%; dark green: increase >100%; grey: insufficient birds for meaningful trend analysis. Dots show the most recent five-year mean distribution of birds by sector, with each dot representing five birds.

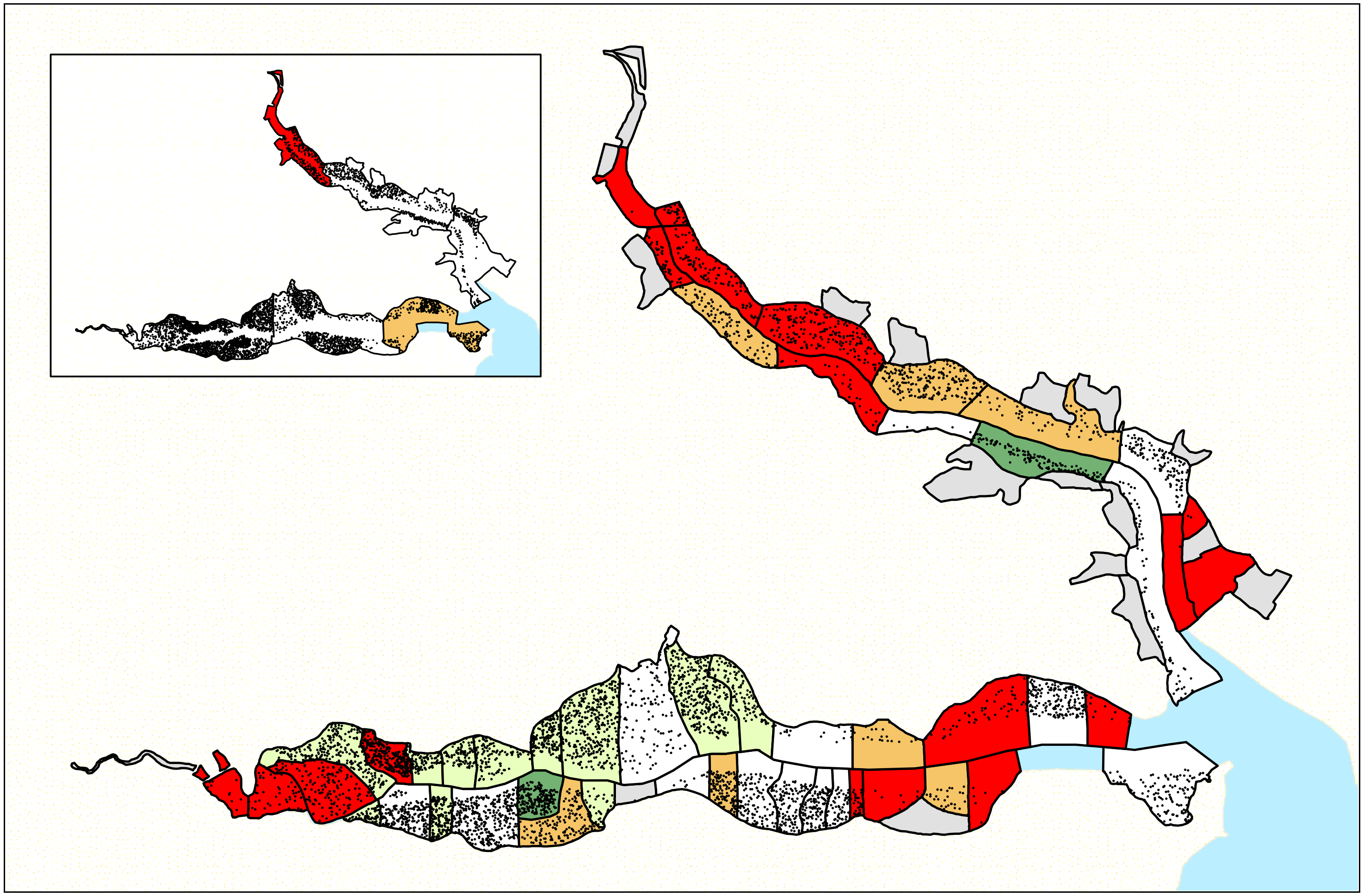


Figure 7. Dunlin 5-yr trends on the Stour and Orwell Estuaries. Main figure: individual count sectors; Inset: lower, mid and upper estuary sector consolidations. Red: >50% decline; Orange:25%-50% decline: white: decline <25% or increase <33% (i.e. "no substantial change"); pale green: increase 33%-100%; dark green: increase >100%; grey: insufficient birds for meaningful trend analysis. Dots show the most recent five-year mean distribution of birds by sector, with each dot representing ten birds.

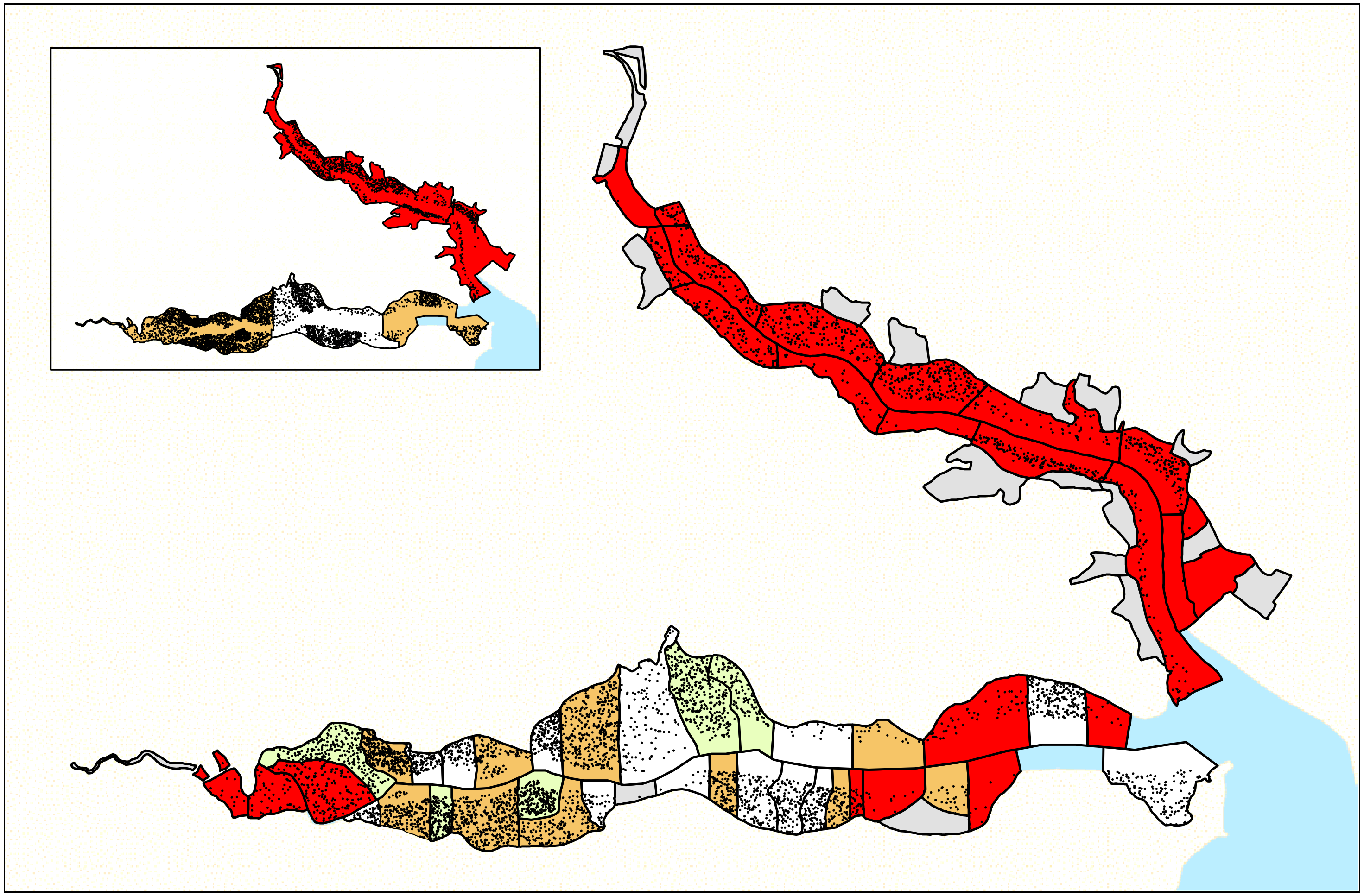


Figure 8. Dunlin 10-yr trends on the Stour and Orwell Estuaries. Main figure: individual count sectors; Inset: lower, mid and upper estuary sector consolidations. Red: >50% decline; Orange:25%-50% decline: white: decline <25% or increase <33% (i.e. “no substantial change”); pale green: increase 33%-100%; dark green: increase >100%; grey: insufficient birds for meaningful trend analysis. Dots show the most recent five-year mean distribution of birds by sector, with each dot representing five birds.

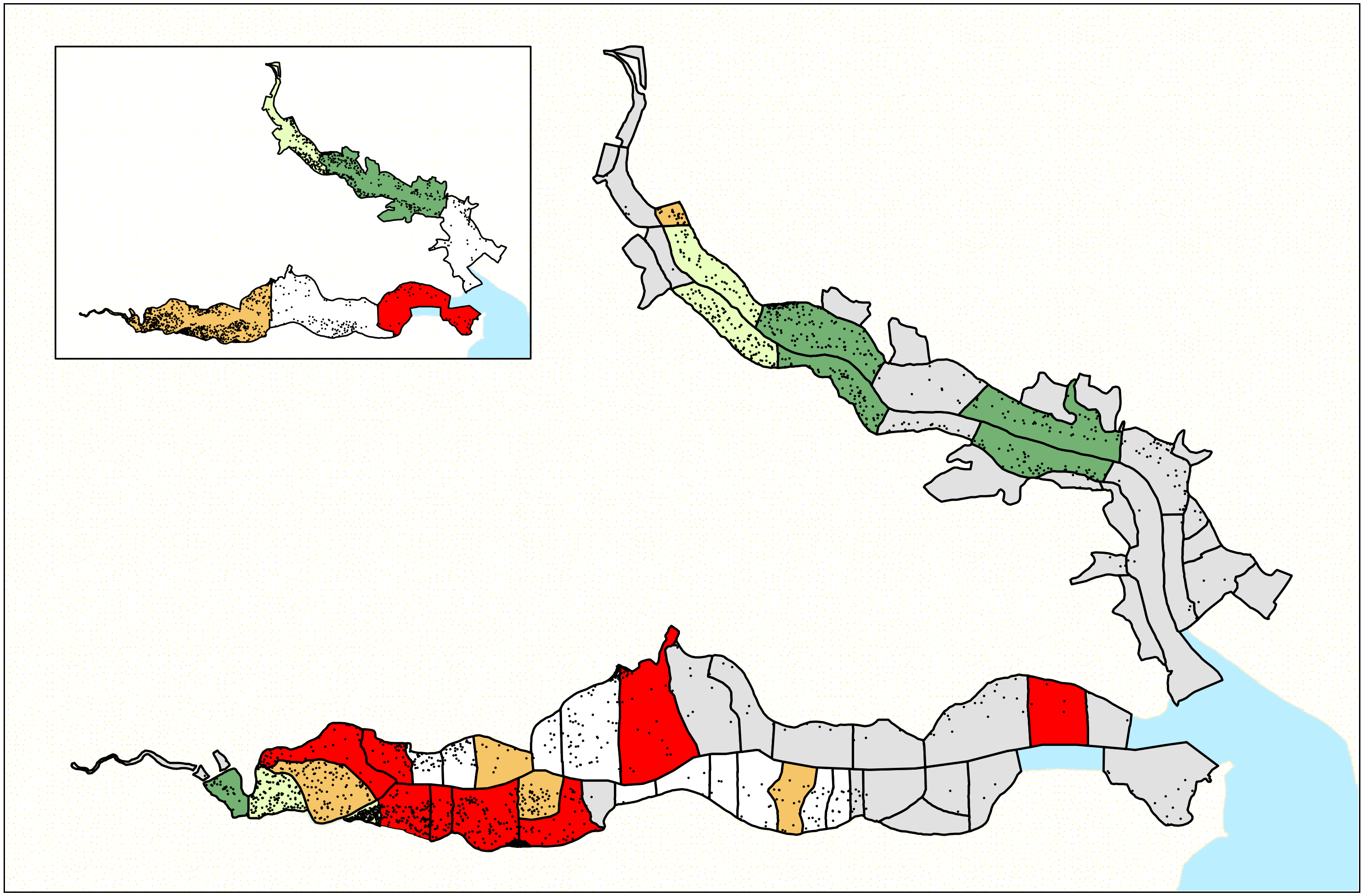


Figure 9. Black-tailed Godwit 5-yr trends on the Stour and Orwell Estuaries. Main figure: individual count sectors; Inset: lower, mid and upper estuary sector consolidations. Red: >50% decline; Orange:25%-50% decline: white: decline <25% or increase <33% (i.e. "no substantial change"); pale green: increase 33%-100%; dark green: increase >100%; grey: insufficient birds for meaningful trend analysis. Dots show the most recent five-year mean distribution of birds by sector, with each dot representing one bird.

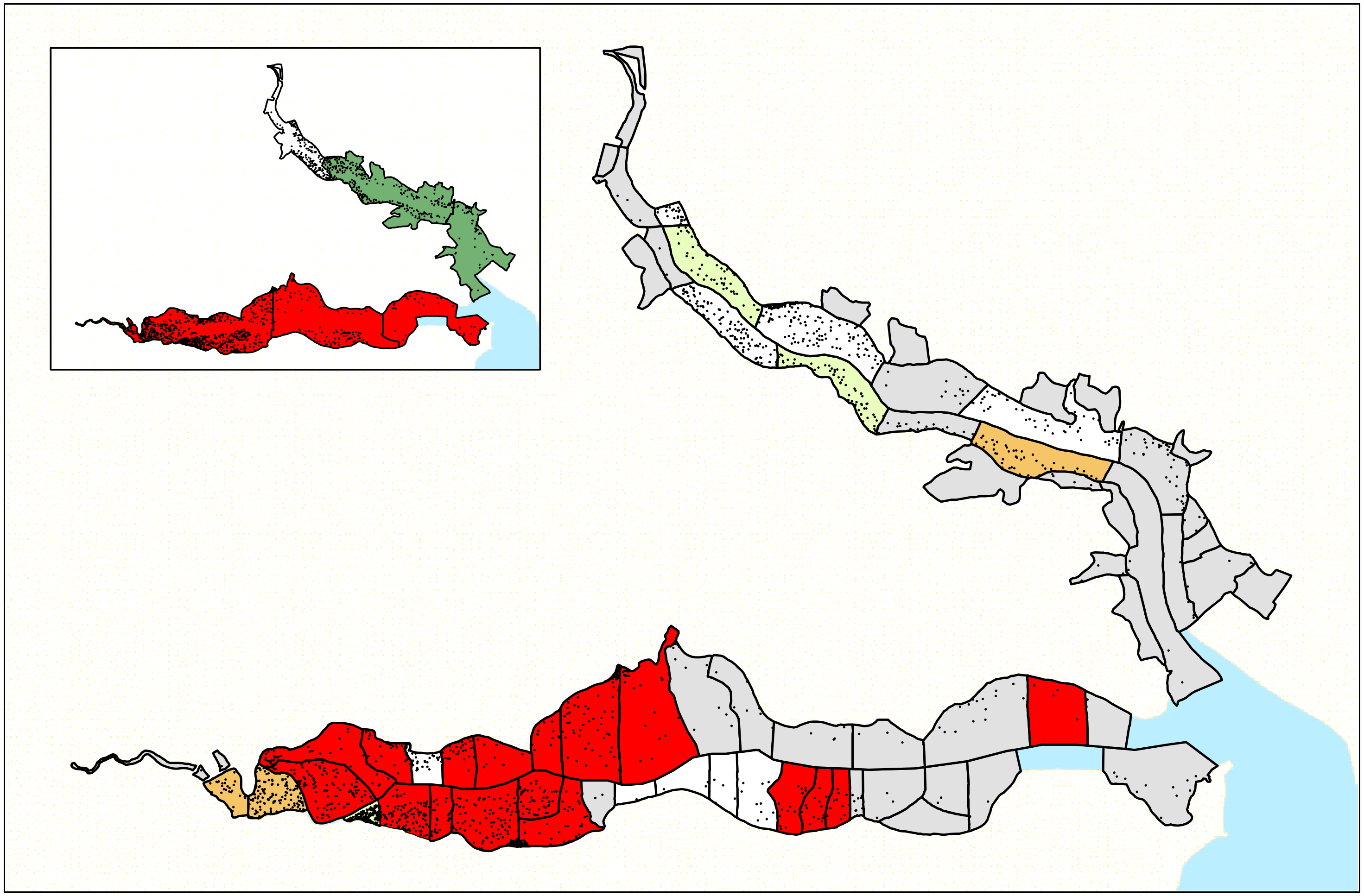


Figure 10. Black-tailed Godwit 10-yr trends on the Stour and Orwell Estuaries. Main figure: individual count sectors; Inset: lower, mid and upper estuary sector consolidations. Red: >50% decline; Orange:25%-50% decline: white: decline <25% or increase <33% (i.e. “no substantial change”); pale green: increase 33%-100%; dark green: increase >100%; grey: insufficient birds for meaningful trend analysis. Dots show the most recent five-year mean distribution of birds by sector, with each dot representing one bird.

3.2 Proportional changes by count sector, in wider local contexts

The results of comparisons between sector trends and trends in wider contexts are shown in Tables 3–9. In these tables, cells are coloured where there is a statistically significant slope to the trend for the sector, after correction for the trend for the wider region, irrespective of the steepness of that slope. Red and amber both indicate significant residual decreases, with red where there is a probability of at least 99% that the slope is not equal to zero, and amber a probability of at least 95%. Green colours indicate significant residual increases, with dark green indicating a probability of at least 99% that the slope is not equal to zero, and light green a probability of at least 95%. The actual values of the modelled slope are also given. Because the trends are more biologically meaningful the more birds are present in the sector, the five-year means of peak counts of birds in the sector are also tabulated.

Slopes and significance are not reported where the mean of peak counts of birds is below 20, since small counts are more likely to produce large chance variations in the proportional counts and throw up results which are apparently significant but which in reality are more likely to be spurious. It is possible for results still to be unreliable even where the mean count is over 100. In sector 12 in the lower Orwell, for example, Dunlin were normally absent except for a very large count in winter 2006/07, putting the mean count over the reporting threshold; the trend has been modelled as a massively steep (but statistically insignificant) increase.

In comparison with the estuary, green means that the consolidation or sector showed a significantly more positive population trend than did the whole estuary. This can arise, for example, where the trend in the estuary is a decrease but within the consolidation or sector there was an increase, stability, or a less steep decrease than in the whole estuary. Red means that trends in the consolidation or sector were significantly more negative than in the whole estuary. In some cases, however, a trend at estuary level may mean that birds have redistributed, perhaps temporarily, to another estuary nearby.

In comparison with the Stour and Orwell together, green would show that the trend in the consolidation or sector was more positive than was found in the whole SPA, and red that it was more negative. This comparison would be valid irrespective of any redistribution that might have occurred between the two estuaries.

Similarly, comparisons with the wider group of estuaries (SODHW) treat the birds within this whole group of sites as a single population, liable to use different estuaries within the group in different months. Comparisons are valid irrespective of any redistribution of birds that may have occurred within this wider group of sites.

In all comparisons, unshaded cells indicate that the trend in the consolidation or sector is effectively the same as that in the wider region. In this case, it is unlikely that any trends observed derive from local causes; rather, they are the product of factors impacting at a wider geographical scale.

3.2.1 Summed LTCs for estuary sub-area consolidations

In Table 3, summed LTCs for estuary sub-area consolidations are compared with the estuary as a whole, the Stour and Orwell together, and the SODHW region. Because these are summed LTCs, not actual LTCs as they are from individual sectors, these results require treating with some caution: this is because the sum of LTCs from adjacent sectors will contain an unknown and variable amount of overcounting i.e. multiple counts of the same individuals.

Consolidation	Species	5-yr mean of peaks	Estuary		Stour+Orwell		Stour+Orwell+Deben+ Hamford Water	
Stour Lower	Knot	1141	-0.04	ns	-0.04	ns	-0.02	ns
	Dunlin	1689	0.03	**	0.05	***	0.03	**
	Black-tailed Godwit	40	-0.03	ns	-0.02	ns	-0.04	ns
Stour Mid	Knot	3270	0.10	***	0.09	***	0.11	***
	Dunlin	4262	0.05	***	0.09	***	0.05	***
	Black-tailed Godwit	139	-0.02	ns	-0.02	ns	-0.03	*
Stour Upper	Knot	5245	-0.03	ns	-0.04	ns	-0.02	ns
	Dunlin	9879	-0.07	ns	0.06	*	0.04	*
	Black-tailed Godwit	1021	-0.07	ns	-0.03	ns	-0.04	ns
Orwell Lower	Knot	246	0.13	*	0.15	ns	0.16	ns
	Dunlin	854	-0.01	ns	-0.07	*	-0.09	**
	Black-tailed Godwit	56	0.07	*	0.06	ns	0.03	ns
Orwell Mid	Knot	2074	-0.01	ns	0.06	ns	0.04	ns
	Dunlin	2152	-0.06	ns	-0.08	**	-0.11	***
	Black-tailed Godwit	330	0.04	ns	0.07	ns	0.06	ns
Orwell Upper	Knot	878	-0.03	ns	-0.09	ns	-0.15	**
	Dunlin	1092	-0.07	ns	-0.21	***	-0.23	***
	Black-tailed Godwit	280	-0.01	ns	-0.02	ns	-0.03	ns

Table 3. Summed Low Tide Counts for upper middle and lower consolidations of the Stour and Orwell, and comparison of trends with those of the whole estuary (Stour or Orwell), the Stour and Orwell together, and the wider group of local estuaries (including the Deben and Hamford Water).

The full details of year-to-year comparisons are shown in Figs 14–19, where the annual counts and smoothed trend for each estuary sub-area consolidation appear in the left-hand graphs, and the three graphs to the right are for the comparisons with the estuary, Stour and Orwell together, and the SODHW region. Solid dots represent actual cou and open dots represent counts wholly or partially imputed by the GAM analysis.

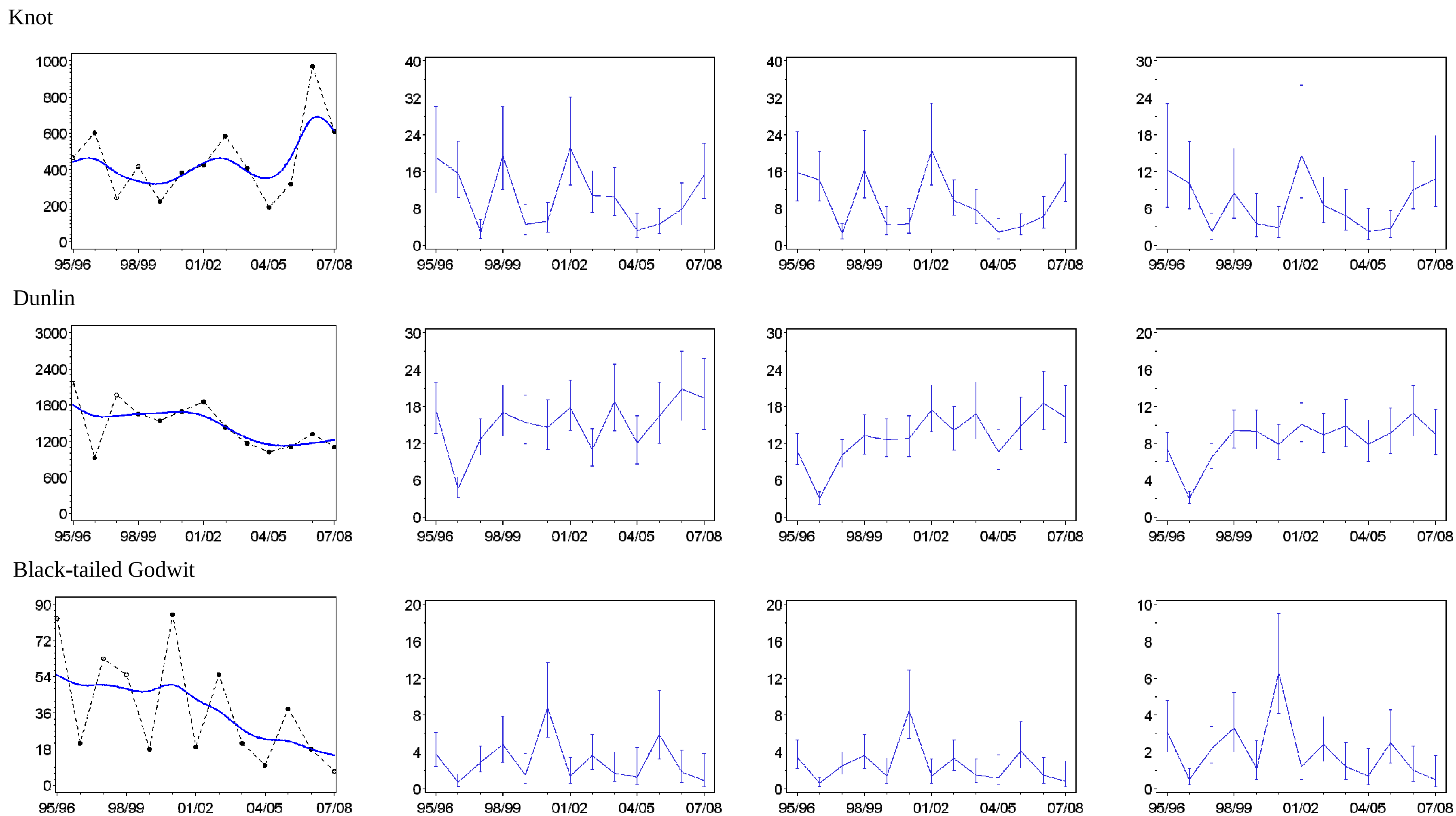


Figure 11. Population trends of each species in the Lower Stour consolidation (left-hand graphs), and the proportional population found in this consolidation per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

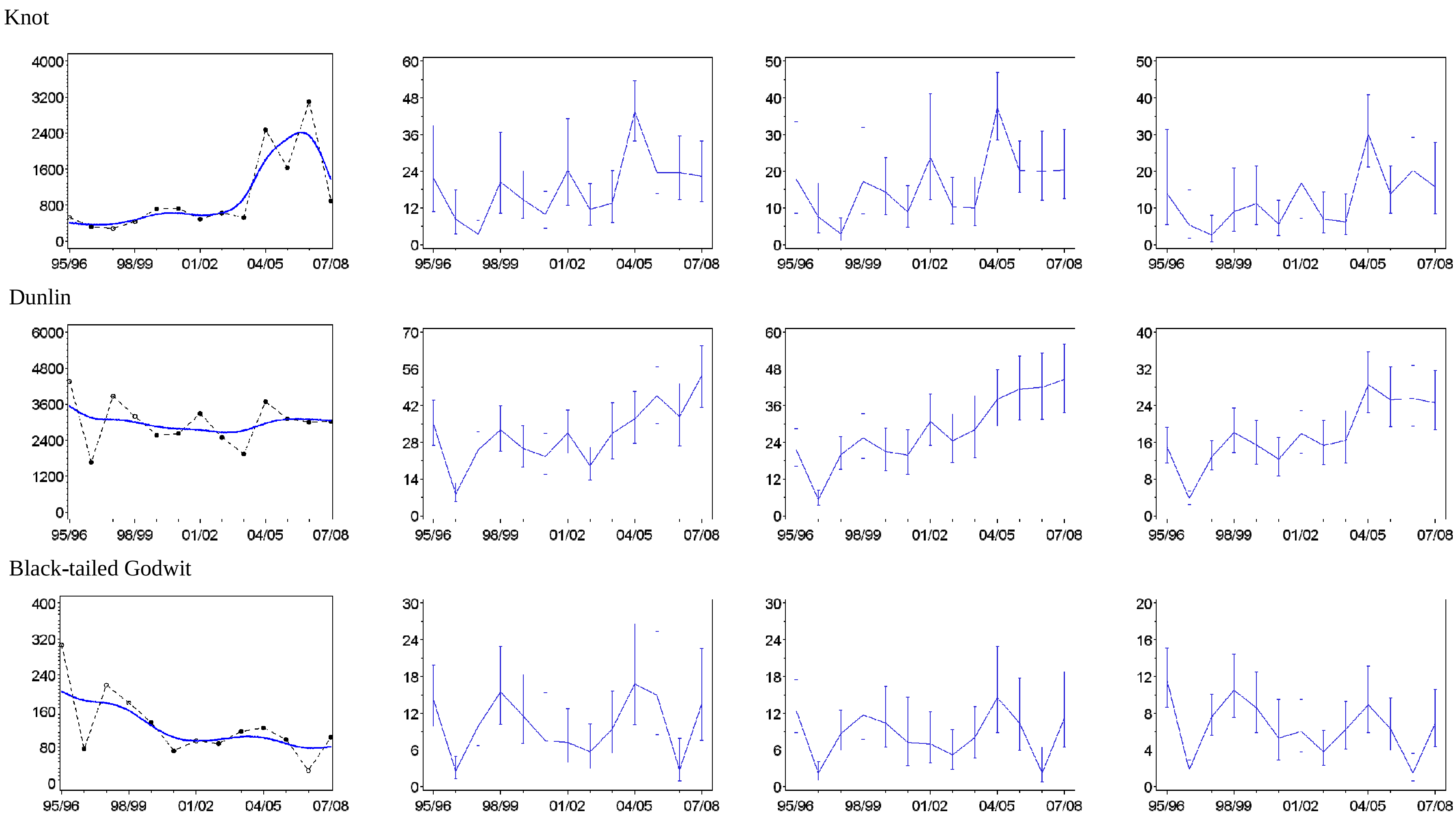
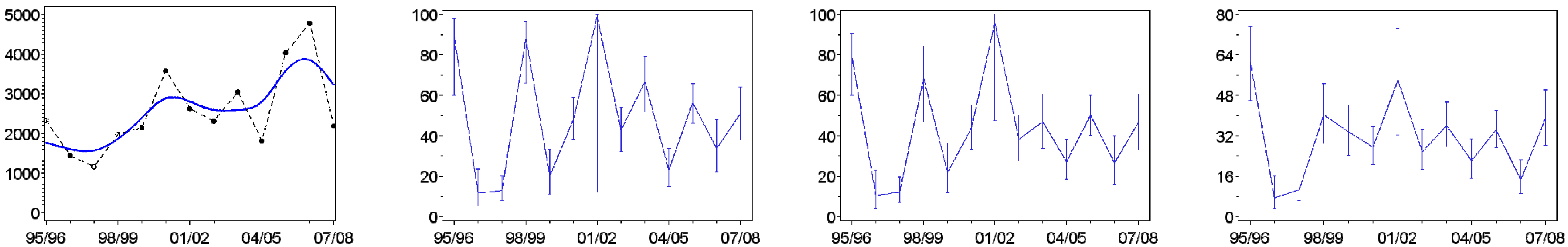
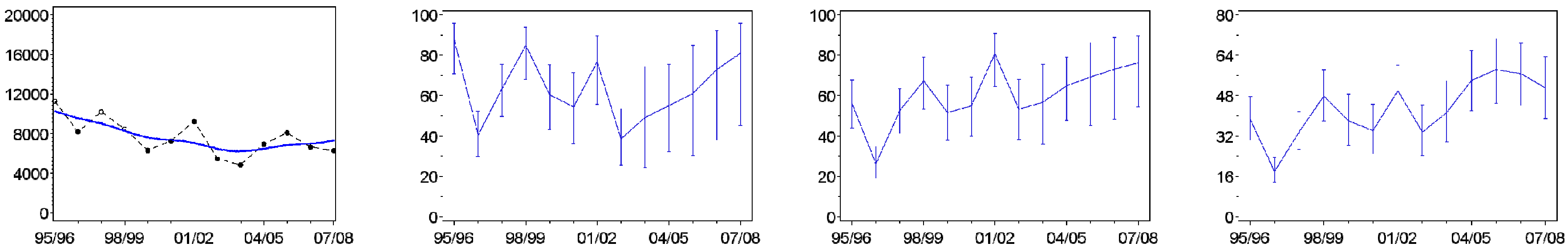


Figure 12. Population trends of each species in the Mid Stour consolidation (left-hand graphs), and the proportional population found in this consolidation per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

Knot



Dunlin



Black-tailed Godwit

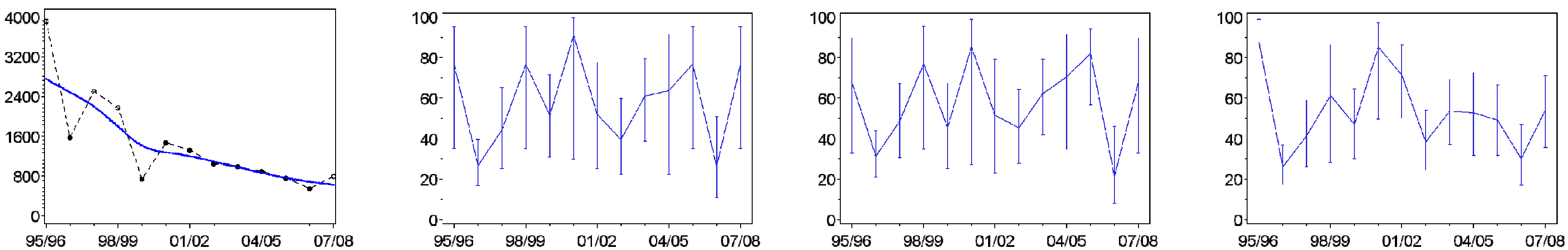


Figure 13. Population trends of each species in the Upper Stour consolidation (left-hand graphs), and the proportional population found in this consolidation per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

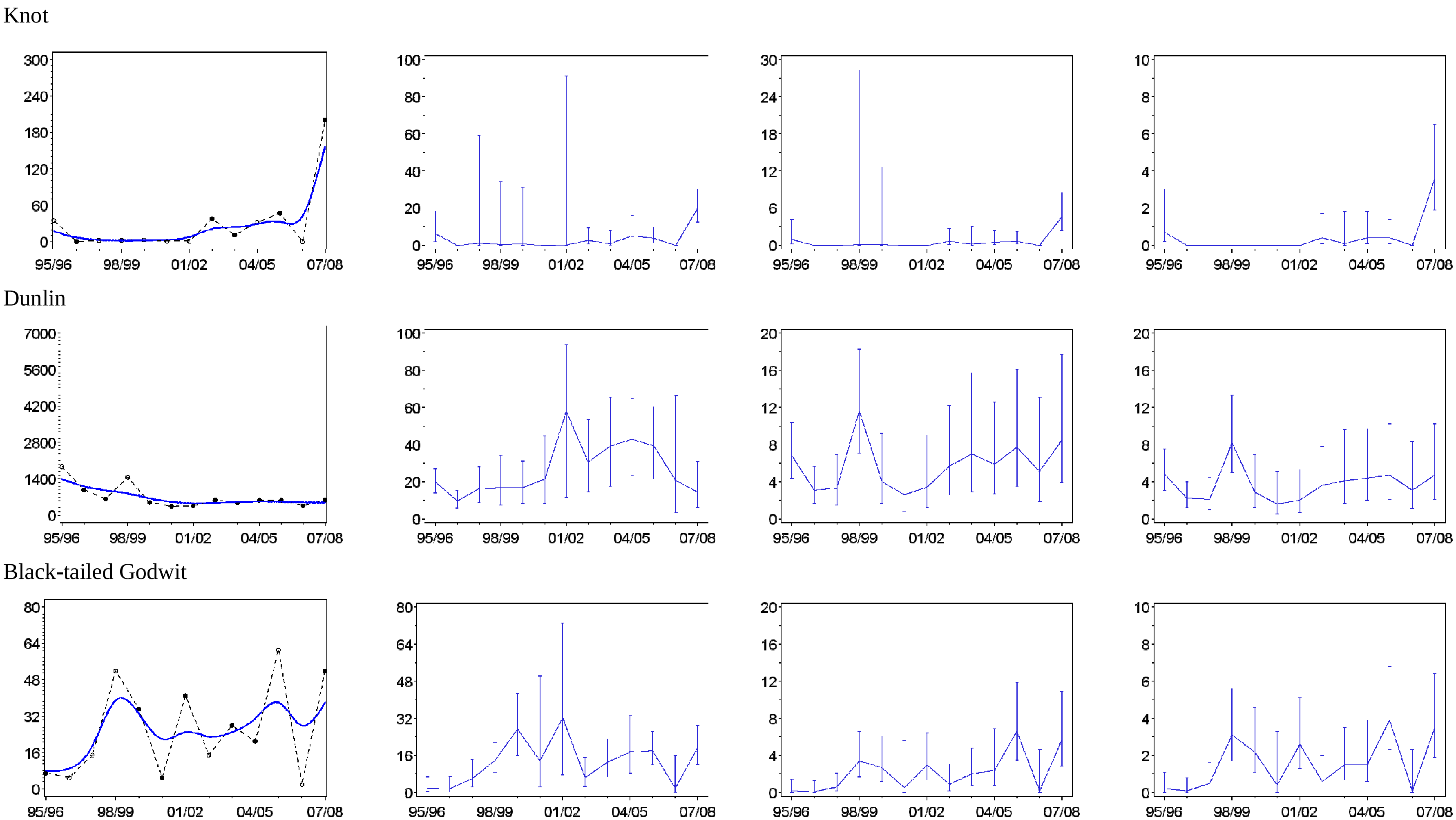


Figure 14. Population trends of each species in the Lower Orwell consolidation (left-hand graphs), and the proportional population found in this consolidation per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

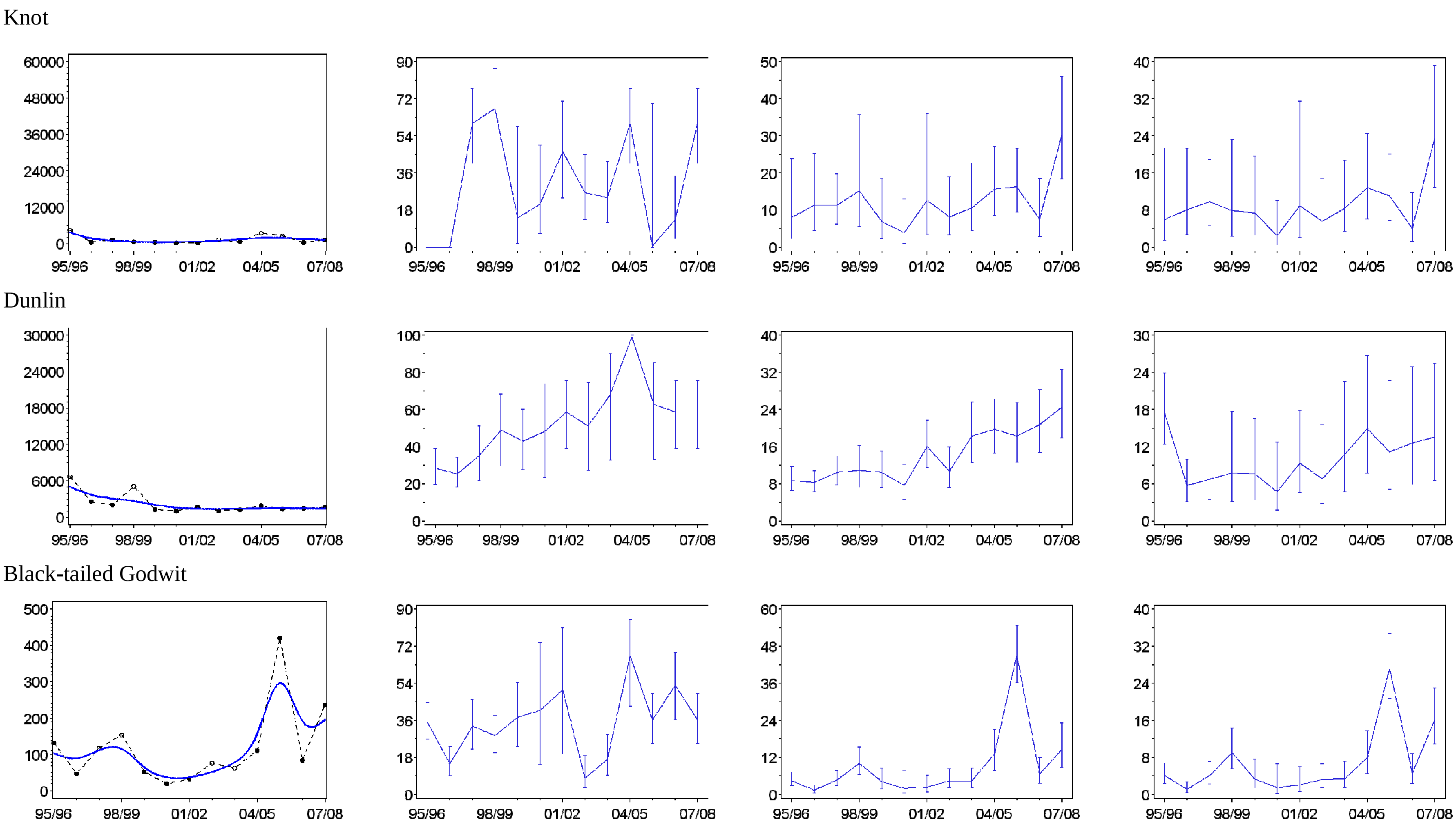


Figure 15. Population trends of each species in the Mid Orwell consolidation (left-hand graphs), and the proportional population found in this consolidation per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

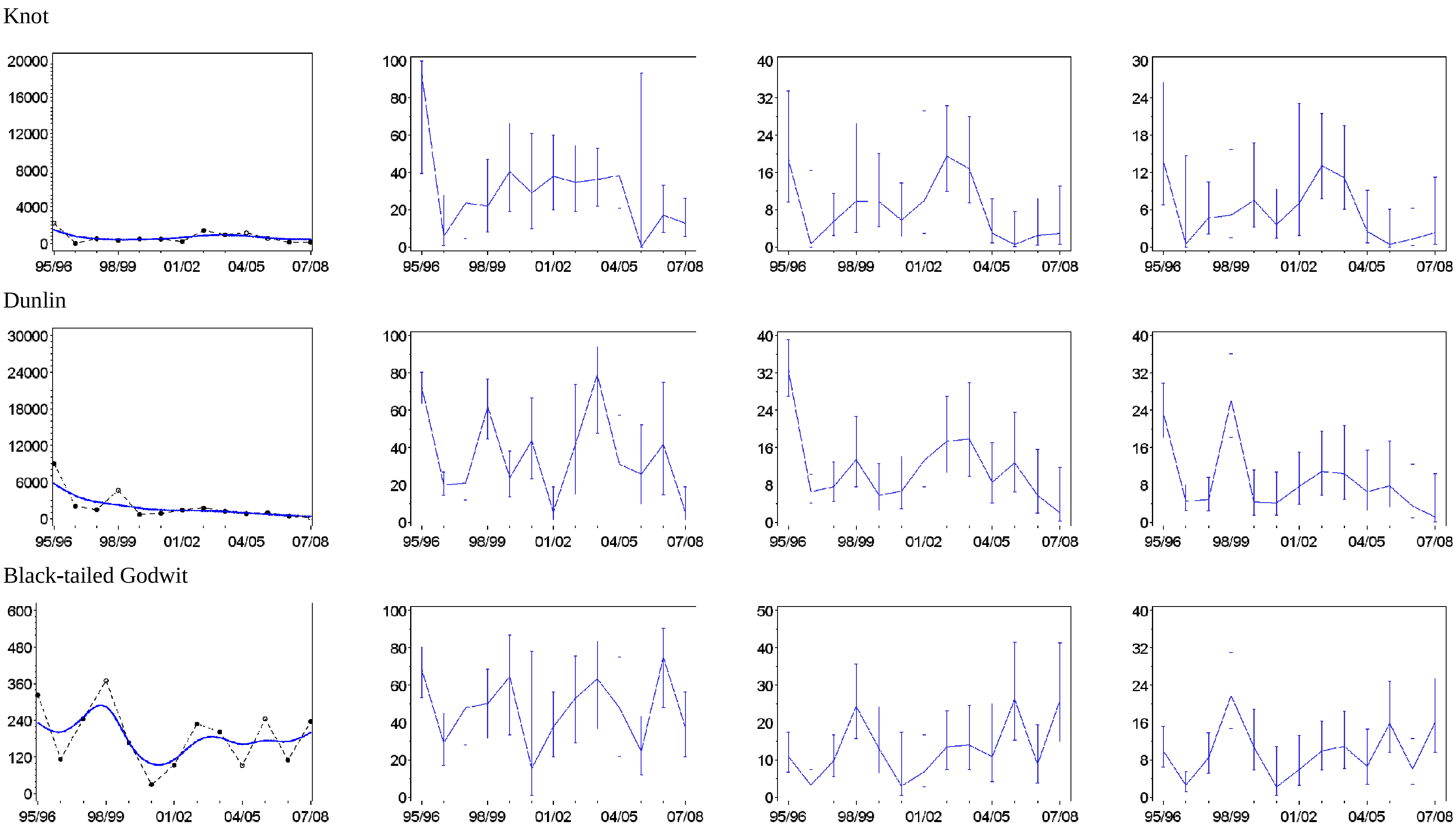


Figure 16. Population trends of each species in the Upper Orwell consolidation (left-hand graphs), and the proportional population found in this consolidation per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

3.2.2 LTCs by count sector

Tables 4 & 5 show the results for Knot on the Stour and Orwell Estuaries respectively. No results are presented where the five-year mean of peak counts is below 20 birds. Tables 6 & 7 are the equivalent tables for Dunlin, and Tables 8 & 9 those for Black-tailed Godwit.

The full details of year-to-year comparisons are shown in the Appendix, where the annual counts and smoothed trend for each count sector appear in the left-hand graphs, and the three graphs to the right are for the comparisons with the estuary, Stour and Orwell together, and the SODHW region. Figs S1–S36 are for count sectors on the Stour, and Figs O1–O14 for sectors on the Orwell. No graphs are presented for sectors where all three species were absent or had a mean five-year peak count of less than 20 birds.

Sector	Consolidation	5-yr mean of peaks	Estuary		Stour+Orwell		Stour+Orwell+Deben+Hamford Water	
CU001	Lower	417	-0.07	*	-0.07	*	-0.08	**
CU003	Lower	135	0.26	ns	0.25	ns	0.26	ns
CU005	Lower	0						
CU038	Lower	60	-0.08	*	-0.08	**	-0.09	**
CU039	Lower	682	-0.01	ns	0.03	ns	0.03	ns
CU040	Lower	83	0.24	ns	0.23	ns	0.24	ns
CU002	Mid	1						
CU004	Mid	0						
CU006	Mid	6						
CU007	Mid	2						
CU008	Mid	20	-0.06	ns	-0.07	ns	-0.07	ns
CU009	Mid	294	0.17	ns	0.16	ns	0.17	ns
CU010	Mid	531	0.15	ns	0.14	ns	0.14	ns
CU011	Mid	198	-0.05	ns	-0.06	ns	-0.06	ns
CU012	Mid	1						
CU013	Mid	0						
CU033	Mid	1430	0.15	***	0.14	***	0.18	***
CU034	Mid	1550	0.08	*	0.09	**	0.09	**
CU035	Mid	307	0.13	ns	0.12	ns	0.12	ns
CU036	Mid	7						
CU037	Mid	4						
CU014	Upper	67	-0.06	ns	-0.05	ns	-0.07	ns
CU015	Upper	1204	0.04	ns	0.04	ns	0.04	ns
CU016	Upper	553	0.08	ns	0.08	ns	0.08	ns
CU017	Upper	719	0.02	ns	0.01	ns	0.01	ns
CU018	Upper	1038	0.16	ns	0.25	*	0.26	*
CU019	Upper	1169	-0.01	ns	-0.02	ns	0.04	ns
CU020	Upper	442	0.00	ns	-0.01	ns	-0.01	ns
CU021	Upper	0						
CU022	Upper	43	0.84	***	0.86	***	0.88	***
CU023	Upper	442	0.01	ns	0.00	ns	0.00	ns
CU024	Upper	0						
CU025	Upper	803	-0.07	*	-0.07	*	-0.08	**
CU026	Upper	1679	-0.01	ns	-0.01	ns	0.06	ns
CU027	Upper	999	0.04	ns	0.03	ns	0.03	ns
CU028	Upper	37	-0.03	ns	-0.03	ns	-0.04	ns
CU029	Upper	0						
CU030	Upper	22	-0.10	ns	-0.10	ns	-0.11	ns
CU031	Upper	62	-0.10	ns	-0.10	ns	-0.11	ns
CU032	Upper	458	0.16	***	0.15	**	0.16	**

Table 4. Low Tide Counts for Knot on the Stour Estuary, by count sector, and comparison of trends with those for wider areas.

Sector	Consolidation	5-yr mean of peaks	Estuary		Stour+Orwell		Stour+Orwell+Deben+Hamford Water	
EW009	Lower	0						
EW010	Lower	0						
EW011	Lower	63	0.06	ns	0.08	ns	0.09	ns
EW012	Lower	0						
EW013	Lower	0						
EW027	Lower	0						
EW028	Lower	0						
EW029	Lower	0						
EW030	Lower	0						
EW031	Lower	184	-0.05	ns	-0.03	ns	-0.04	ns
EW032	Lower	0						
EW033	Lower	0						
EW034	Lower	0						
EW006	Mid	136	0.01	ns	0.03	ns	0.03	ns
EW007	Mid	0						
EW008	Mid	0						
EW014	Mid	0						
EW015	Mid	0						
EW016	Mid	0						
EW019	Mid	64	0.08	*	0.11	ns	0.11	ns
EW020	Mid	0						
EW024	Mid	0						
EW025	Mid	0						
EW026	Mid	376	-0.15	ns	-0.12	ns	-0.13	ns
EW035	Mid	0						
EW036	Mid	0						
EW037	Mid	310	-0.16	*	-0.16	*	-0.20	**
EW038	Mid	1406	-0.11	ns	-0.07	ns	-0.07	ns
EW039	Mid	0						
EW040	Mid	0						
EW041	Mid	510	-0.20	**	-0.15	**	-0.16	**
EW001	Upper	0						
EW002	Upper	0						
EW003	Upper	1						
EW004	Upper	0						
EW005	Upper	210	0.03	ns	-0.14	*	-0.15	*
EW017	Upper	691	-0.13	*	-0.09	ns	-0.15	*
EW018	Upper	116	-0.09	*	-0.09	ns	-0.10	ns
EW021	Upper	0						
EW022	Upper	13						
EW023	Upper	0						

Table 5. Low Tide Counts for Knot on the Orwell Estuary, by count sector, and comparison of trends with those for wider areas.

Sector	Consolidation	5-yr mean of peaks	Estuary		Stour+Orwell		Stour+Orwell+Deben+Hamford Water	
CU001	Lower	607	0.04	***	0.06	***	0.04	***
CU003	Lower	147	0.00	ns	0.03	ns	0.01	ns
CU005	Lower	28	-0.04	ns	-0.02	ns	-0.04	ns
CU038	Lower	255	-0.02	ns	0.00	ns	-0.02	ns
CU039	Lower	965	0.05	***	0.07	***	0.05	***
CU040	Lower	49	-0.06	*	-0.04	ns	-0.06	*
CU002	Mid	50	-0.02	ns	0.01	ns	-0.02	ns
CU004	Mid	1						
CU006	Mid	156	-0.01	ns	0.01	ns	-0.01	ns
CU007	Mid	349	0.03	ns	0.05	**	0.03	ns
CU008	Mid	605	0.03	*	0.05	***	0.03	*
CU009	Mid	590	0.03	*	0.05	***	0.03	*
CU010	Mid	590	0.04	*	0.06	***	0.04	*
CU011	Mid	620	0.03	ns	0.05	ns	0.03	ns
CU012	Mid	52	0.04	*	0.06	***	0.04	*
CU013	Mid	5						
CU033	Mid	554	0.04	*	0.06	***	0.04	*
CU034	Mid	1683	0.08	***	0.10	***	0.07	***
CU035	Mid	532	0.08	***	0.10	***	0.08	***
CU036	Mid	81	0.03	ns	0.05	ns	0.03	ns
CU037	Mid	102	0.03	ns	0.05	**	0.03	ns
CU014	Upper	185	0.06	**	0.08	***	0.06	***
CU015	Upper	769	0.00	ns	0.03	*	0.01	ns
CU016	Upper	1144	0.09	***	0.11	***	0.09	***
CU017	Upper	1781	0.02	ns	0.05	***	0.03	ns
CU018	Upper	291	0.03	ns	0.05	*	0.03	ns
CU019	Upper	1004	0.01	ns	0.03	ns	0.01	ns
CU020	Upper	848	0.09	***	0.11	***	0.09	***
CU021	Upper	3						
CU022	Upper	64	-0.02	ns	0.00	ns	-0.02	ns
CU023	Upper	228	-0.02	ns	0.00	ns	-0.02	ns
CU024	Upper	4						
CU025	Upper	757	-0.01	ns	0.01	ns	-0.01	ns
CU026	Upper	1224	0.07	**	0.09	***	0.07	**
CU027	Upper	1567	0.01	ns	0.04	ns	0.02	ns
CU028	Upper	535	0.06	**	0.09	***	0.07	**
CU029	Upper	449	0.03	*	0.06	***	0.04	*
CU030	Upper	548	0.02	ns	0.05	*	0.03	ns
CU031	Upper	861	0.05	*	0.07	***	0.05	*
CU032	Upper	1859	0.02	ns	0.04	*	0.02	ns

Table 6. Low Tide Counts for Dunlin on the Stour Estuary, by count sector, and comparison of trends with those for wider areas.

Sector	Consolidation	5-yr mean of peaks	Estuary		Stour+Orwell		Stour+Orwell+Deben+Hamford Water	
EW009	Lower	0						
EW010	Lower	5						
EW011	Lower	630	-0.02	ns	-0.09	**	-0.11	**
EW012	Lower	119	23.17	ns	23.65	ns	23.61	ns
EW013	Lower	0						
EW027	Lower	0						
EW028	Lower	0						
EW029	Lower	0						
EW030	Lower	348	-0.03	ns	-0.11	***	-0.13	***
EW031	Lower	9						
EW032	Lower	0						
EW033	Lower	0						
EW034	Lower	0						
EW006	Mid	125	-0.04	ns	-0.11	**	-0.13	***
EW007	Mid	0						
EW008	Mid	0						
EW014	Mid	0						
EW015	Mid	0						
EW016	Mid	0						
EW019	Mid	26	-0.06	*	-0.14	***	-0.16	***
EW020	Mid	0						
EW024	Mid	0						
EW025	Mid	0						
EW026	Mid	697	-0.03	ns	-0.09	**	-0.11	**
EW035	Mid	0						
EW036	Mid	0						
EW037	Mid	332	-0.13	***	-0.17	***	-0.19	***
EW038	Mid	1050	-0.18	***	-0.19	***	-0.21	***
EW039	Mid	0						
EW040	Mid	0						
EW041	Mid	980	0.01	ns	-0.21	***	-0.21	***
EW001	Upper	0						
EW002	Upper	0						
EW003	Upper	7						
EW004	Upper	0						
EW005	Upper	488	-0.06	ns	-0.12	***	-0.14	***
EW017	Upper	490	-0.16	***	-0.25	***	-0.27	***
EW018	Upper	169	-0.08	ns	-0.11	**	-0.14	***
EW021	Upper	0						
EW022	Upper	198	-0.07	*	-0.13	***	-0.15	***
EW023	Upper	8						

Table 7. Low Tide Counts for Dunlin on the Orwell Estuary, by count sector, and comparison of trends with those for wider areas.

Sector	Consolidation	5-yr mean of peaks	Estuary		Stour+Orwell		Stour+Orwell+Deben+Hamford Water	
CU001	Lower	24	0.06	ns	0.07	ns	0.04	ns
CU003	Lower	3						
CU005	Lower	2						
CU038	Lower	17						
CU039	Lower	7						
CU040	Lower	3						
CU002	Mid	3						
CU004	Mid	0						
CU006	Mid	17						
CU007	Mid	23	-0.04	ns	-0.03	ns	-0.05	*
CU008	Mid	28	-0.05	ns	-0.04	ns	-0.06	*
CU009	Mid	28	-0.06	ns	-0.05	ns	-0.06	**
CU010	Mid	22	-0.05	ns	-0.04	ns	-0.05	ns
CU011	Mid	6						
CU012	Mid	3						
CU013	Mid	2						
CU033	Mid	26	-0.03	ns	-0.02	ns	-0.04	ns
CU034	Mid	14						
CU035	Mid	13						
CU036	Mid	7						
CU037	Mid	5						
CU014	Upper	3						
CU015	Upper	64	-0.02	ns	-0.02	ns	-0.03	ns
CU016	Upper	95	-0.10	***	-0.08	***	-0.09	***
CU017	Upper	165	-0.07	**	-0.06	**	-0.07	**
CU018	Upper	286	0.09	**	0.11	**	0.09	**
CU019	Upper	174	-0.07	*	-0.05	ns	-0.07	*
CU020	Upper	51	-0.04	ns	-0.03	ns	-0.04	ns
CU021	Upper	4						
CU022	Upper	37	0.02	ns	0.03	ns	0.01	ns
CU023	Upper	244	0.01	ns	0.02	ns	0.00	ns
CU024	Upper	4						
CU025	Upper	200	-0.16	***	-0.13	***	-0.14	***
CU026	Upper	41	-0.05	ns	-0.04	ns	-0.06	*
CU027	Upper	29	-0.02	ns	-0.01	ns	-0.03	ns
CU028	Upper	61	0.08	ns	0.08	ns	0.06	ns
CU029	Upper	60	-0.07	*	-0.06	ns	-0.08	**
CU030	Upper	19						
CU031	Upper	23	-0.01	ns	-0.01	ns	-0.02	ns
CU032	Upper	97	-0.04	ns	-0.03	ns	-0.04	**

Table 8. Low Tide Counts for Black-tailed Godwit on the Stour Estuary, by count sector, and comparison of trends with those for wider areas.

Sector	Consolidation	5-yr mean of peaks	Estuary		Stour+Orwell		Stour+Orwell+Deben+Hamford Water	
EW009	Lower	0						
EW010	Lower	4						
EW011	Lower	39	0.17	***	0.18	***	0.16	**
EW012	Lower	14						
EW013	Lower	0						
EW027	Lower	0						
EW028	Lower	9						
EW029	Lower	0						
EW030	Lower	4						
EW031	Lower	8						
EW032	Lower	0						
EW033	Lower	7						
EW034	Lower	0						
EW006	Mid	63	0.02	ns	-0.01	ns	-0.02	ns
EW007	Mid	0						
EW008	Mid	0						
EW014	Mid	0						
EW015	Mid	0						
EW016	Mid	0						
EW019	Mid	35	0.04	*	0.02	ns	0.00	ns
EW020	Mid	0						
EW024	Mid	0						
EW025	Mid	9						
EW026	Mid	45	-0.02	ns	-0.05	ns	-0.06	*
EW035	Mid	0						
EW036	Mid	0						
EW037	Mid	95	0.04	*	0.02	ns	0.00	ns
EW038	Mid	23	0.06	ns	0.05	ns	0.03	ns
EW039	Mid	0						
EW040	Mid	0						
EW041	Mid	164	-0.04	*	-0.03	ns	-0.04	ns
EW001	Upper	0						
EW002	Upper	0						
EW003	Upper	10						
EW004	Upper	0						
EW005	Upper	190	-0.01	ns	-0.01	ns	-0.03	ns
EW017	Upper	95	0.04	ns	0.01	ns	-0.01	ns
EW018	Upper	52	0.02	ns	0.01	ns	0.00	ns
EW021	Upper	0						
EW022	Upper	2						
EW023	Upper	0						

Table 9. Low Tide Counts for Black-tailed Godwit on the Orwell Estuary, by count sector, and comparison of trends with those for wider areas.

3.3 Comparisons with the East Anglian region

In Figs 20–22, the trends for the three study species are presented for the Stour and Orwell and for the local consolidations of sites (Stour and Orwell together, SODHW), individually and in comparison with the East Anglian regional trend. These help put the trends on the study sites into a wider context.

These site consolidations are based on WeBS Core Counts. The values on the *y*-axis of the trend plots (left-hand graphs) refer to the whole-winter average (November to March) and not to the peak as reported in the WeBS annual report; indices are always fitted to cumulative 'bird-months' using all winter months.

The values on the *y*-axis for the comparison plots (right-hand graphs) are the percentage of the East Anglian regional total. Data are not yet available for the whole East Anglian region in winter 2007/08, and so the comparative trends finish at 2006/07.

Knot trends at all levels within the study area appear to be following the regional trend quite closely (Fig 20). Within SODHW the upward trend may be stronger than that in the East Anglian region, whereas on the Orwell there appears to be no difference between the estuary and the regional trend.

Dunlin have been in decline across the East Anglian region, but they have been declining more steeply on all the estuary consolidations than in the region as a whole (Fig 21). The Stour previously held about 20% of the East Anglian regional total but this figure is now down to about 10%; similarly, the Orwell percentage has fallen from about 10% to less than 5% of the regional total. There appears to be little additional proportional loss that is attributable to the Deben or Hamford Water. The WeBS Alerts report (Maclean & Austin 2008) shows Dunlin as being relatively stable on Hamford Water since the mid 1980s.

The Stour and Orwell are exceptional in a British context in showing declines in Black-tailed Godwit (Fig 22). The declines on the Stour in particular are driving the pattern seen across the Stour and Orwell together and the four estuaries combined (SODHW). The WeBS Alerts report shows numbers of this species on Hamford Water to be relatively stable in the long-term.

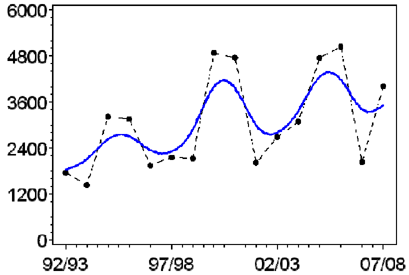
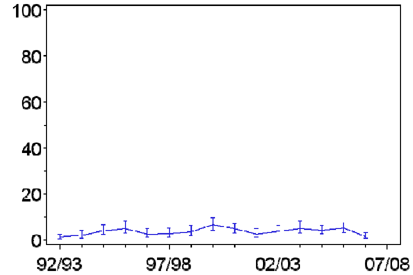
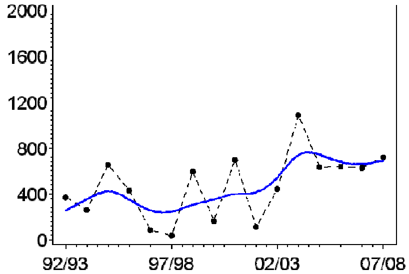
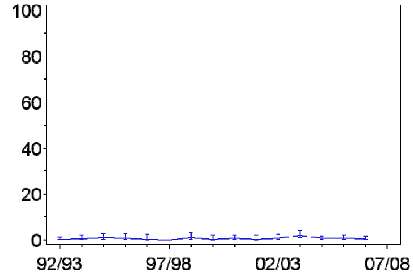
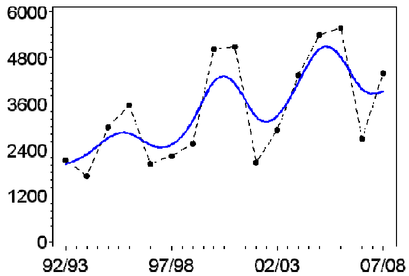
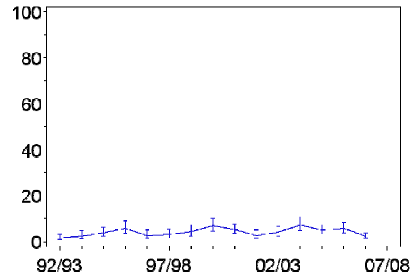
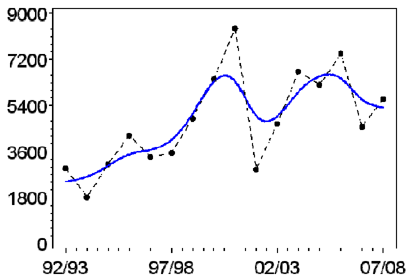
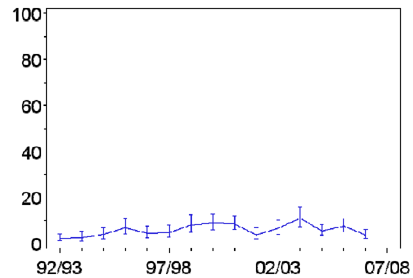
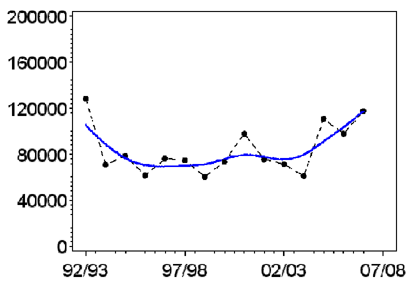
Estuary or region	Trend	Trend in relation to whole East Anglian region
Stour		
Orwell		
Stour & Orwell		
Stour, Orwell, Deben & Hamford Water		
Environment Agency East Anglian Region		

Figure 17. Knot: winter average graphs (left-hand figures) and (right-hand figures) comparisons with the whole East Anglian region. The *y*-axis in the right-hand graphs is the percentage of the East Anglian regional total.

<table>
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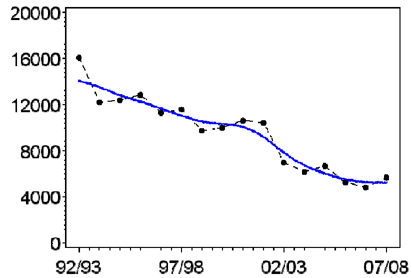

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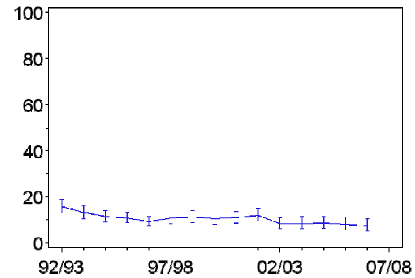

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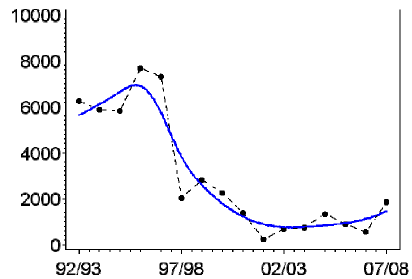

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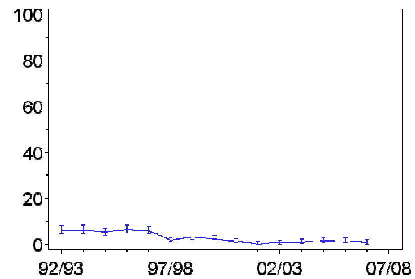

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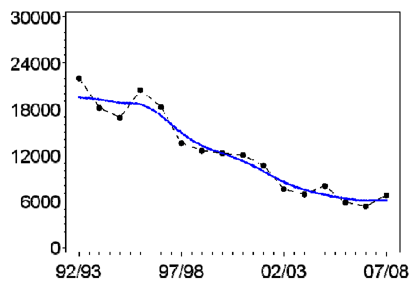

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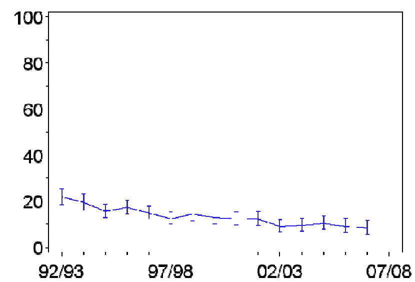

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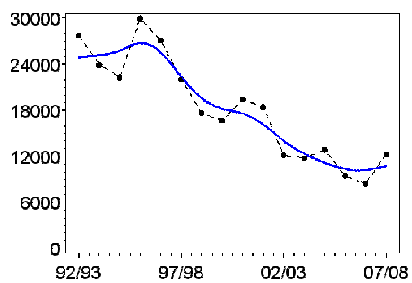
<tr><td>Stour, Orwell, Deben & Hamford Water</td><td>


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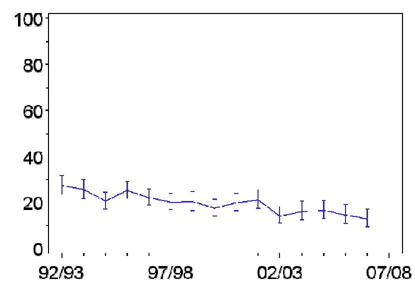

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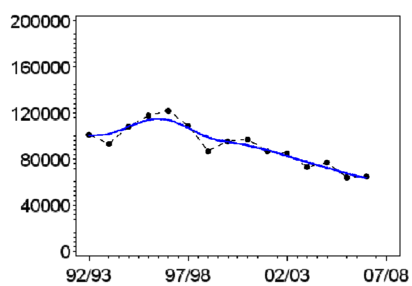
<tr><td>Environment Agency East Anglian Region</td><td>


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</table>

Figure 18. Dunlin: winter average graphs (left-hand figures) and (right-hand figures) comparisons with the whole East Anglian region. The *y*-axis in the right-hand graphs is the percentage of the East Anglian regional total.

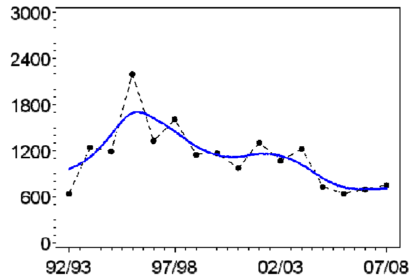
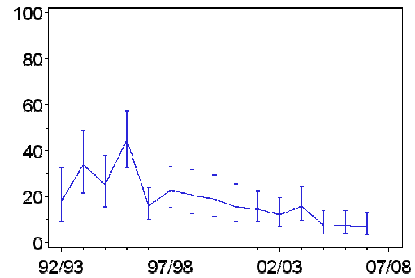
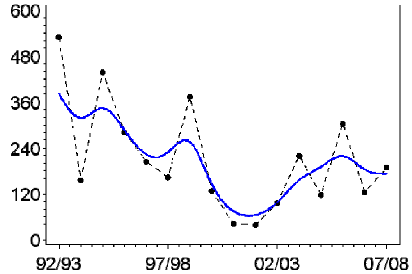
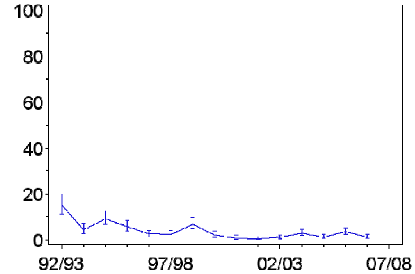
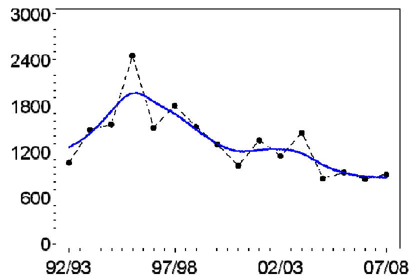
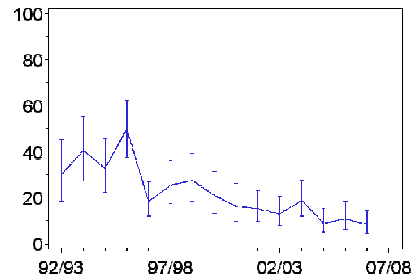
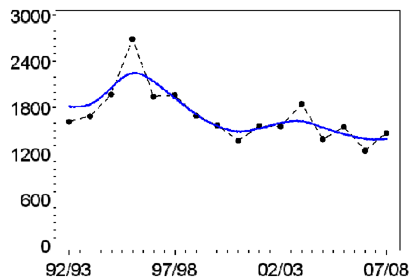
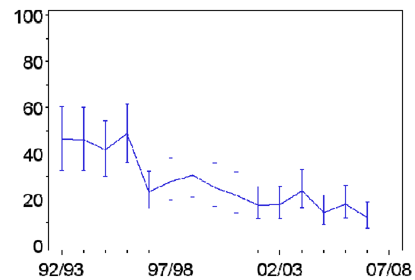
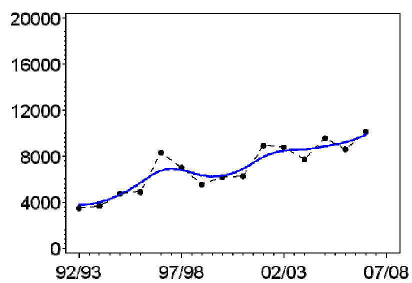
Estuary or region	Trend	Trend in relation to whole East Anglian region
Stour		
Orwell		
Stour & Orwell		
Stour, Orwell, Deben & Hamford Water		
Environment Agency East Anglian Region		

Figure 19. Black-tailed Godwit: winter average graphs (left-hand figures) and (right-hand figures) comparisons with the whole East Anglian region. The *y*-axis in the right-hand graphs is the percentage of the East Anglian regional total.

4 DISCUSSION

The results of this analysis are discussed firstly for each of the three study species in turn (sections 4.1–4.3) and secondly by estuary, to look for any common factors that apply to all three species (section 4.4). Comparisons are made between the results of this latest analysis that quantifies the reference populations using Core Count data and those of previous analyses that have used Low Tide data. A final section of the discussion (section 4.6) considers the methodology used and makes recommendations for further studies.

4.1 Knot *Calidris canutus*

Knot is a high-arctic breeder with a circumpolar range. The population that winters in Britain is part of the *islandica* race that nests in Greenland and northeast Canada, for which the large estuaries of western Britain and the southern North Sea are the core wintering area. Small narrow estuaries are generally shunned in favour of large sites, where Knots can feed and roost in dense flocks, often of tens of thousands.

Ringing shows extensive movement between its major concentrations at Morecambe Bay, the Wash and the Waddensee, even within a single winter. Large between-year fluctuations in numbers are typical of this species but there is no clear long-term trend in the British wintering population (Austin *et al.* 2008).

Typically all the Knot on an estuary will be found in a small number of large feeding flocks which may be quite mobile between count sectors, especially if disturbed. Knot are short-billed and detect shallow-living prey using their vibration-sensitive bill-tips. The most productive feeding substrate is soft wet mud, often far from shore. They specialise in feeding on hard-shelled animals such as the small mollusc *Macoma balthica*.

This species favours wide open spaces and is relatively susceptible to human disturbance and to development. Consequently, they may have already been reacting in the past to lower levels of disturbance than those perceived today and so their response to any increased disturbance levels may not be as apparent as in other. species.

4.1.1 Knot on the Lower Stour

Knot make less use of the Lower Stour than of the Mid and Upper consolidations of the estuary (Fig 5). There has been an increase in use in both the five- and the 10-year periods, but increase has possibly been less strong than elsewhere on the estuary (Table 1). Fig 14 shows that the 2007/08 count, on which the increases are based, may be simply a high point in a fluctuating trend.

There are no differences between trends on the Lower Stour consolidation and those on the whole estuary, Stour and Orwell together, or SODHW (Table 3).

Within the Lower Stour, Knot make most use at low tide of sectors CU039 (Erwarton Ness to Shotley) and CU001 (Bathside Bay) (Table 4, Fig 8). The trend at CU039 shows a strong increase that is similar to that for the estuary as a whole. However, at CU038 (Erwarton Ness to Shotley), Knot show a downward trend and both here and at CU001 the trends are negative relative to those for the Stour, Stour and Orwell together, and SODHW (Tables 1 & 4).

The localised decrease at CU038 suggest that this sector has become less favourable for Knot over time and birds have possibly been displaced to the adjacent sector (CU039). Conditions on CU001 appear to be such that increasing estuary-wide Knot population are prevented from increasing their usage of this sector.

4.1.2 Knot on the Mid Stour

Knot numbers on the Mid Stour consolidation are intermediate between lower numbers on the Lower estuary and higher numbers in the Upper estuary (Fig 5). Strong increases have occurred on most count sectors in both the five- and 10-year periods (Table 1). Increase is due largely to three consecutive high counts in the period 2004–07 (Fig 15).

Knot trends on the Mid Stour consolidation appear favourable compared to those on the Stour, Stour and Orwell together, and SODHW (Table 3).

Count sectors most used by Knot are CU033 (Stutton Ness to Holbrook Creek) and CU034 (Holbrook Creek to Nether Hall), which are adjacent sectors on the Suffolk side of the estuary (Fig 8). At both these sectors, the increase has been stronger than elsewhere on the Stour, Stour and Orwell together, and SODHW, whereas no other Mid Stour sector shows any differences from the wider trends (Table 4).

It would therefore appear that no activities are having an adverse affect on the Mid Stour and that, in this part of the estuary, sectors CU033 and CU034 are absorbing most of the recent increase in estuary-wide Knot numbers.

4.1.3 Knot on the Upper Stour

Knot make more use of the Upper Stour than the Mid and Lower Stour (Fig 5). Increase has occurred overall on the Upper Stour consolidation but has been patchy and not as strong as in the Mid Stour (Table 1). The long-term trend shows a more consistent long-term increase than the Mid and Lower Stour (Fig 16). Together these observations suggest that the Mid and Lower consolidations offer less attractive habitat for this species and birds have only began to infill elsewhere as the Upper Stour has approached capacity.

There are no differences between trends on the Upper Stour consolidation and those on the whole estuary, Stour and Orwell together, or SODHW (Table 3).

The sectors on the Upper Stour most heavily used by Knot are CU026 (Seafield Bay from North Shore), and CU015 (Sluice Rill to Nether Hall), CU019 and CU018 (both East Mistley to Nether Hall) on the Essex bank. At CU018, the increasing trend has been significantly more positive than on the Stour and Orwell together, and SODHW, but similar to the trend on the Stour as a whole. At the other most heavily used sectors, there have been no differences from the wider trends (Table 4).

In sectors CU022 (Cattawade to Mistley Quay) and CU032 (Stutton Ness to Holbrook Creek) usage is lower but trends have been significantly stronger than elsewhere on the Stour, Stour and Orwell together, and SODHW (Table 4, Fig 8).

In sector CU025 (Seafield Bay from South Shore) there is heavy usage by Knot but the trend has been a strong decrease, significantly more negative than the trends for wider areas. CU031 (Stutton Ness to Holbrook Creek) has also shown strong decreases but rather few Knot use this sector.

So while, across the Upper Stour as a whole, conditions appear to be favourable, there are clear differences between the individual sectors in this area. There appears to have been some degree of redistribution between sectors of the Upper Stour and this suggest localised changes in habitat quality shifting the equilibrium between sectors. As overall the Upper Stour seems to be absorbing recent increases in numbers of this species across the wider reference areas, this suggests that on balance no activities are having an undue affect on Knot on this part of the estuary.

4.1.4 Knot on the Lower Orwell

Of the six estuary consolidations on the Stour and Orwell, Knot makes least use of the Lower Orwell (Fig 5). The trend on the consolidation has been strongly upward (Table 2), but these increases are mainly the result of exceptional numbers being recorded in the 2007/08 winter (Fig 17).

The trend has been significantly more positive on the Lower Orwell consolidation than on the Orwell as a whole (Table 3) but, again, this result is dependent on the unusually high counts in 2007/08. Otherwise, trends have not differed from those in the wider areas (Tables 3 & 5).

The sectors used by Knot on the Lower Orwell are EW031 (Trimley Retreat Area) and EW011 (Thorpe Bay) (Fig 9). Strongly upward trends have been recorded in EW031, the only sector holding sufficient numbers to allow a meaningful trend to be fitted, but these do not differ from trends on the Orwell as a whole, Stour and Orwell together, and SODHW (Table 5).

It is therefore difficult to draw any conclusions regarding the favourability of this part of the Orwell for this species.

4.1.5 Knot on the Mid Orwell

Most Knot on the Orwell are found in the Mid Orwell consolidation during low tide. Numbers are lower there, however, than on the Mid and Upper Stour (Fig 5). The 10-year trend is a rapid decrease, but the five-year trend is a rapid increase (Table 2, Fig 5). The graph of numbers by winter serves to resolve this apparent contradiction: numbers using the Mid Orwell dropped in the mid 1990s to a low base from which they have since shown rather little numerical change (Fig 18).

There are no differences between trends on the Mid Orwell consolidation and those on the whole estuary, Stour and Orwell together, or SODHW (Table 3).

Trends by sector show a rather complex pattern, indicating that considerable redistribution of Knot has taken place within the Mid (and Upper) Orwell. The sector most heavily used has been EW038 (Nacton Shore): here and at EW026 (Collimer Point Shoreline, River and Saltings), which is also well populated, trends have not differed from those in the wider areas (Table 5). Knot also occur in substantial numbers at EW041 (Nacton Quay Shoreline, River and Saltings) and EW037 (Levington Creek Shoreline, River and Saltings), and in these sectors trends have been more negative than on the Orwell as a whole, Stour and Orwell together, and SODHW (Table 5): in both sectors, however, the five-year trend has been a moderate increase.

Thus, although there appears to have been considerable redistribution of usage within the Mid Orwell suggesting localised changes in the relative suitability of habitat, overall there appears to be no change in favourability of the Mid Orwell for this species.

4.1.6 Knot on the Upper Orwell

More Knot use the Upper Orwell than the Lower Orwell, but these are the two least used areas of the SPA (Table 3, Fig 5). The has been a moderate over both the five- and 10-year periods (Table 2). The Upper Orwell is alone among the six consolidations in showing a consistently downward trend in Knot numbers. Much of the decrease occurred in the late 1990s (Fig 19).

Knot trends on the Upper Orwell consolidation are significantly more negative than for the SODHW region, suggesting that some Knot may have redistributed from the Upper Orwell to the Deben Estuary or Hamford Water (Table 3). Trends on the Upper Orwell do not differ from those on the whole Orwell or on the Stour and Orwell together.

The only sectors used more than casually by Knot are EW017 (Black & Pond Ooze), EW005 (Freston) and EW018 (Black Ooze), all in the lower part of the Upper Orwell. At all of these, trends for Knot have been more negative than in one or more of the wider areas (Table 5), perhaps as birds redistribute to the Stour, Deben or Hamford Water. These localised decreases indicate that this part of the estuary (downstream from the Orwell Bridge) has become less favourable for this species.

4.1.7 Knot trends on the Stour and Orwell Estuaries

Knot appear to flourishing on the Stour. On the Orwell, however, the main concentration in the Mid estuary has decreased in the past, and decreases continue in the lower part of the Upper Orwell. Birds from the Orwell may have redistributed to the Stour, or to another part of the SODHW complex.

These changes are occurring against a background of relative stability in the East Anglian region, such that the Stour and Orwell SPA has held a slightly increasing proportion of the regional Knot population during the past 15 years (Fig 20). It is therefore reasonable to conclude that no activities on the Stour and Orwell SPA are having an undue negative impact on Knot.

4.2 Dunlin *Calidris alpina*

Dunlin is a circumpolar breeder at low-arctic and boreal latitudes and has a complex array of subpopulations, each with its own breeding and wintering area. In Britain in winter, most Dunlin are nominate ***alpina***, which arrive from breeding grounds in northern Fenno-Scandia and western Siberia. The British wintering population is in long-term decline (Austin *et al.* 2008). It appears that Siberian birds may increasingly be wintering east of Britain, perhaps in response to climatic warming, and indeed on the Dutch Waddensea Dunlin numbers are increasing (van Roomen ***et.al***. 2007) whilest the relevant international flyway population is considered to be stable (Wetlands International 2006).

This species is among the most widespread waders wintering in Britain. Its diet is less specialised than that of the Knot and includes small worms. Dunlin feed on a variety of muddy substrates, sometimes quite close to shore or above high-tide level on coastal pools. They are more likely than Knot to feed singly or in small groups.

Dunlin are able to use relatively small and enclosed patches of intertidal mud, where Knot would never occur. They are more tolerant of disturbance than Knot but, because they use more sites within an estuary, are affected by almost any loss of habitat. While it may at first seem counter intuitive, with increased levels of disturbance we might expect to see a greater response in Dunlin than Knot because the latter would already have been responding to much lower levels of disturbance whereas for Dunlin the response would be more incremental.

4.2.1 Dunlin on the Lower Stour

The Lower Stour is the least used part of the Stour by Dunlin (Table 3, Fig 6). The overall trend on the Lower Stour consolidation has been a moderate decrease in both the five- and 10-year periods (Table 1). Fig 14 indicates that the declining trend has been a consistent one over the 10-year period.

Despite the decrease, the trend on the Lower Stour consolidation has been significantly more positive than elsewhere on the Stour, Stour and Orwell together, and SODHW (Table 3).

Within the Lower Stour, Dunlin make most use of sectors CU039 (Erwarton Ness to Shotley) and CU001 (Bathside Bay). At both of these sectors, trends have been significantly more positive than elsewhere on the Stour, Stour and Orwell together, and SODHW (Table 6, Fig 10).

Sector CU040 (Erwarton Ness to Shotley) showed a significantly more negative trend than the whole Stour and SODHW (Table 6) however this sector holds few Dunlin relative to the rest of the estuary suggesting it is relatively poor habitat for the species and so would be amongst the first areas to be abandoned by a declining population.

Thus although there have been significant declines in Dunlin numbers on the Lower Stour these are in line with the those across the estuary as a whole and indeed the region and county. Consequently, there is no indication that any activities on the Lower Stour are having an impact on Dunlin numbers.

4.2.2 Dunlin on the Mid Stour

The Mid Stour consolidation holds large numbers of Dunlin and is second in importance within the SPA only to the Upper Stour consolidation (Table 3, Fig 6). The trend trend has been roughly stable over both the five- and 10- year periods (Table 1). The annual trend shows a decrease in the mid 1990s that has since levelled out (Fig 15).

Having shown relatively little overall decrease, the trends on the Mid Stour consolidation have been significantly more positive than elsewhere on the Stour, Stour and Orwell together, and SODHW (Table 3). The slope relative to the Stour and Orwell together has been steep, suggesting that the Mid Stour may have received some birds redistributing from the Orwell.

Seven of the 15 Mid Stour sectors are used by more than 500 Dunlin, as measured by the five-year mean of peak counts. At six of these, the trend has been significantly more positive than elsewhere on the Stour, Stour and Orwell together, and SODHW (Table 6). Of particular note are sectors CU034 and CU035 (both Holbrook Creek to Nether Hall), where moderate increase has occurred over the recent 10-year and five-year periods, despite the regional and national decreases in wintering Dunlin. In no sector has the trend been more negative than in the wider areas.

Thus overall and despite declines on most of the sectors of the Mid Stour, these results indicate that this part of the estuary is in a relatively favourable condition for Dunlin at present. It appears to have absorbed some of the birds lost from the Orwell (see later) and declines declines that are evident are being driven by a redistribution of the entire northwest European flyway population.

4.2.3 Dunlin on the Upper Stour

The Upper Stour is the most important part of the estuary for Dunlin in the SPA (Table 3, Fig 6). The overall trend for the Upper Stour consolidation has been a moderate decline but no change is evident over the recent five years (Table 1, Fig 16).

The trend on the Upper Stour has been similar to that on the Stour as a whole, but significantly more positive than on the Stour and Orwell together, and SODHW (Table 6). Along with the Mid Stour, the Upper Stour may therefore have received some bird redistributing from the Orwell.

There are six sectors of the Upper Stour that are used by more than 1,000 Dunlin at low tide, as measured by the five-year mean of peak counts (Table 6). At four of these, trends have been significantly more positive in comparison to one or more of the Stour, Stour and Orwell together, and SODHW (Table 6). At three of the six most-used sectors – CU016 (Sluice Rill to Nether Hall), CU026 (Seafield Bay from North Shore) and CU032 (Stutton Ness to Holbrook Creek) – a steep or moderate increase in numbers has occurred over the most recent five years, despite the declining trend in wintering Dunlin as a whole (Table 1). Rapid decreases have occurred in sector CU027 (Seafield Bay from North Shore) (Table 1), but these are in line with the wider trends (Table 6). In no sector has the trend been more negative than in the wider areas (Table 6).

Thus, as for the Mid Stour, these results indicate that the Upper Stour is in a relatively favourable condition for Dunlin at present. It appears to have absorbed some of the birds lost from the Orwell (see later) and declines declines that are evident are being driven by a redistribution of the entire northwest European flyway population.

4.2.4 Dunlin on the Lower Orwell

Of the six sector consolidations used on the Stour and Orwell, Dunlin makes least use of the Lower Orwell (Table 3, Fig 6). The trend on the consolidation has been strongly downward (Table 2), but appears to have levelled out over the recent five years (Fig 17).

The trend has been similar to that on the whole Orwell, but more negative than on the Stour and Orwell together, and SODHW (Table 3).

The sectors most used by Dunlin on the Lower Orwell are EW011 (Thorpe Bay) and EW030 (Shotley Shoreline, River and Saltings) (Table 7, Fig 11). At each of these there has been a rapid decrease over the 10-year period but little change during the recent five years as numbers had already hit very low levels (Table 2). Decreases in the two main sectors have been similar to that in the Orwell as a whole, but more severe than in the Stour and Orwell together, and SODHW (Table 7). This suggests that, overlain on the overall regional and national decrease, some birds from the Lower Orwell have redistributed to the Stour and maybe to other estuaries nearby.

These results indicate that Dunlin are experiencing severe problems on the Orwell and that, within the lower estuary, sectors EW011 and EW030 which comprise the majority of the waterfront of the lower Orwell are of particular concern. Historically these sectors recorded high numbers of Dunlin (in excess of 2000 each), on par with the better sectors of the Stour, suggesting this is not simply a case of the least suitable habitat being the first to be abandoned by a declining population but rather that there has been a decrease in habitat quality be it changes to intertidal sediments, invertebrate availability or community composition or increased disturbance.

4.2.5 Dunlin on the Mid Orwell

The Mid Orwell consolidation is that part of the Orwell estuary that is most heavily used by Dunlin (Table 3) although numbers there are very much lower than on the Mid and Upper consolidations of the Stour (Table 3, Fig 6). As on the Lower Orwell, the trend has been strongly downward (Table 2), but appears to have levelled out over the recent five years (Fig 18).

The trend has been similar to that on the whole Orwell, but more negative than on the Stour and Orwell together, and SODHW (Table 3).

The sectors most used by Dunlin on the Mid Orwell are EW038 (Nacton Shore), EW041 (Nacton Quay Shoreline, River and Saltings), EW026 (Collimer Point Shoreline, River and Saltings) and EW037 (Levington Creek Shoreline, River and Saltings) (Table 7, Fig 11). At each of these, the trend has been significantly more negative than on the Stour and Orwell together, and SODHW (Table 6). These results suggest that, overlain on the overall regional and national decrease, some birds from the Mid Orwell have redistributed to the Stour and maybe to other estuaries nearby.

These results re-emphasise that Dunlin are experiencing severe problems on the Orwell. Within the Mid Orwell, sectors EW038 and EW037 are of particular concern as for these sectors, decline was even more severe than in the Orwell as a whole and EW041 of particular concern given the large numbers it used to hold (Table 7, Fig 11).

4.2.6 Dunlin on the Upper Orwell

The Upper Orwell consolidation held more Dunlin than the Lower consolidation of the estuary, but fewer than in any consolidation of the Stour (Table3, Fig 6). A severe decline was already evident in the mid 1990s and has continued strongly into the recent five-year period (Table 2, Fig 19).

The trend has been similar to that on the whole Orwell, but more negative than on the Stour and Orwell together, and SODHW (Table 3).

The sectors most used by Dunlin on the Upper Orwell are EW017 (Black & Pond Ooze), EW005 (Freston), EW022 (Strand shoreline, River and Saltings) and EW018 (Black Ooze) (Table 7, Fig 11). At each of these, the trend has been significantly more negative than on the Stour and Orwell together, and SODHW (Table 6). These results suggest that, overlain on the overall regional and national decrease, some birds from the Upper Orwell have redistributed to the Stour and maybe to other estuaries nearby.

These results confirm that Dunlin are experiencing severe problems on the Orwell. Within the Upper consolidation of the estuary, sectors EW017 and EW022 are of particular concern: at these sectors, decline was even more severe than in the Orwell as a whole (Table 7, Fig 11).

4.2.7 Dunlin trends on the Stour and Orwell Estuaries

Trends within the Stour and Orwell Estuaries SPA need to be viewed against the background of the long-term decline that has been occurring in wintering Dunlin both nationally and in the East Anglian region (Fig 21). Numbers have been declining faster in the Stour and Orwell SPA and in SODHW than in the rest of the East Anglian region. This suggests that, although some birds may have redistributed, principally from the Orwell, to adjacent estuaries there has been a disproportionate loss from the area.

Within the Stour and Orwell, it is clear that there are major problems for the species on the Orwell, where declines are much more severe than would be expected. Birds from there may have redistributed to the Stour or to the Deben Estuary or Hamford Water. Count sectors of particular concern for Dunlin on the Orwell, in descending order of current usage, are EW038 (Nacton Shore), EW011 (Thorpe Bay), EW017 (Black & Pond Ooze), EW030 (Shotley Shoreline, River and Saltings), EW037 (Levington Creek Shoreline, River and Saltings), and EW022 (Strand shoreline, River and Saltings).

On the Stour, Dunlin numbers are also in decline. Although over the last 15 years, the Stour has held a declining proportion of the Dunlin wintering in the East Anglian region the discrepancy is far less than that for the Orwell and indeed when including the adjoining estuaries. Some count sectors on the Stour have shown increases in recent years, and no count sectors there appear to be presenting local conservation problems for this species. The major factors affecting wintering Dunlin on the Stour are those operating at regional and national levels.

Overall, it is evident that decline in the number of Dunlin across the local estuaries is been driven by the steep decline on the Orwell.

4.3 Black-tailed Godwit *Limosa limosa*

Black-tailed Godwit breeds across the Palaearctic from Iceland to eastern Siberia and forms a Holarctic superspecies with its American relative Hudsonian Godwit *L. haemastica*. Most populations are highly migratory but race *islandica*, which breeds principally in Iceland but with a few pairs in Scotland and Norway, winters largely in Britain, Ireland and western France.

Almost all the world population of *L. l. islandica* occurs in British or Irish estuaries during the annual cycle. This population has increased strongly in recent decades, and this is reflected in the GB wintering index, which has increased by a factor of about six since the mid 1970s (Austin *et al.* 2008).

Black-tailed Godwits on an estuary normally have a small number of favoured feeding areas where the bulk of the population is found. They sometimes feed at the tideline but spend most time probing in thick, deep mud, often close to shore. Food includes large, deep-living worms that are inaccessible to shorter-billed waders. Flocks may be tolerant of passers-by but are susceptible to disturbance or development of their favoured sites.

4.3.1 Black-tailed Godwit on the Lower Stour

Black-tailed Godwits make little use of the Lower Stour (Table 3, Fig 12). Trends on the Lower Stour consolidation have been strongly downward in both the five- and 10-year periods (Table 1, Fig 7).

Possibly because numbers are small, there are no significant differences between trends on the Lower Stour consolidation and those on the whole estuary, Stour and Orwell together, or SODHW (Table 3).

Within the Lower Stour, Black-tailed Godwit make most use at low tide of sector CU001 (Bathside Bay) (Table 4, Fig 8) although numbers on all the sectors of the Lower Stour are too low to make a meaningful interpretation of trends.

4.3.2 Black-tailed Godwit on the Mid Stour

Black-tailed Godwit occur at low density on the Mid Stour, but there are more birds there than on the Lower Stour and Lower Orwell (Table 3, Fig 7). The trend for the Mid Stour consolidation over the last 10 years has been a rapid decline with little change during the recent five years (Table 1, Fig 7).

The trend shows no difference from that on the Stour as a whole, or the Stour and Orwell together, but has been significantly more negative than in the wider SODHW region (Table 3).

The sectors used most heavily by Black-tailed Godwit on the Mid Stour are CU008 and CU009 (both Copperas Wood Farm to Shore Farm), CU033 (Stutton Ness to Holbrook Creek) and CU007 (also Copperas Wood Farm to Shore Farm) (Table 8). Trends have been strongly downward at each of these sectors, although decreases in CU007 and CU008 appear to have levelled off (Table 1). Trends in CU009, CU008 and CU007 have been significantly more negative than in the SODHW region (Table 8): this may be the result of increases on the Deben and Hamford Water that have softened the decline evident elsewhere in SODHW (Fig 22). Numbers are small in all of these sectors, however, and so it is not clear what degree of importance should be attached to these declines.

4.3.3 Black-tailed Godwit on the Upper Stour

The Upper Stour is by far the most important sector consolidation for Black-tailed Godwit in the Stour and Orwell SPA (Table 3, Fig 7). There has been a consistent decline in numbers in this area, however, since the mid 1990s (Table 1, Fig 16).

There are no significant differences between trends on the Upper Stour conslidation and those on the whole estuary, Stour and Orwell together, or SODHW (Table 3). It would be expected that trends in the Stour and the Stour and Orwell would be similar to that in the Upper Stour, because Black-tailed Godwit are so concentrated into that part of the SPA (Fig 7).

As measured by the five-year means of peak counts, there are three sectors of the Upper Stour currently used more heavily by Black-tailed Godwit than any other count sectors in the whole SPA (Tables 8 & 9): these are CU018 (East Mistley to Nether Hall), CU023 (Cattawade to Mistley Quay) and CU025 (Seafield Bay from South Shore). There have been strongly contrasting trends at these three sites (Tables 1 & 8, Fig 12). At CU018, a consistent increase in numbers has been registered and trends have been consistently more positive than in the Stour as a whole, the Stour and Orwell together and SODHW. There has also been an increase at CU023 in the recent five-year period, but trends there do not differ significantly from those in the wider regions. At CU025 and most other Upper Stour sectors, there has been a strong decrease in usage by Black-tailed Godwit and trends have been significantly more negative than in the Stour as a whole, the Stour and Orwell together and SODHW.

These results suggest an increasing concentration of Black-tailed Godwit on the Stour into sector CU018 (East Mistley to Nether Hall), perhaps with birds being drawn from adjacent sectors on the Essex bank – CU025, CU017 (Sluice Rill to Nether Hall) and CU019 (also East Mistley to Nether Hall).

Thus, there has been a redistribution of this species within the Upper Stour although overall there has been a net loss of numbers which suggests that birds are being displaced from those sectors showing a decline rather than being increasingly attracted to those sectors showing an increase.

4.3.4 Black-tailed Godwit on the Lower Orwell

Black-tailed Godwit usage of the Lower Orwell consolidation is very light, although more birds are seen there than on the Lower Stour consolidation (Table 3, Fig 7). Numbers have shown a moderate decrease (Table 2, Figs 7 & 17).

Trends on the Lower Orwell have been more positive than on the Orwell as a whole, despite the low numbers of birds counted, but similar to those of Stour and Orwell together and the SODHW region (Table 3).

The most important sector for Black-tailed Godwit on the Lower Orwell has been EW011 (Thorpe Bay) although bird numbers on all sectors are too low for meaningful interpretation of trends.

4.3.5 Black-tailed Godwit on the Mid Orwell

The Mid Orwell consolidation is the most heavily area of the Orwell used by Black-tailed Godwit, but numbers there are much lower than on the Upper Stour (Table 3, Fig 7). The trend in both the five- and 10-year periods has been a small increase (Table 2), although a more detailed look at the trend shows a shallow decrease to 2000/01 followed by a rapid increase (Fig 18).

There are no significant differences between trends on the Mid Orwell and those on the whole estuary, Stour and Orwell together, or SODHW (Table 3) although given the relatively small numbers the power to detect a difference is weak.

The sectors most used by Black-tailed Godwit within the Mid Orwell are EW041 (Nacton Quay Shoreline, River and Saltings), EW037 (Levington Creek Shoreline, River and Saltings) and EW006 (Woolverstone) (Table 9). Strong increases have occurred at each of these sectors during the recent five years (Table 2), although in sector EW041 the trend has been more negative than on the Orwell as a whole (Table 9). The trend on sector EW037 has been significantly more positive than on the Orwell as a whole.

Thus, numbers of this species occurring on this part of the Orwell are increasing possibly absorbing some of the birds displaced from elsewhere on the Orwell or Stour.

4.3.6 Black-tailed Godwit on the Upper Orwell

Densities of Black-tailed Godwit on the Upper Orwell consolidation are much lower than on the Upper Stour but are higher than in other areas within the SPA. Five-year mean counts are not quite as high as for the Mid Orwell consolidation, but the area of this consolidation is much greater (Table 3, Fig 7). The trend shows decrease to 2000/01, followed by a shallow increase (Table 2, Fig 19).

There are no significant differences between trends on the Upper Orwell and those on the whole estuary, Stour and Orwell together, or SODHW (Table 3).

Within the Upper Orwell, EW005 (Freston), EW017 (Black & Pond Ooze) and EW018 (Black Ooze) are the sectors most heavily used by Black-tailed Godwit on the Upper Orwell (Table 9). Although not significantly different from the trends on the whole estuary, Stour and Orwell together, or SODHW, there have been numerical decreases in sector EW018 (immediately above the Orwell Bridge on the northeast bank).

4.3.7 Black-tailed Godwit trends on the Stour and Orwell Estuaries

Overall increase would be expected in the Stour and Orwell SPA as part of the population increase of *L. l. islandica* and the upward trends recorded in Britain as a whole and in the East Anglian region (Fig 22). These expectations have not been met in the SPA or in the wider SODHW region. This general observation suggests that these estuaries are not of primary importance for this species, and that the winter population increase has been absorbed by other estuaries, including some in the East Anglian region.

On the Orwell, decrease was recorded until 2001/02, followed by increase. Numbers on the Stour increased until the mid 1990s, and have subsequently declined, this decrease being in stark contrast to almost every other estuarine site within the species winter range. This decline clearly points to deteriorating suitability of habitat for this species on the Stour be this due to changes in intertidal sediments leading to changes in abundance of or community structure of invertebrate prey or due to increased disturbance.

4.4 Overview of wader trends on the Stour and Orwell Estuaries

Here we have considered the trends, at various geographic scales of three species of wader that encompass a broad range of ecological requirements. Whilst this means that we can expect the results to shown a broad spectrum of possible response to any perceived pressures on the two estuaries, restricting the analysis to three species makes it more difficult to narrow down the list of potential causes for any trends observed. Whilst it must always be acknowledged that coincidence of changes in bird numbers with changes in habitat does not demonstrate a causal relationship, when similar patterns in trends are observed across several species with similar requirements in some particular aspect of their ecology then the circumstantial evidence pointing towards a potential cause is much more convincing.

In summary, trends in numbers of Knot on the Stour and Orwell are favourable showing a slight increase relative to the East Anglian EA region. It is therefore reasonable to conclude that no activities on the Stour and Orwell SPA are having an undue negative impact on Knot. The perceived increase in disturbance on these estuaries have probably not had a noticeable impact on this species as, being particularly prone to disturbance, this species has probably always avoided the worst affected areas. There have been local declines but these are not spatially clustered in a manner that might suggest a particular ecological pressure is having an influence.

The large decline observed in Dunlin numbers on the Orwell Estuary represents a disproportional loss of this generally declining species. The declines on the Stour are more in line with what would be expected for an east coast estuary. Although disturbance may be a factor here, Dunlin are not especially prone to disturbance and it might be argued that with fewer birds likely to be vying for space on the Orwell increased levels of disturbance could be absorbed such that the decline would parallel the broader geographic decline. Changes to the intertidal sediments could well explain part of this discrepancy. For example, if the nature of the intertidal areas have shifted towards sandier sediments or been subject to increased disturbance of the substrate then the community structure of the invertebrate prey base can be expected to have shifted away from shellfish to larger and more mobile species, perhaps less suitable for Dunlin.

Numbers of the *islandica* Black-tailed Godwit are increasing substantially on nearly all estuaries within the species winter range and so the declines in numbers on the Stour and the slight increase on the Orwell are in stark contrast to what would be expected which points to deteriorating suitability of habitat for this species on the Stour.

Aside from the general disproportional decline in numbers of Dunlin on the Orwell, the Upper Orwell seems to be loosing birds of all three species on one section or another. This suggests an adverse pressure with broad impact is operating in this area.

There is no consistent story that emerges from a consideration of Knot, Dunlin and Black-tailed Godwit on the Stour Estuary. There has been a widespread increase of Knot, a decrease of Black-tailed Godwit, and Dunlin have shown a complex mixture of increases and decreases at sector level.

Although the current analysis only considered three species there is some suggestion that the Upper Orwell estuary has become less suitable for species that feed on small immobile prey in muddy sediments as represented by Dunlin and shifted to favour species that feed on more mobile prey in sandier sediments as represented by Black-tailed Godwit. Analysis of a more complete suite of species would help to determine whether these two extremes fall into a more general pattern across species with similar ecological preferences.

4.5 Comparison with previous analyses

As expected, the current report is in broad agreement with the previously published trends at the level of the individual count sectors and lower, mid and upper consolidations of each estuary. At this level the data being used are essentially the same other than the current analysis was able to incorporate low tide count data obtained prior to the systematic monitoring funded by Harwich Harbour Authority.

This analysis has, however, used established methods for comparing the trends at the sector and lower, mid and upper estuary consolidations to whole estuary, SPA and immediate area as suggested in the most recent ornithological monitoring report (Anon 2009). Thus in addition to supporting the conclusion from that report that many species are declining on the site, furthermore, this analysis indicates that in the case of Dunlin this decline exceeds the expected rate of decline for this species and for Black-tailed Godwit is unexpected. For these two species then, the favourability of the SPA would appear to be declining. In contrast, Knot appear to be fairing well on the SPA as a whole.

4.6 Conclusions and recommendations

The methods employed by this analysis involve the comparison of sector LTCs with Core Counts for wider areas, rather than with summed LTCs. This method, which avoids the unquantified overcounting that is inherent in summing LTCs across sectors, has successfully identified sectors where trends have differed from those in wider areas. We recommend the use of this method in similar future studies.

By identifying sectors where population changes have not been in line with those expected, it is possible to look for coincidence of these areas with management activities, such as dredging and sediment placement that might be expected to affect the structure of the sediments or activities that might be causing disturbance. Although monitoring of trends in bird numbers alone cannot prove cause and effect, marked changes in numbers and departures from the expected trends can provide convincing circumstantial evidence that a causal relationship exists.

A broader analysis including the full suite of water birds should now be made of the Stour and Orwell data. Including a wader range of species would identify whether there are consistent patterns between species with shared ecological requirements, and this should assist in narrowing down the list of potential drivers of change.
Data on disturbance and site management activities was not available for comparison with these trends. In the event that such data could be obtained modelling changes in bird numbers in relation to these potential pressure my provide insight into what may be driving these changes.

ACKNOWLEDGEMENTS

We are grateful to all volunteers, past and present, who have helped to gather the data reported here.

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APPENDICES

Appendix S (Stour, Tables S1–S36) and Appendix O (Orwell, Tables O1–O14) on the following pages show the detailed population trends of each species, sector by sector, and the proportional population found in each sector per year relative to wider areas. Solid dots represent actual counts and open dots represent imputed counts.

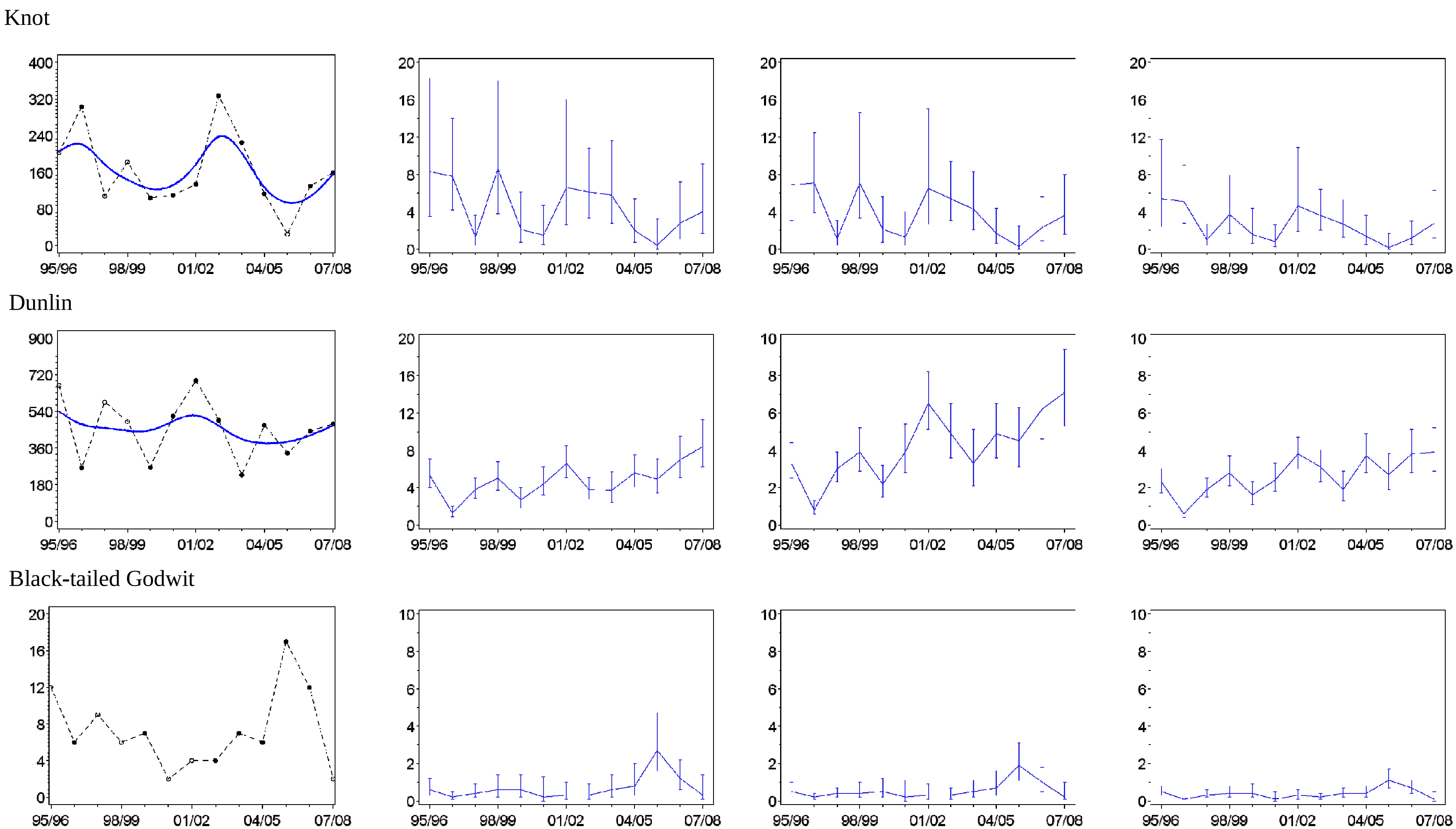
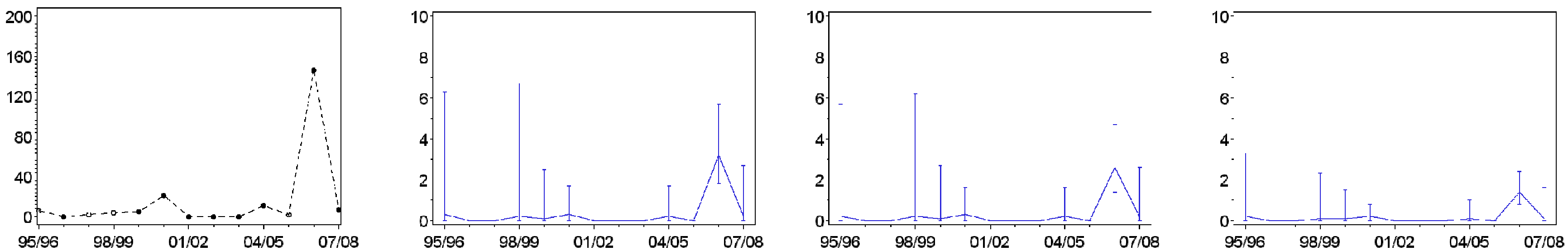
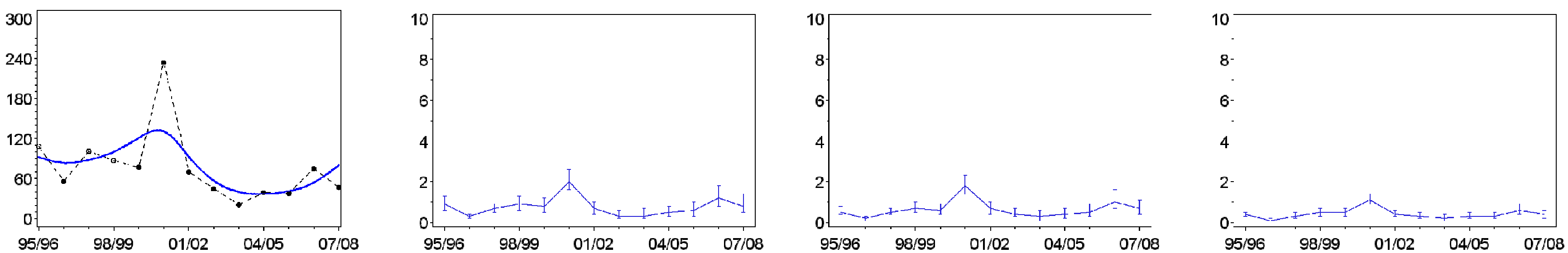


Figure S1. Population trends of each species in Lower Stour sector CU001 (Bathside Bay) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

Knot



Dunlin



Black-tailed Godwit

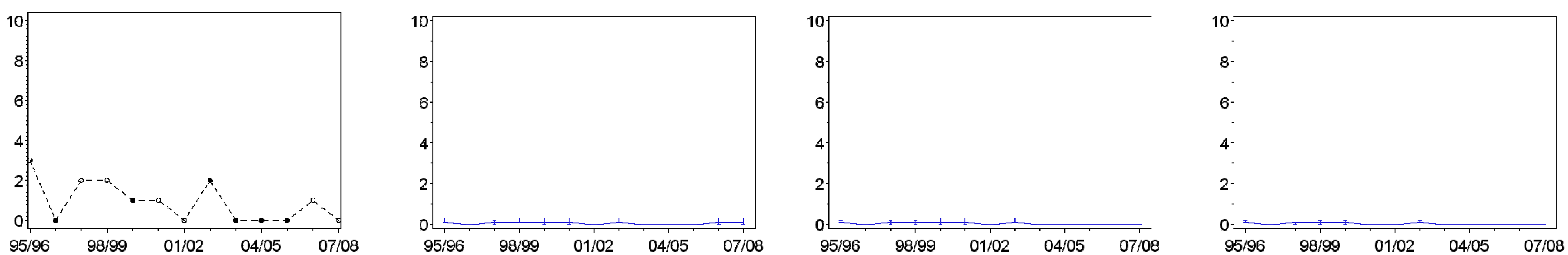


Figure S2. Population trends of each species in Lower Stour sector CU003 (Copperas Wood Farm to Parkeston Quay) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

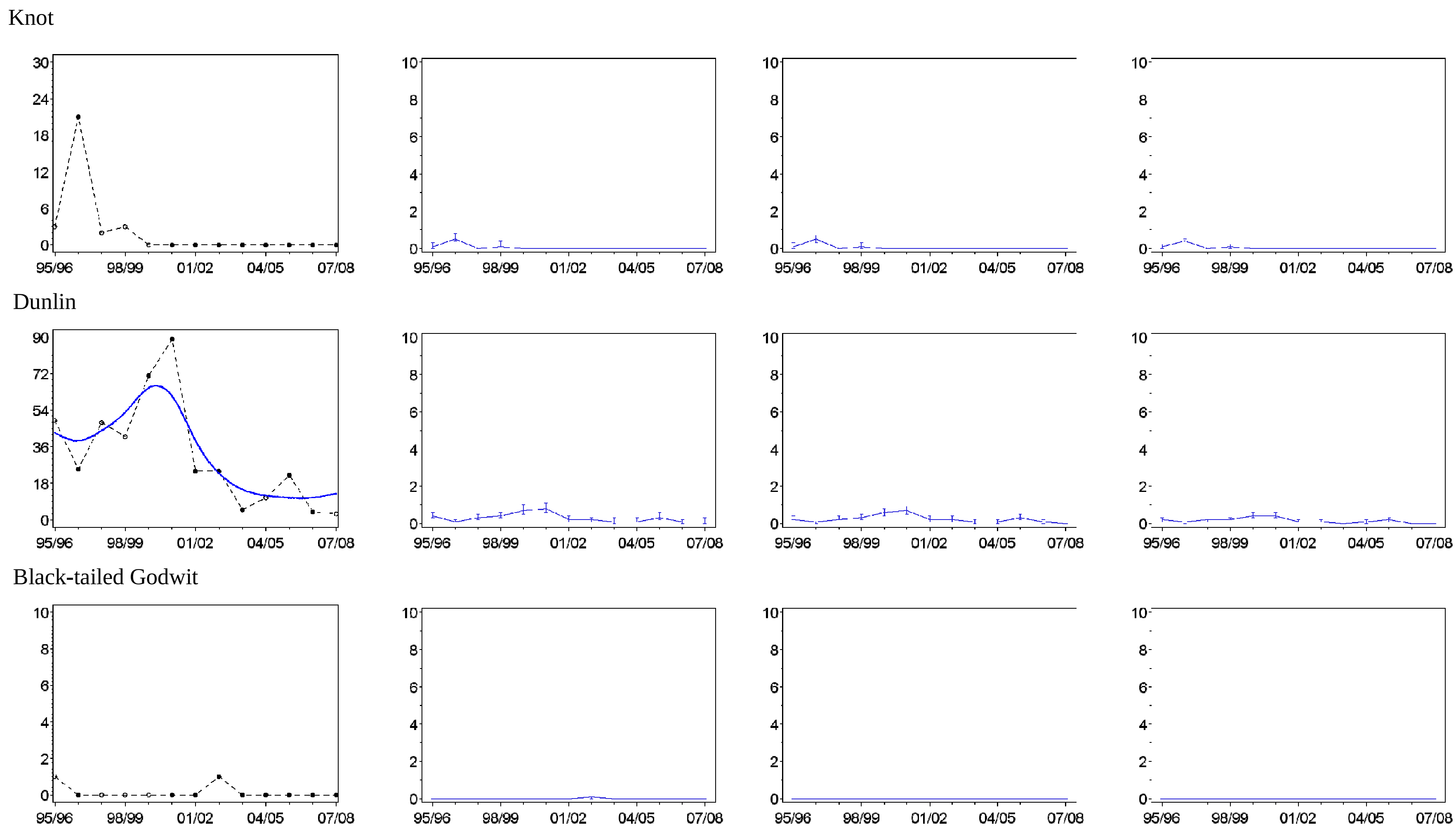


Figure S3. Population trends of each species in Lower Stour sector CU005 (Copperas Wood Farm to Parkeston Quay) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

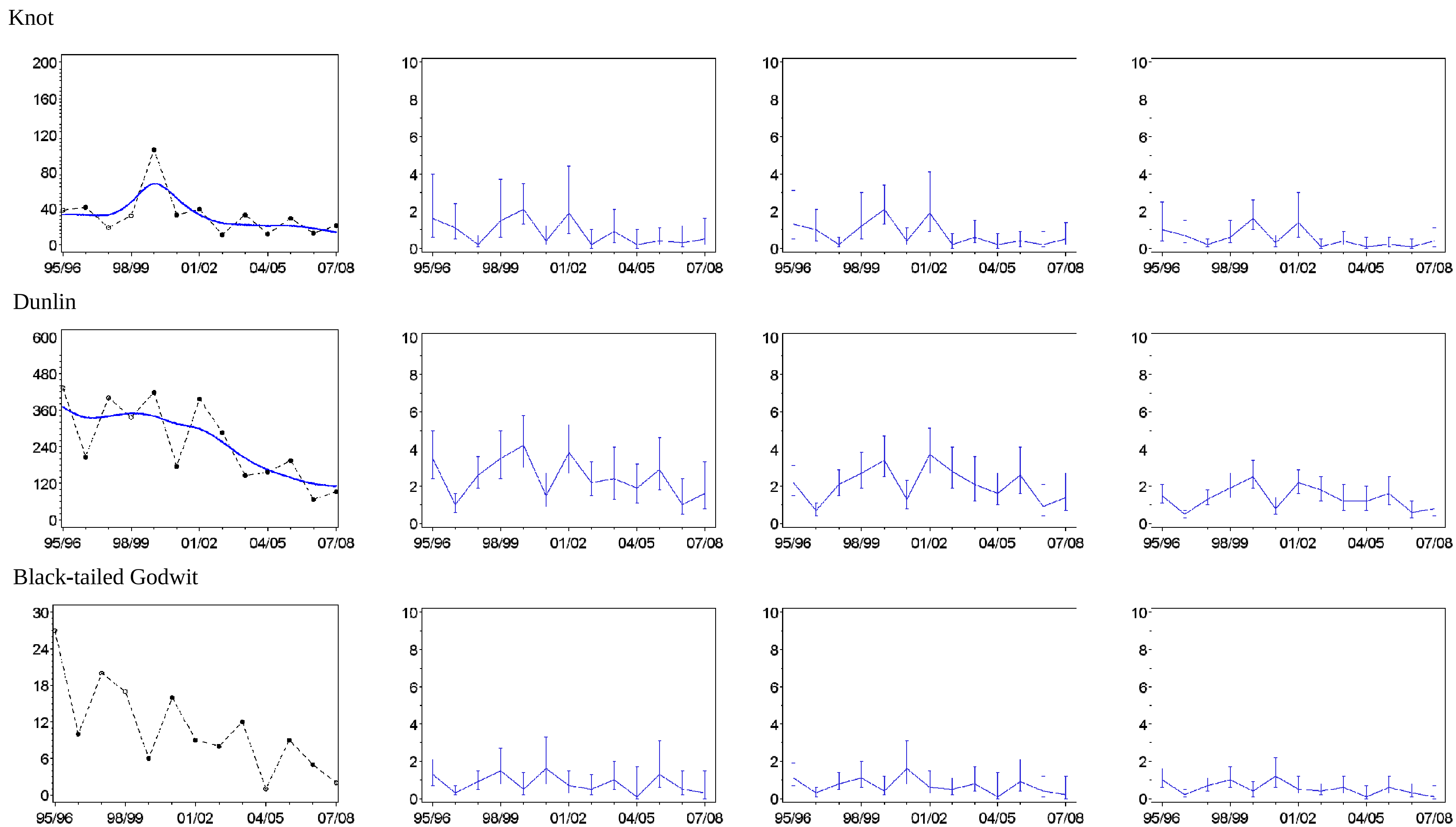


Figure S4. Population trends of each species in Lower Stour sector CU038 (Erwarton Ness to Shotley) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

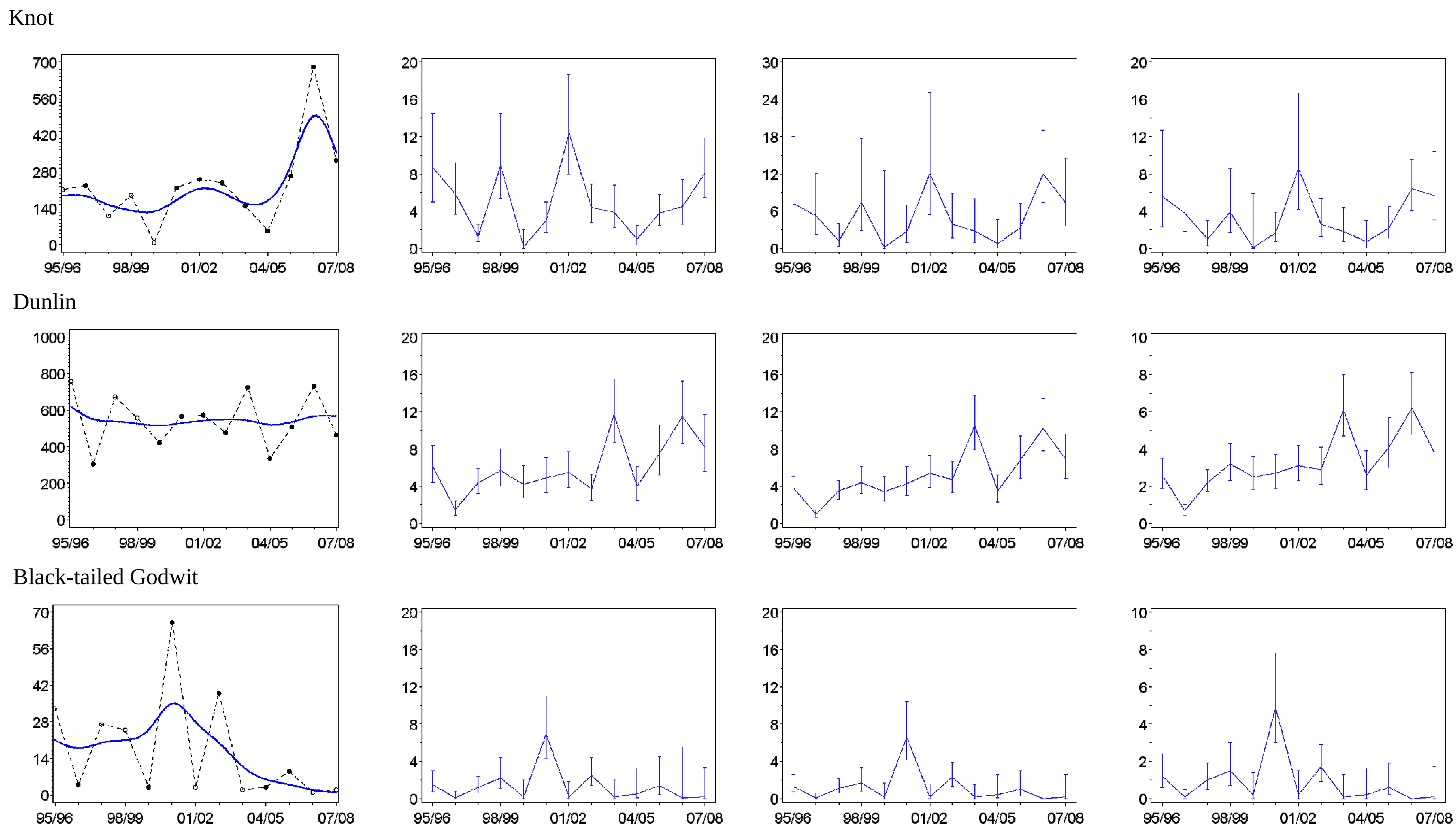


Figure S5. Population trends of each species in Lower Stour sector CU039 (Erwarton Ness to Shotley) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

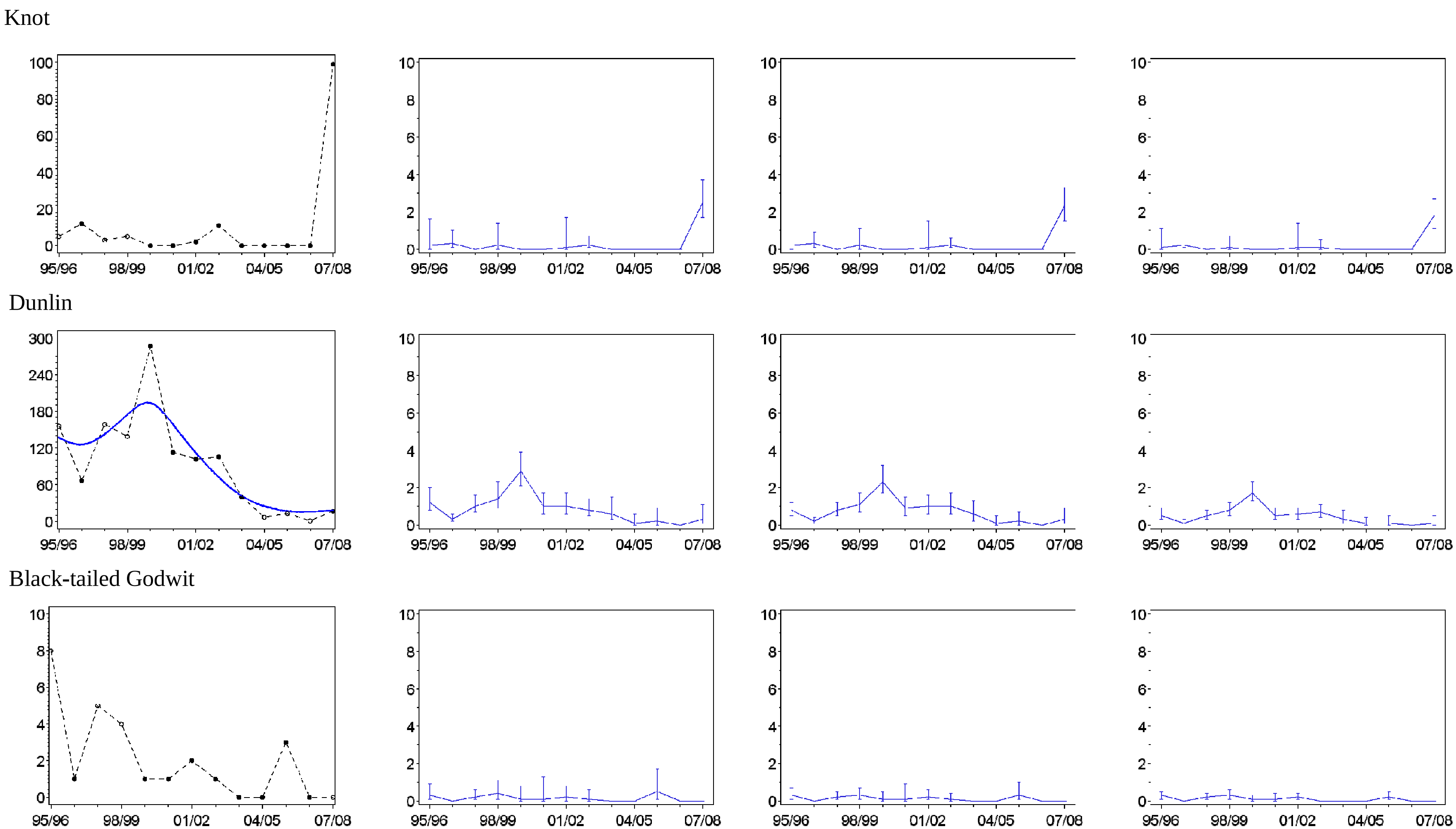


Figure S6. Population trends of each species in Lower Stour sector CU040 (Erwarton Ness to Shotley) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

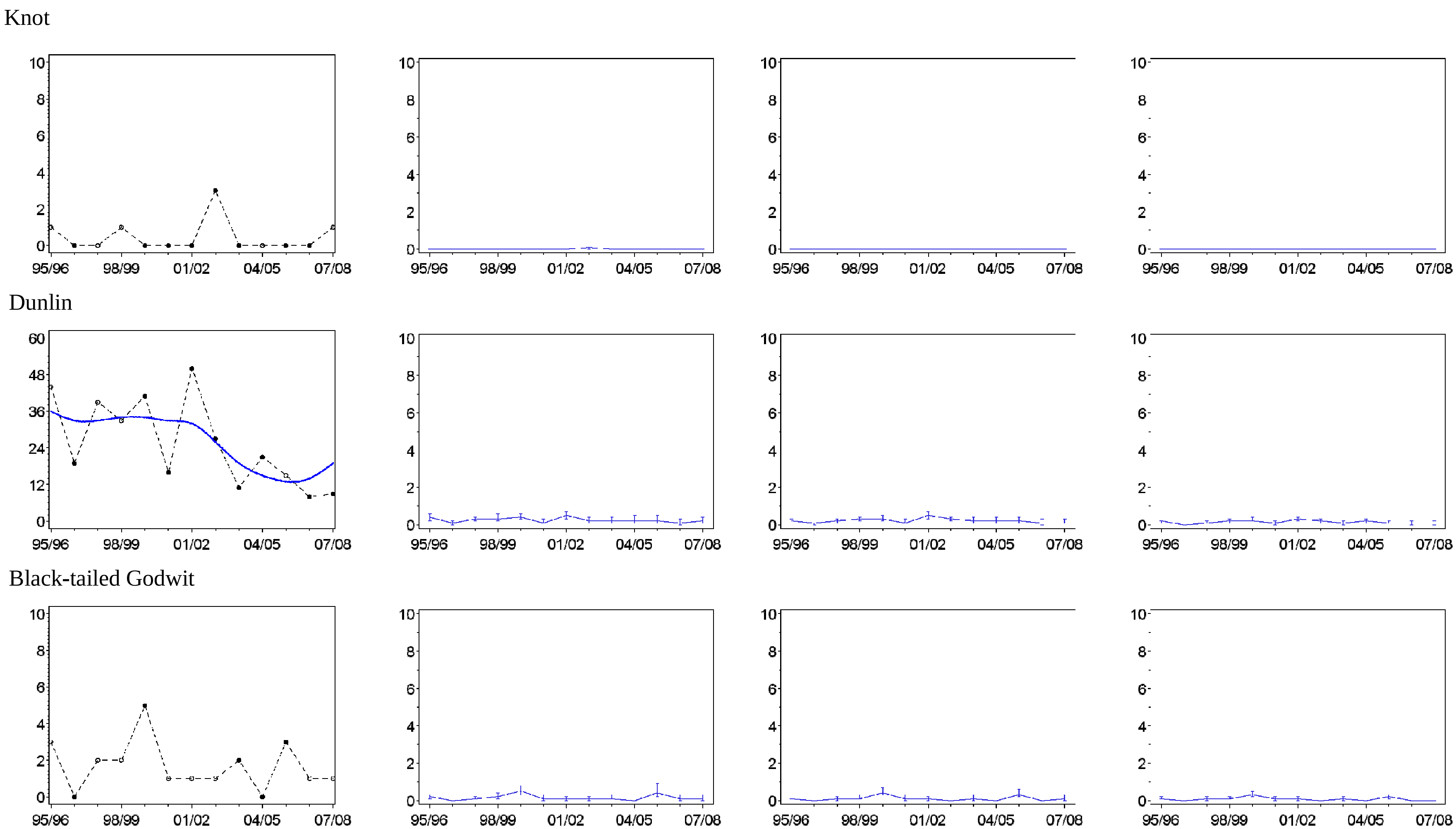


Figure S7. Population trends of each species in Mid Stour sector CU002 (Copperas Wood Farm to Parkeston Quay) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

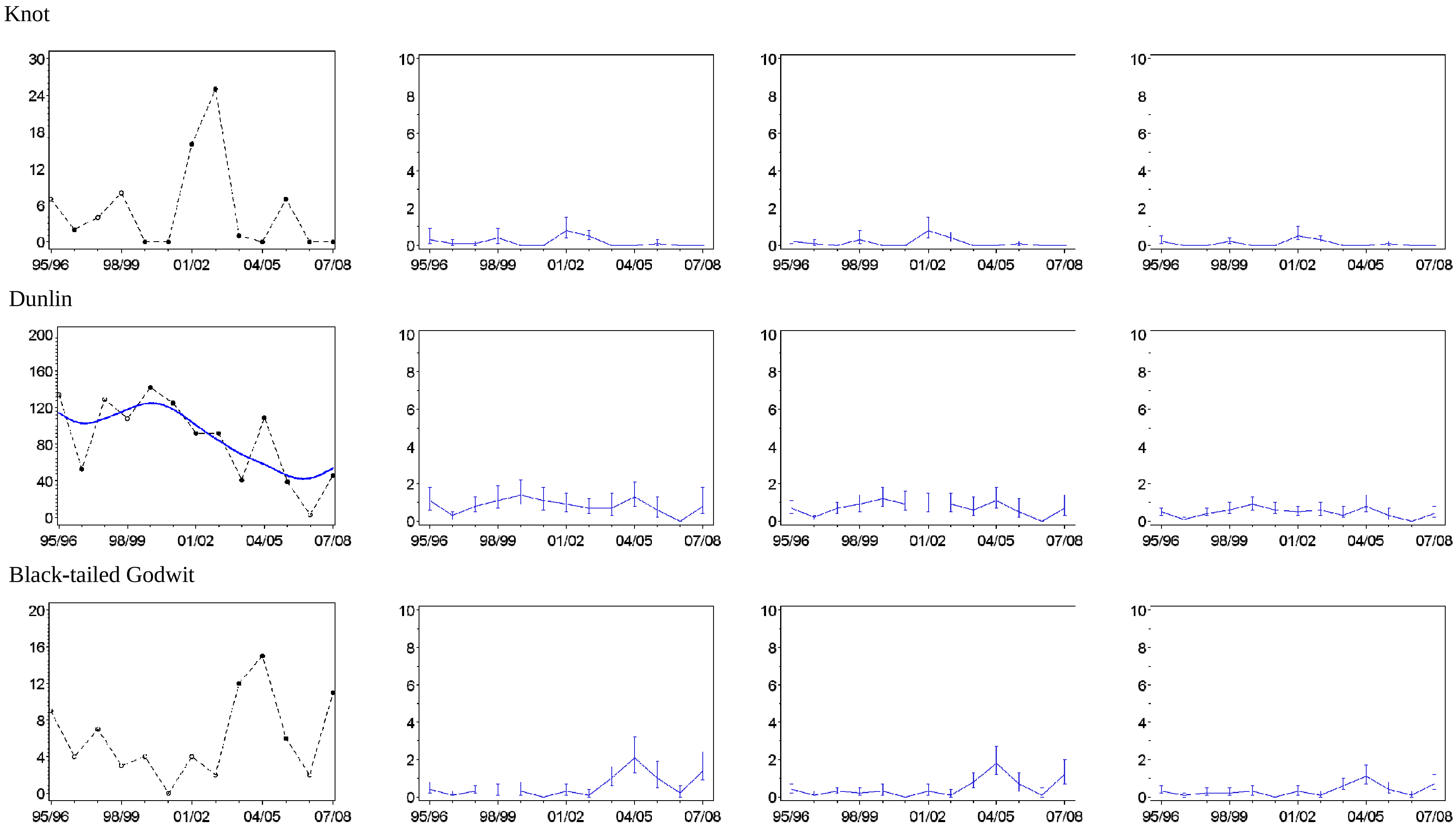


Figure S8. Population trends of each species in Mid Stour sector CU006 (Copperas Wood Farm to Shore Farm) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

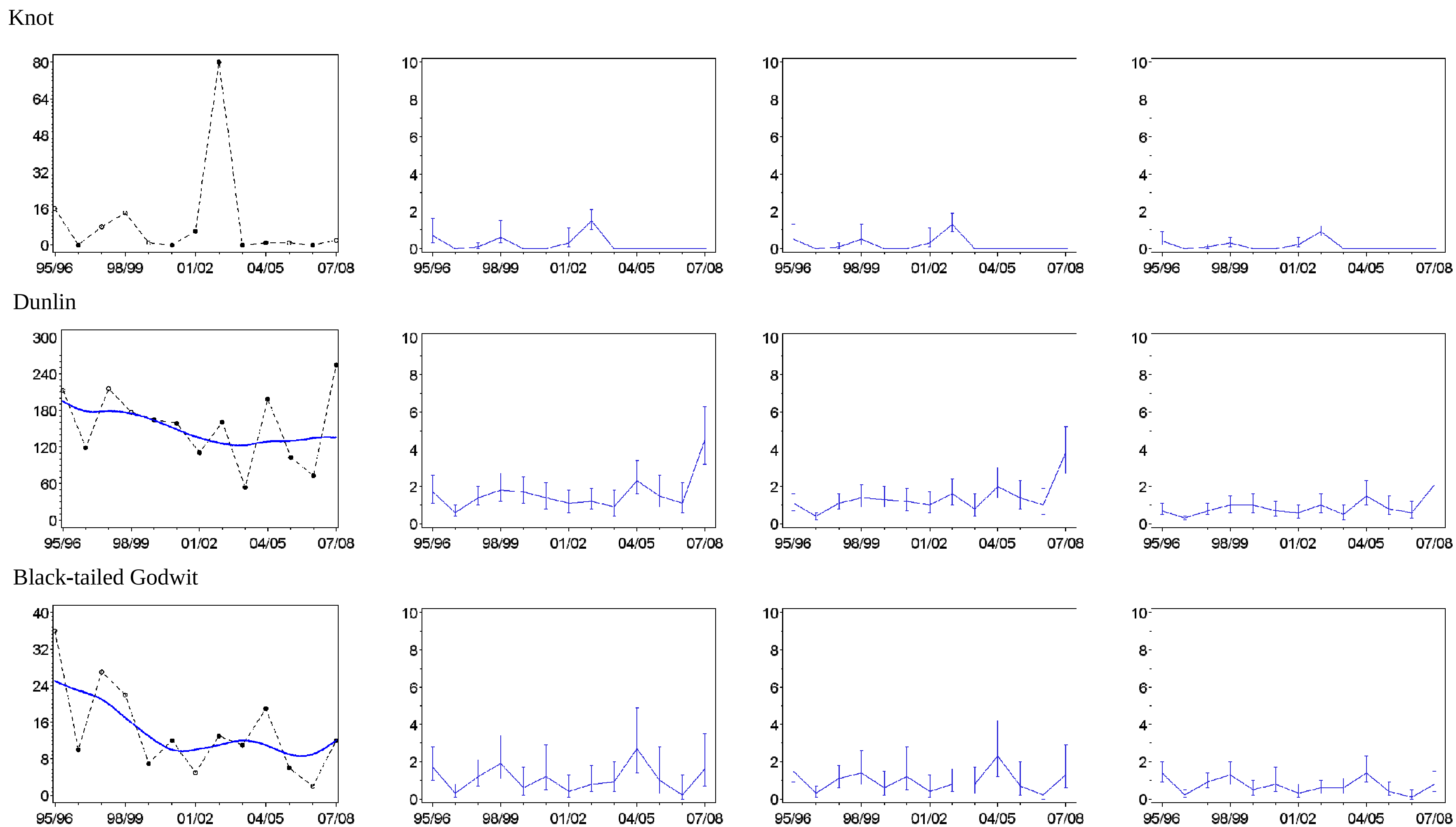


Figure S9. Population trends of each species in Mid Stour sector CU007 (Copperas Wood Farm to Shore Farm) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

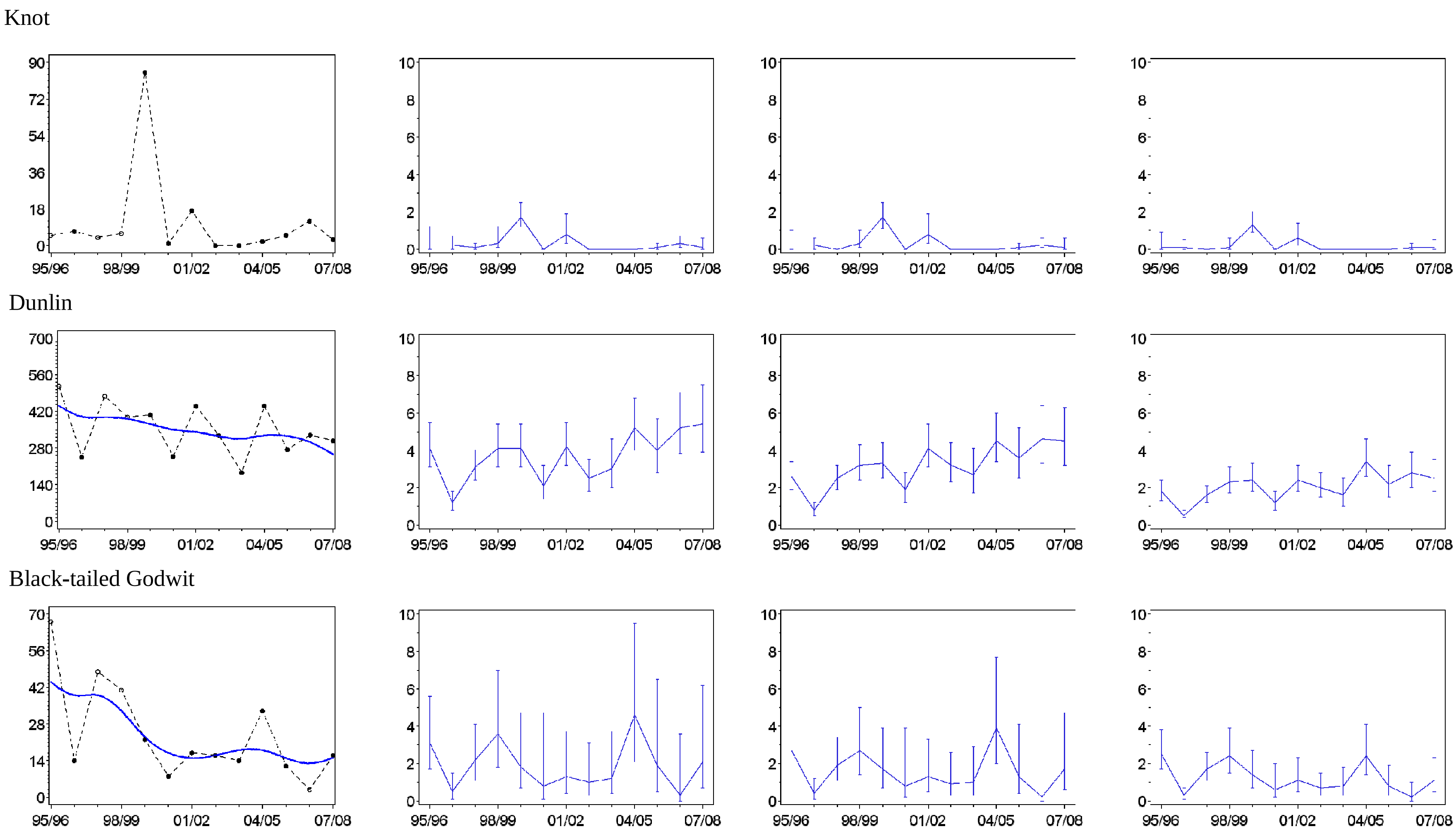


Figure S10. Population trends of each species in Mid Stour sector CU008 (Copperas Wood Farm to Shore Farm) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

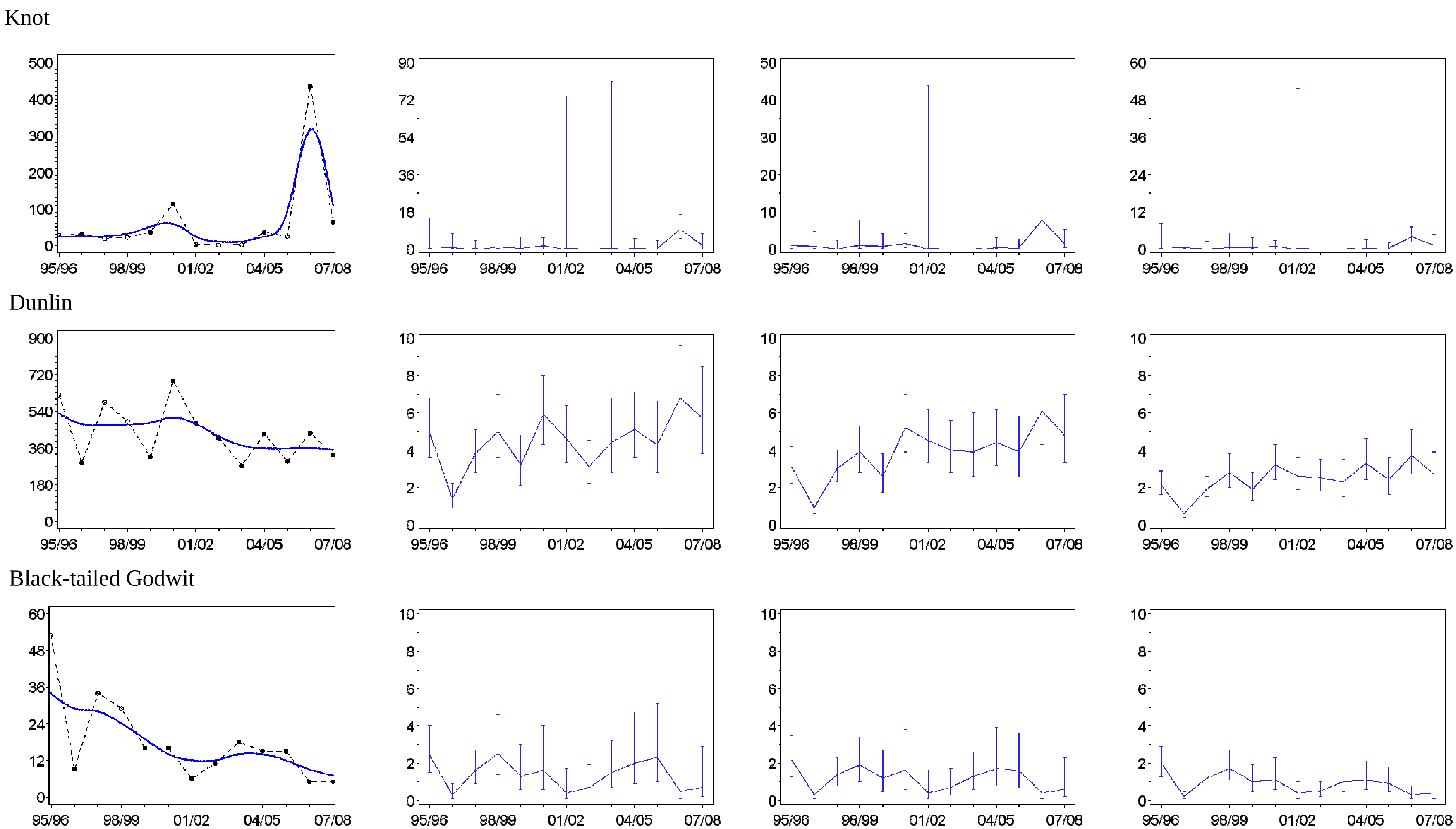


Figure S11. Population trends of each species in Mid Stour sector CU009 (Copperas Wood Farm to Shore Farm) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

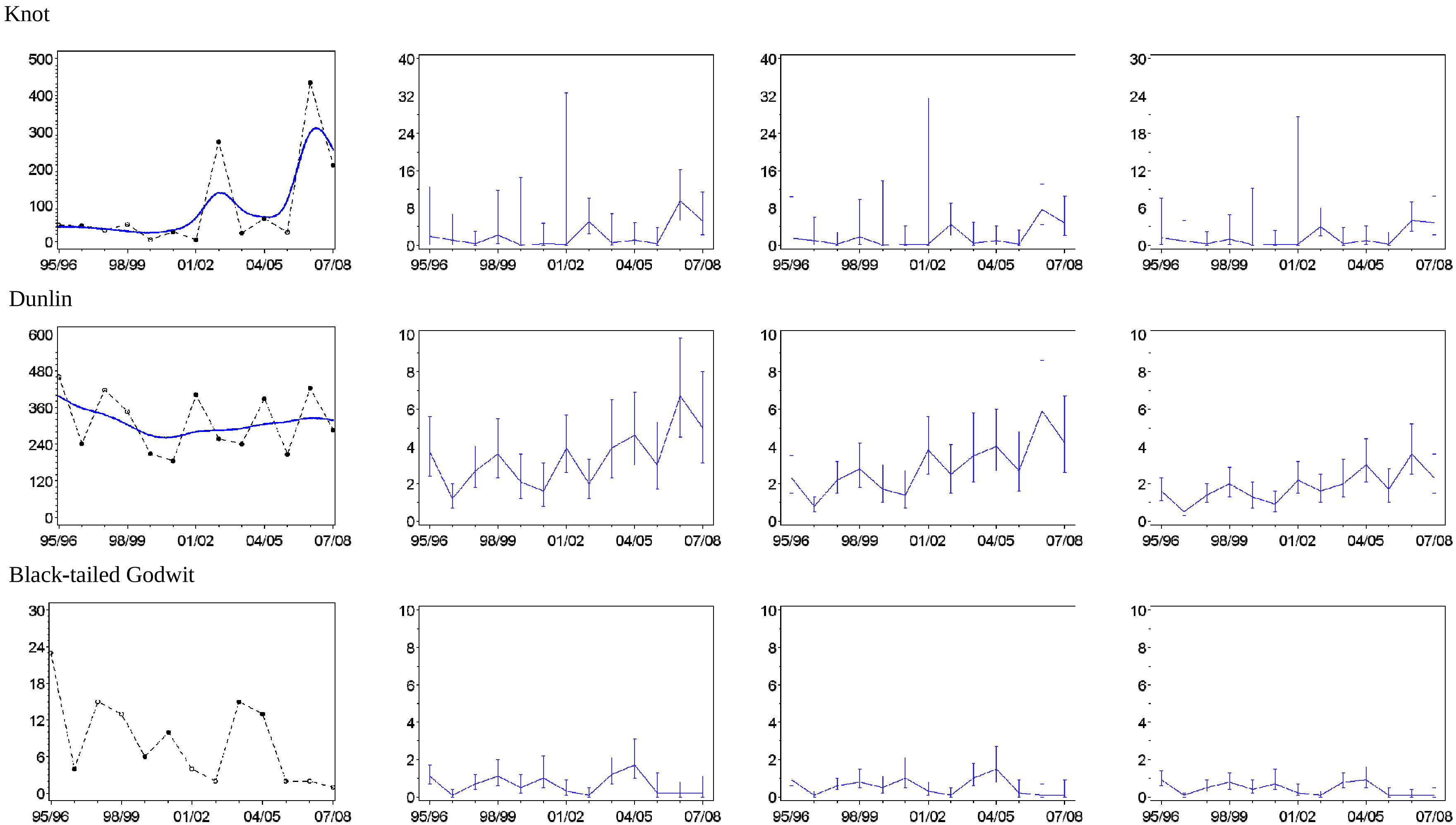


Figure S12. Population trends of each species in Mid Stour sector CU010 (Copperas Wood Farm to Shore Farm) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

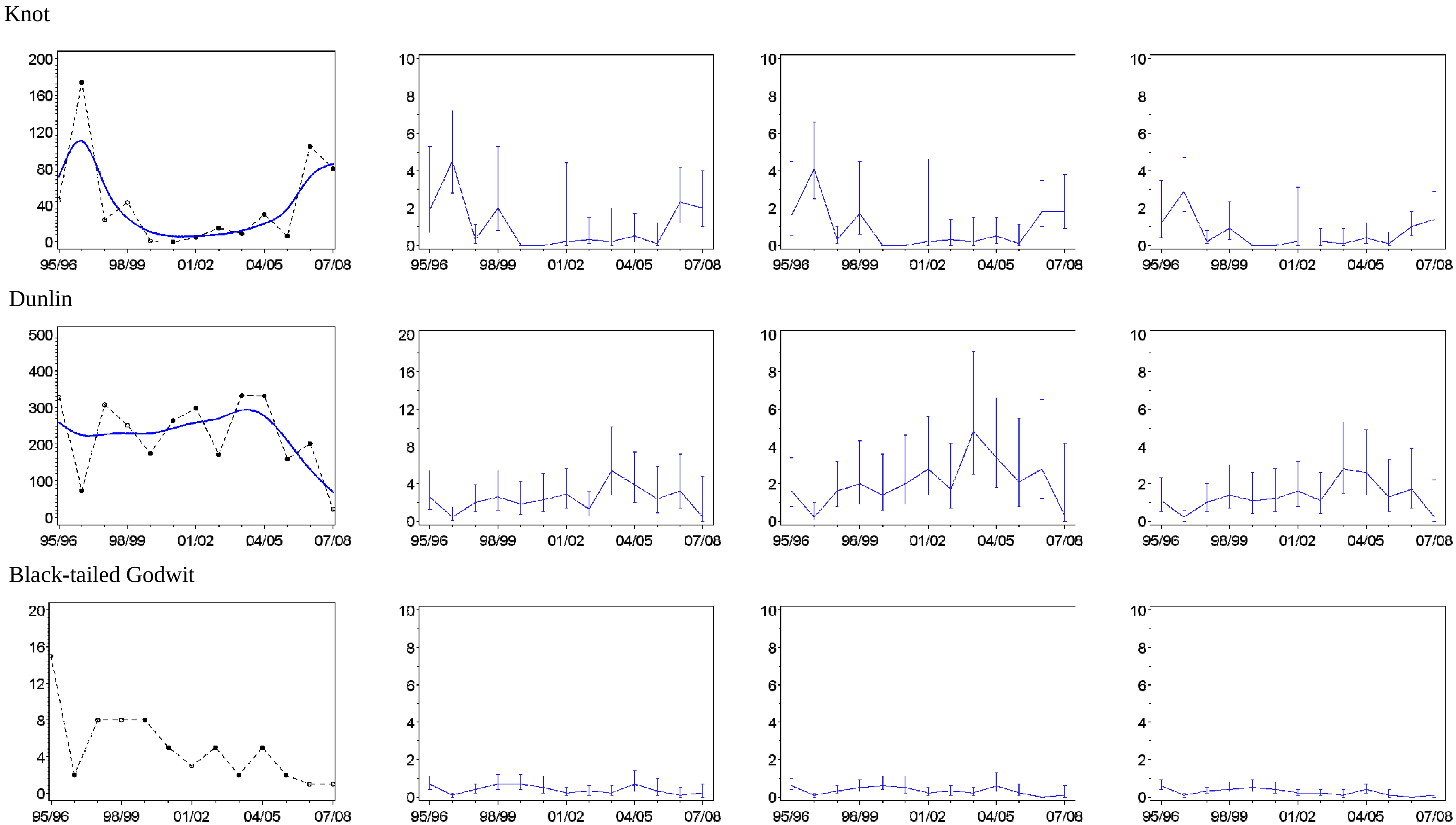


Figure S13. Population trends of each species in Mid Stour sector CU011 (Copperas Wood Farm to Shore Farm) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

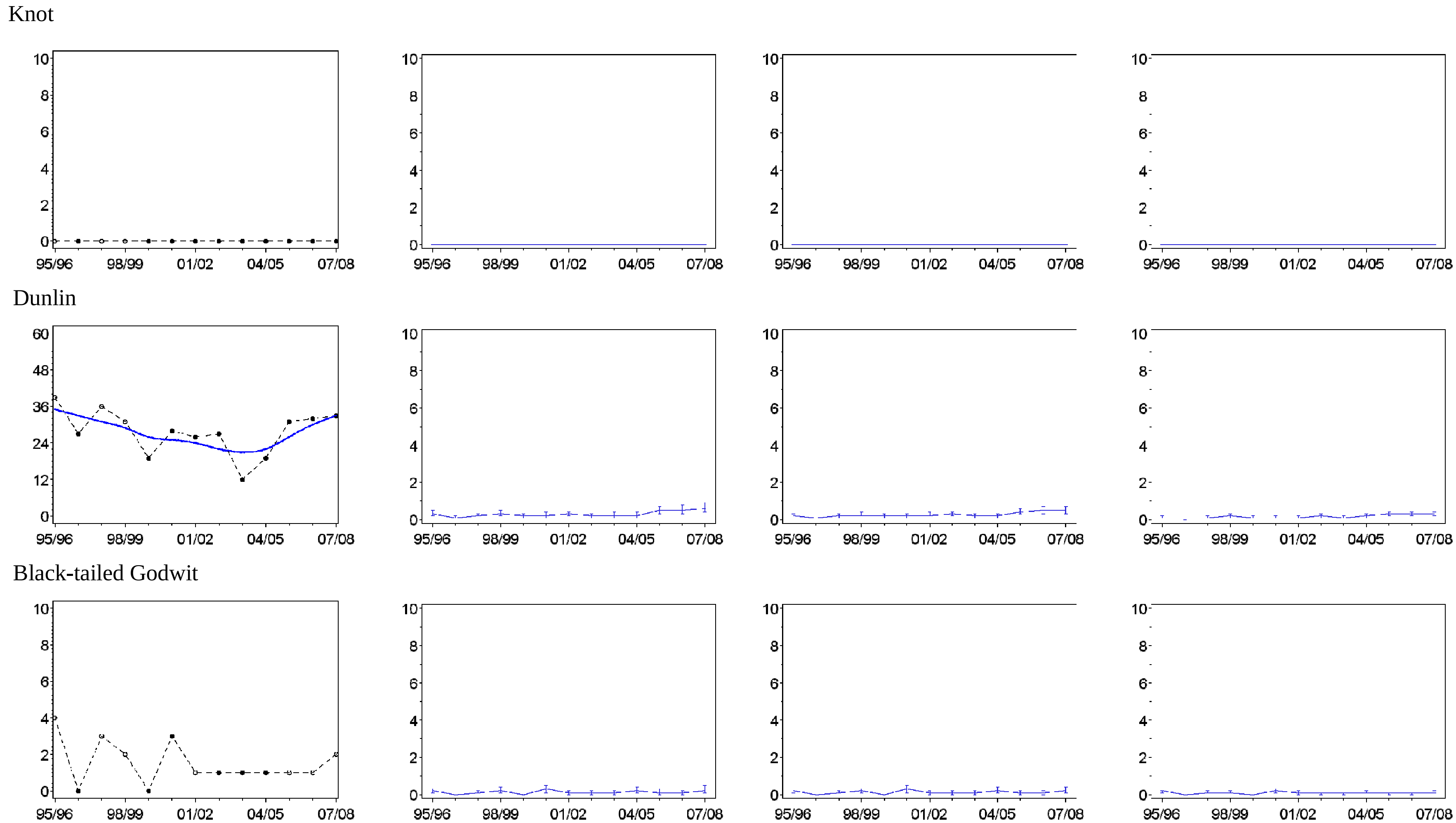
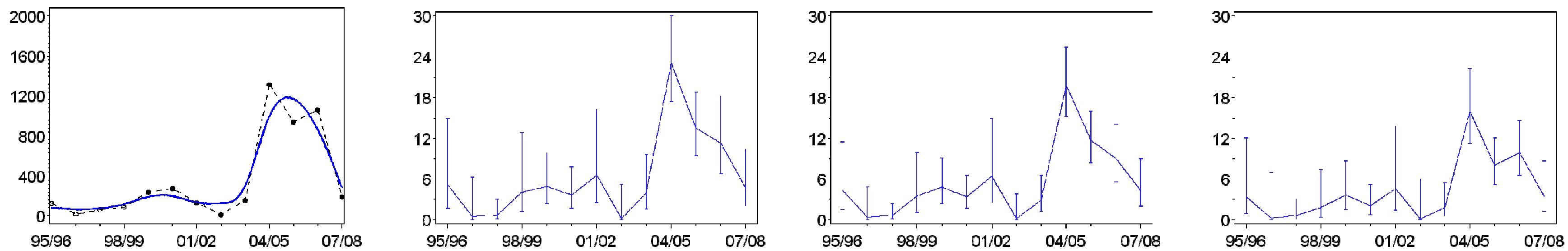
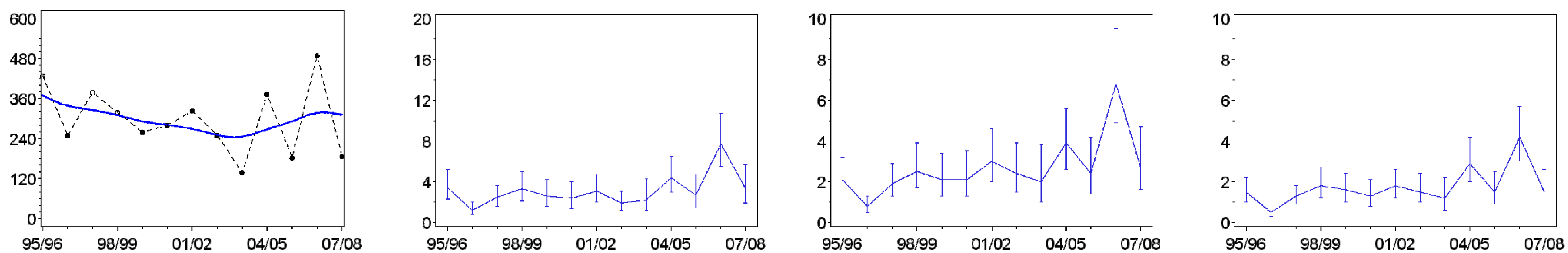


Figure S14. Population trends of each species in Mid Stour sector CU012 (Shore Farm to Sluice Rill) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

Knot



Dunlin



Black-tailed Godwit

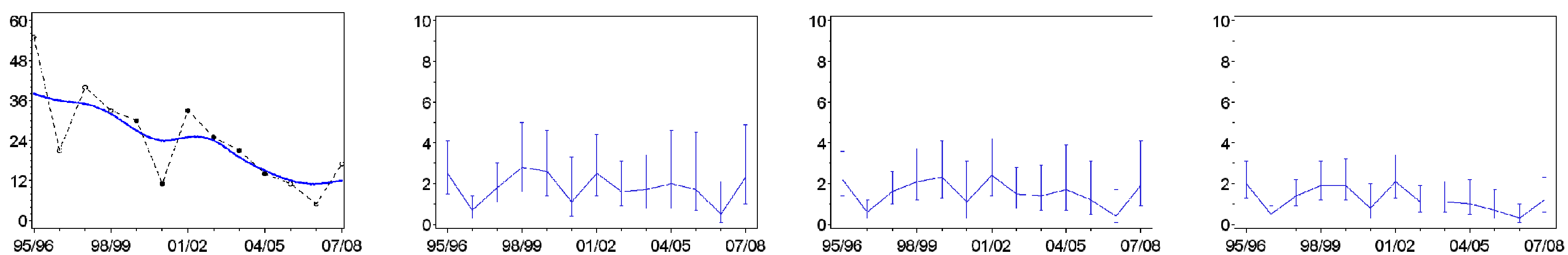


Figure S15. Population trends of each species in Mid Stour sector CU033 (Stutton Ness to Holbrook Creek) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

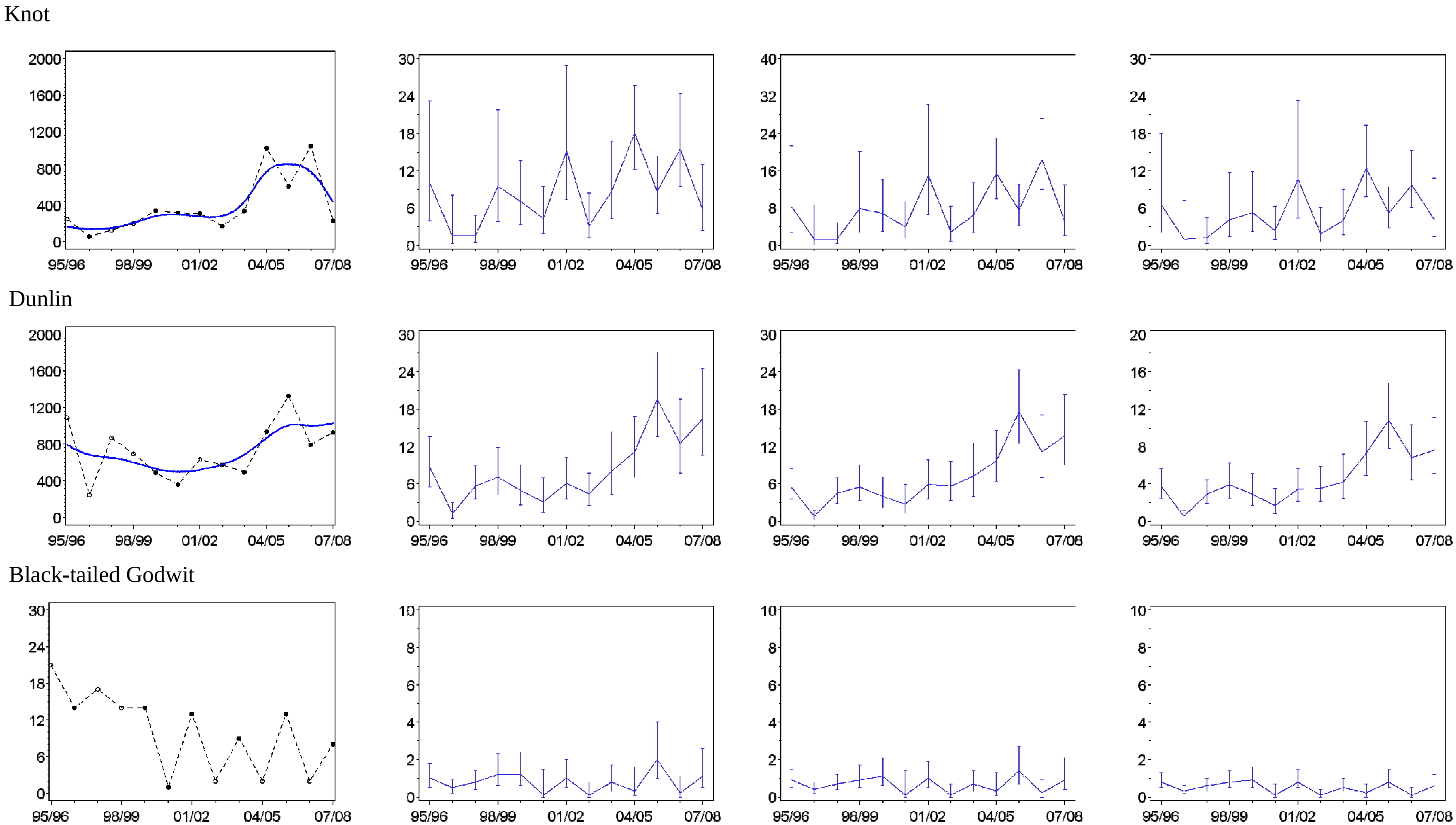


Figure S16. Population trends of each species in Mid Stour sector CU034 (Holbrook Creek to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

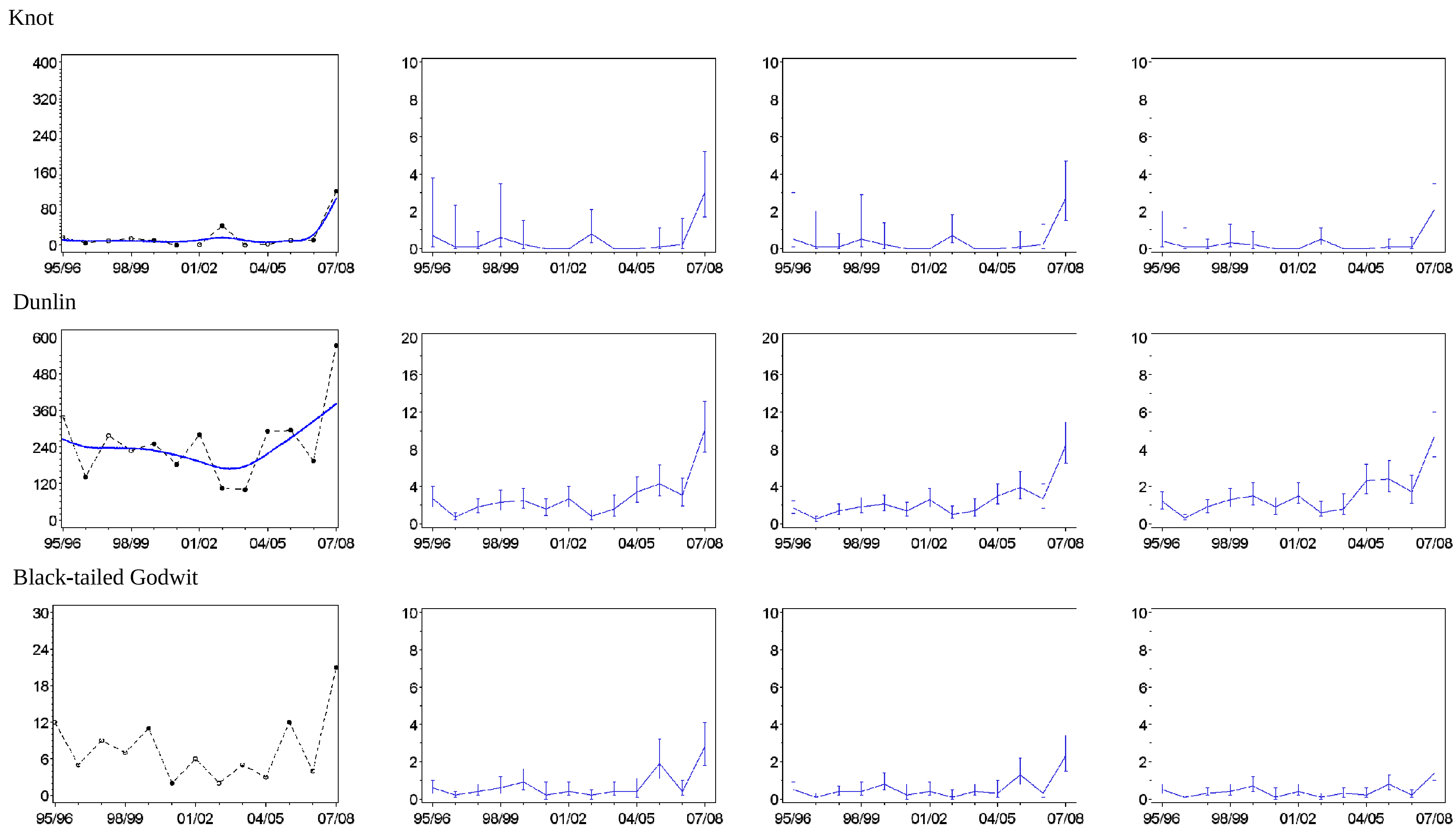


Figure S17. Population trends of each species in Mid Stour sector CU035 (Holbrook Creek to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

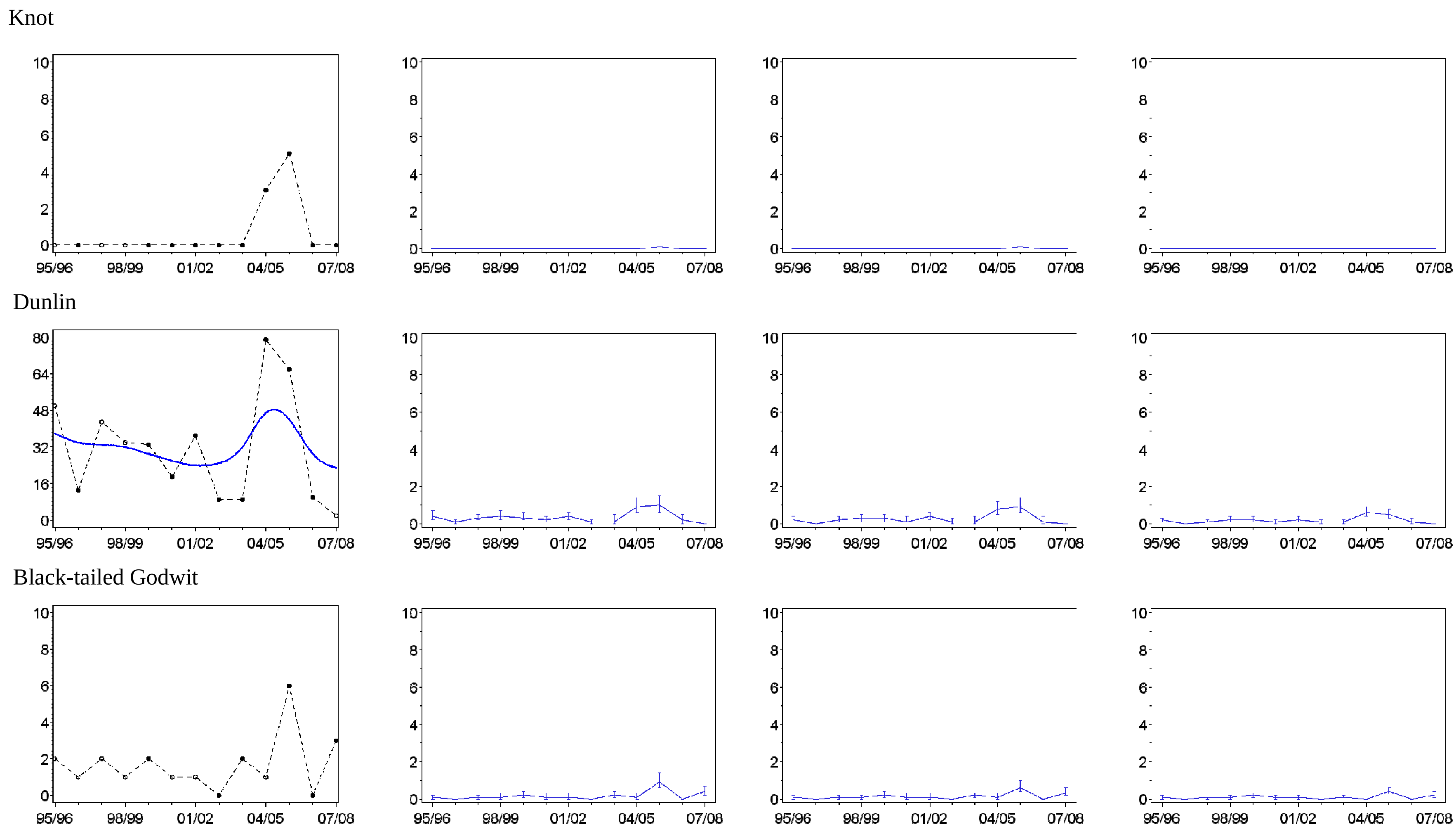


Figure S18. Population trends of each species in Mid Stour sector CU036 (Nether Hall Creek to Erwarton Ness) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

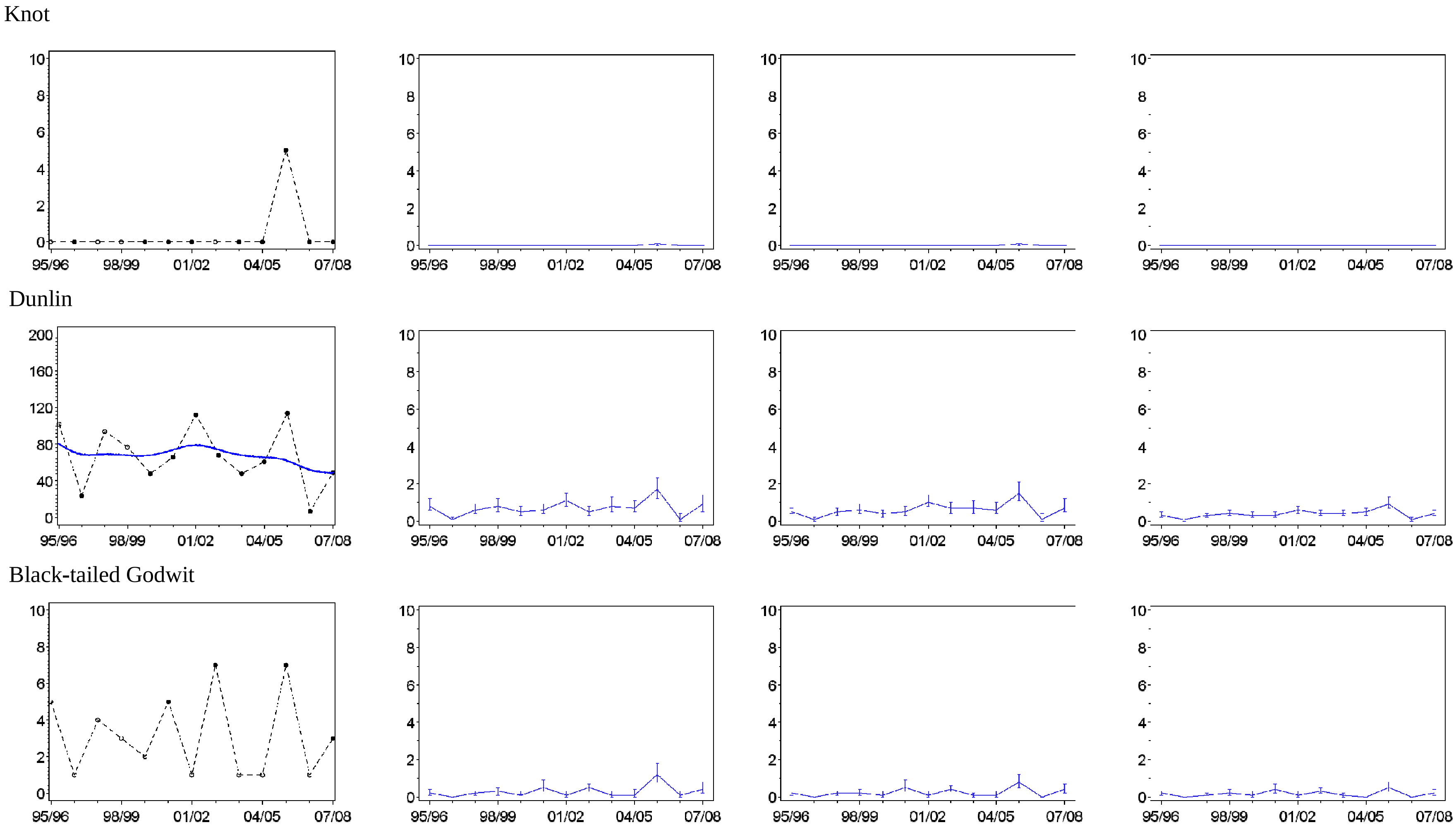


Figure S19. Population trends of each species in Mid Stour sector CU037 (Nether Hall Creek to Erwarton Ness) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

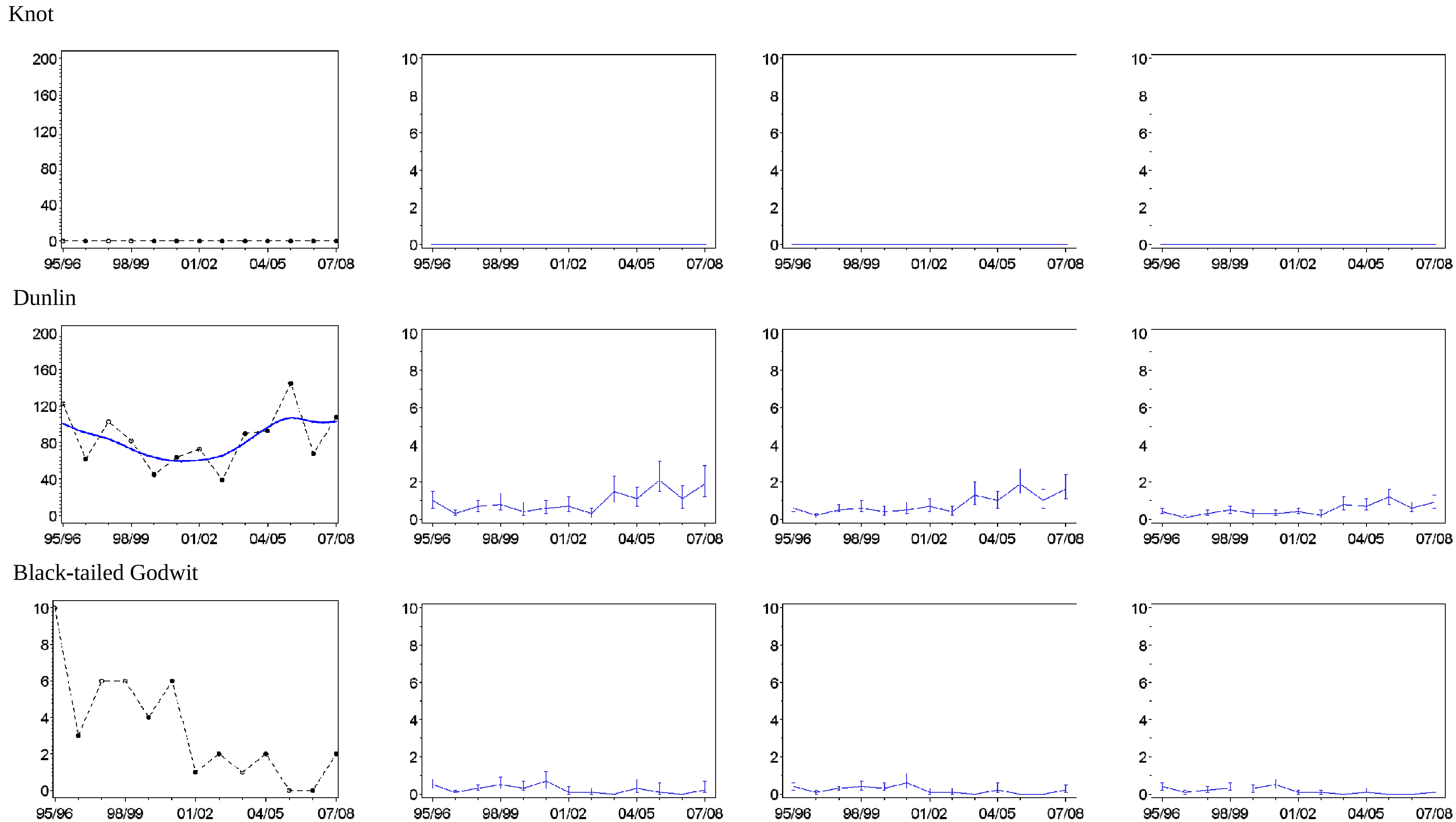


Figure S20. Population trends of each species in Upper Stour sector CU014 (Shore Farm to Sluice Rill) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

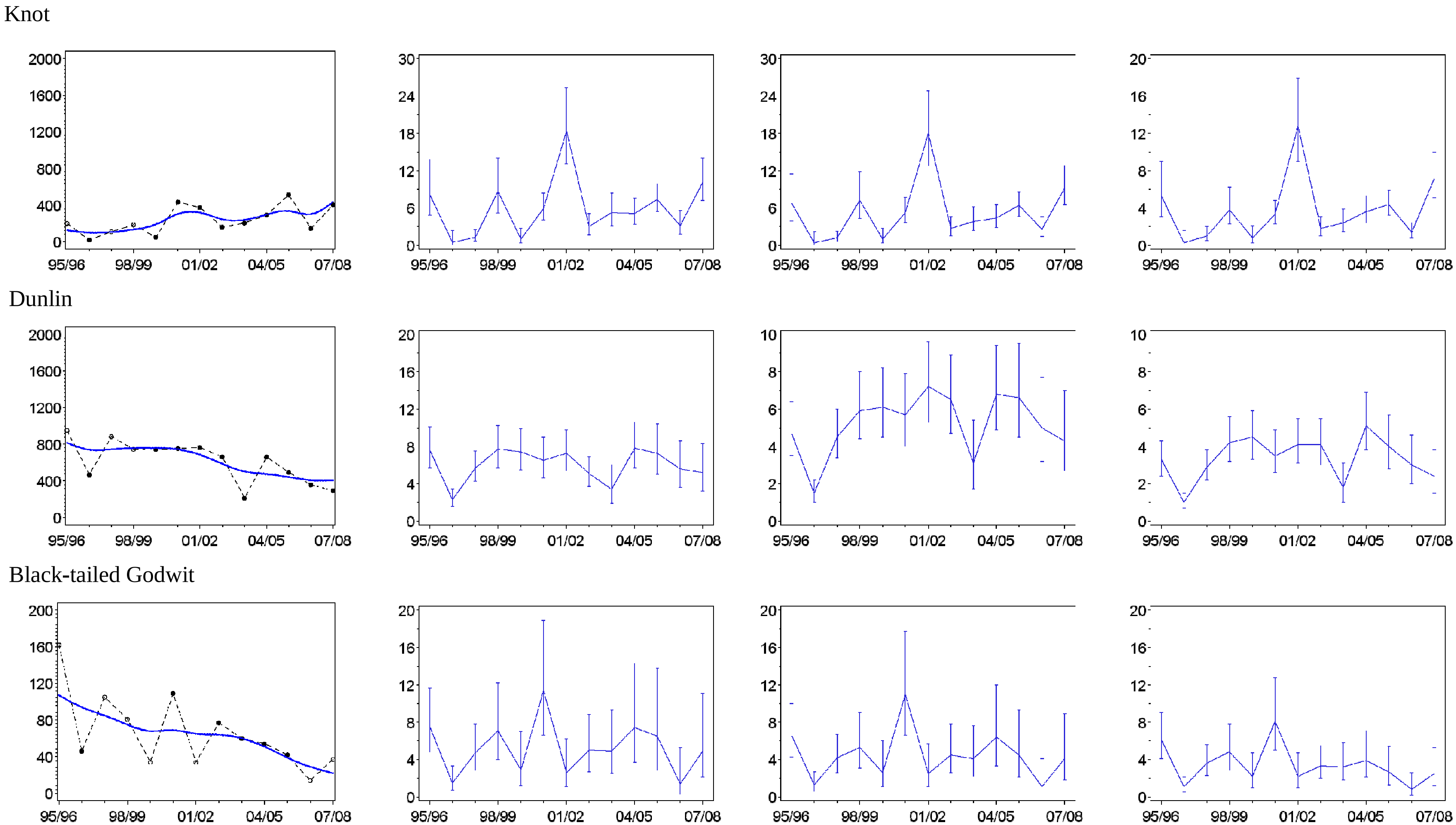


Figure S21. Population trends of each species in Upper Stour sector CU015 (Sluice Rill to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

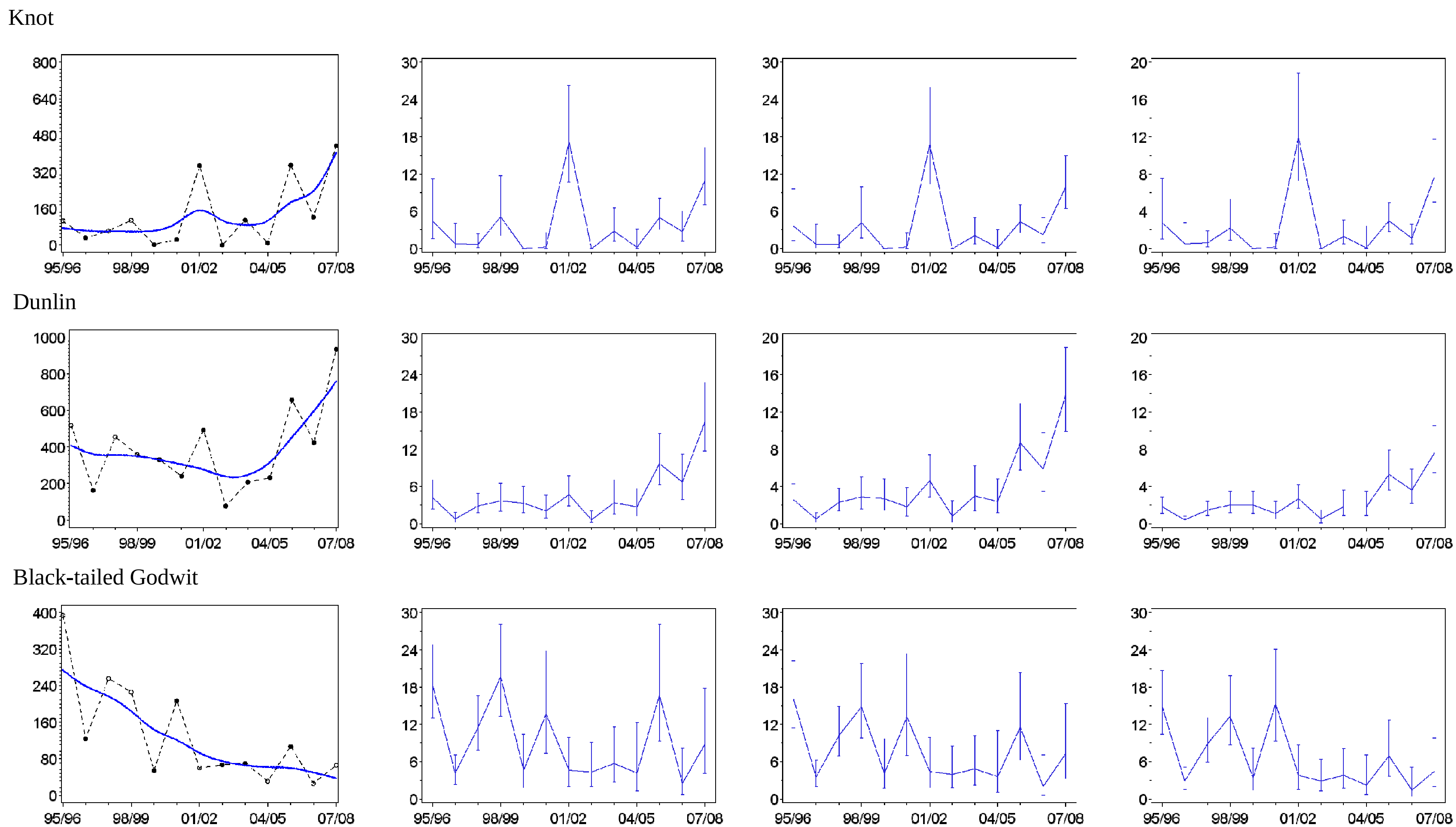


Figure S22. Population trends of each species in Upper Stour sector CU016 (Sluice Rill to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

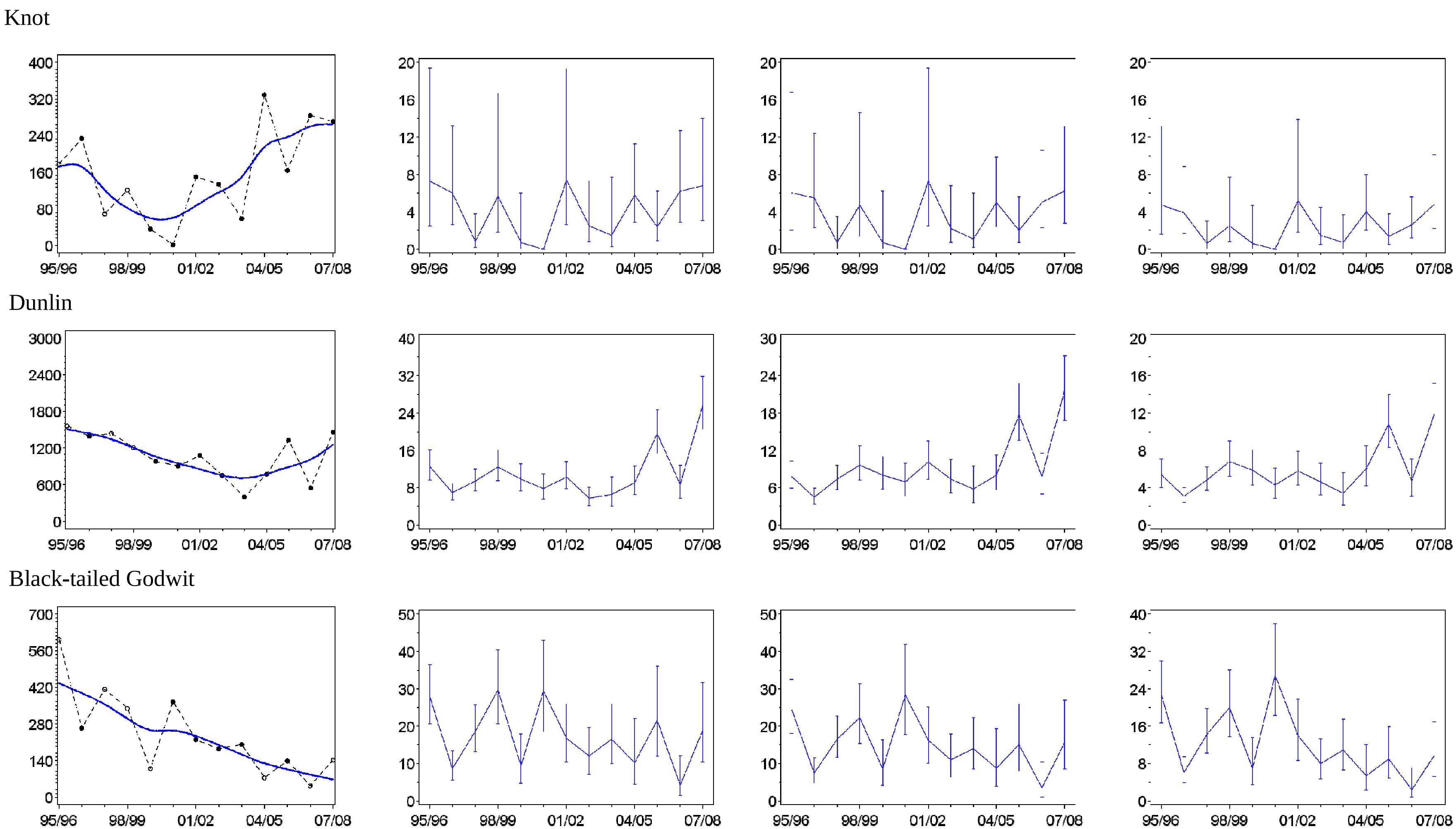


Figure S23. Population trends of each species in Upper Stour sector CU017 (Sluice Rill to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

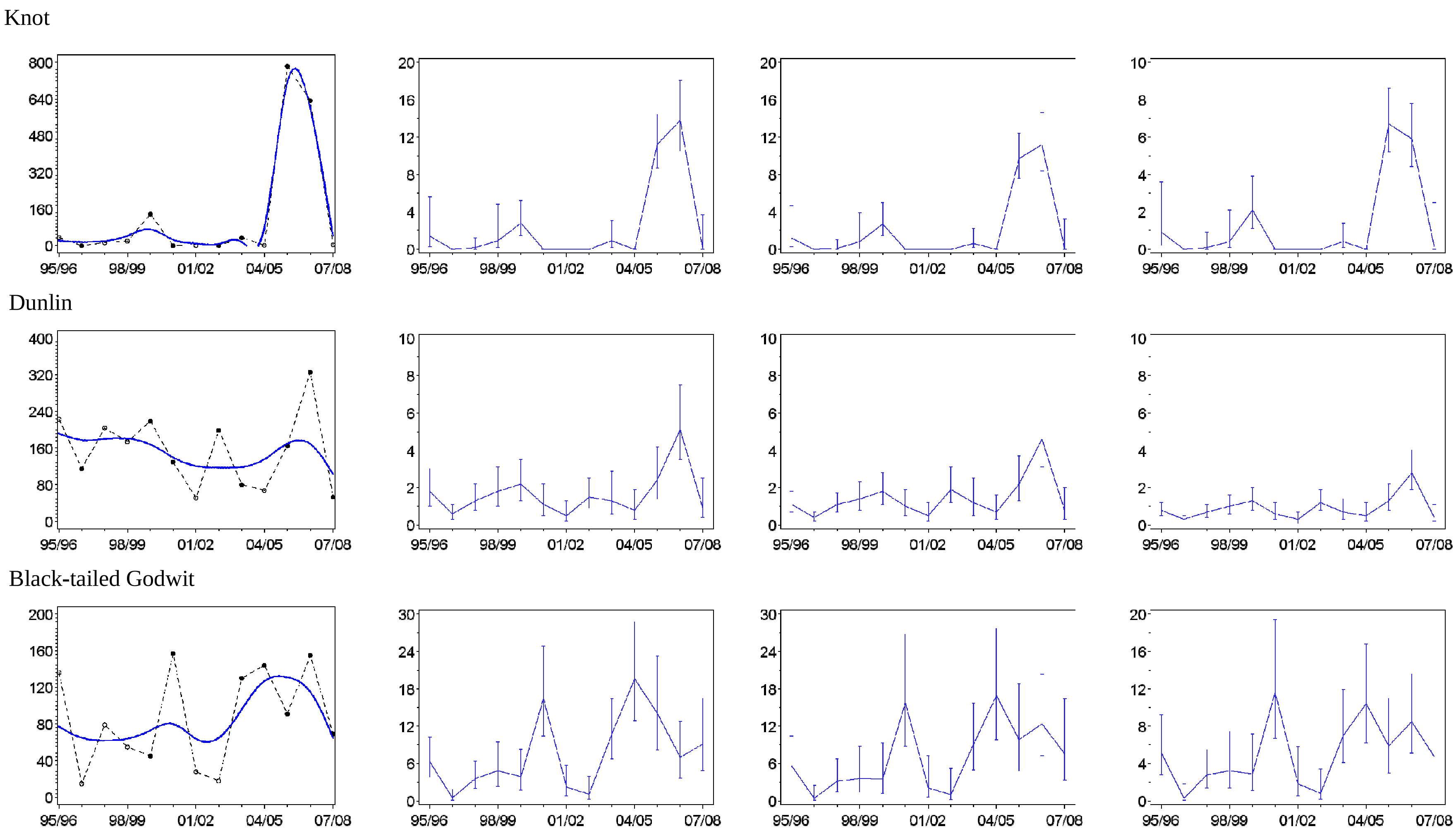


Figure S24. Population trends of each species in Upper Stour sector CU018 (East Mistley to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

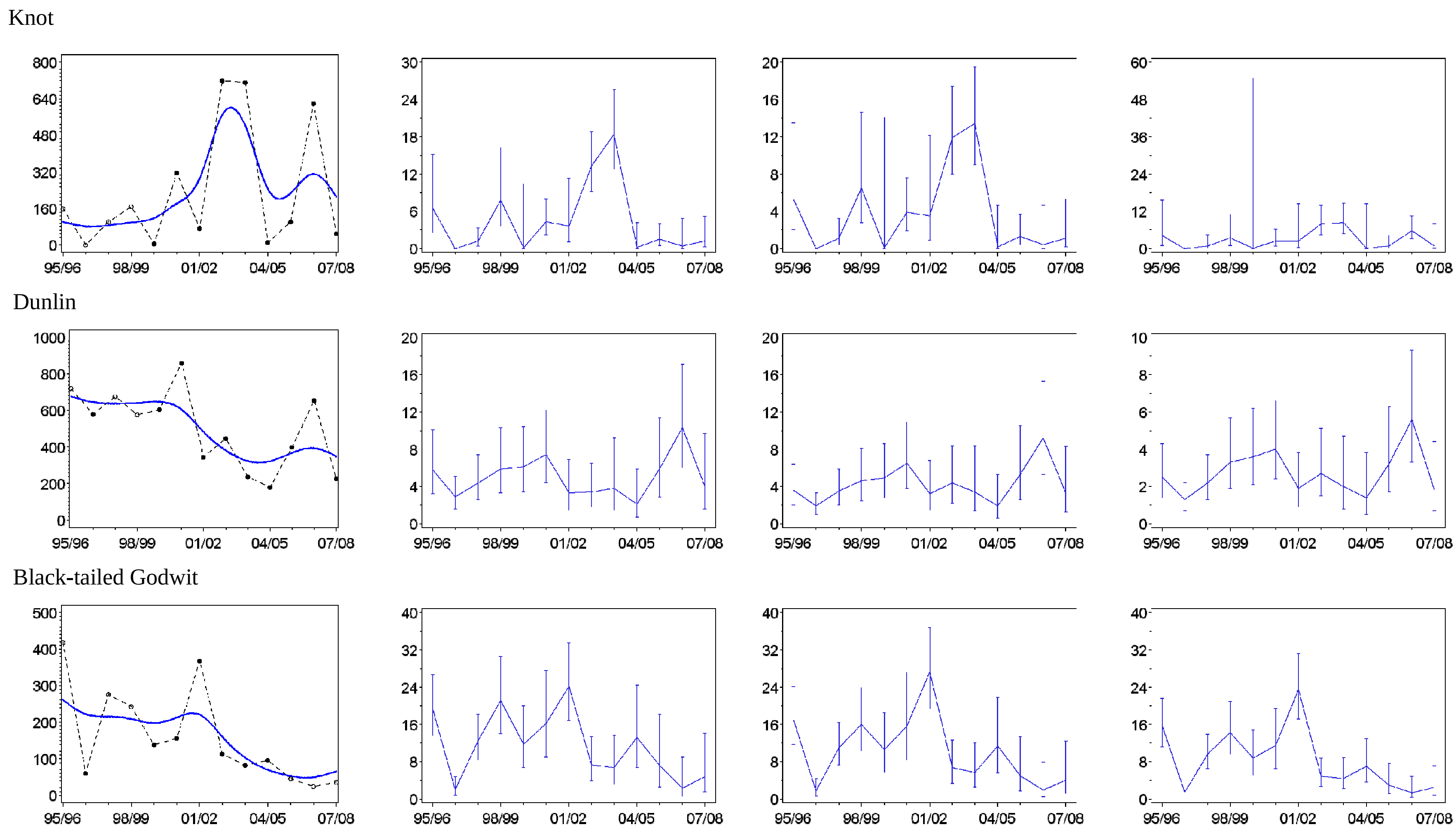


Figure S25. Population trends of each species in Upper Stour sector CU019 (East Mistley to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

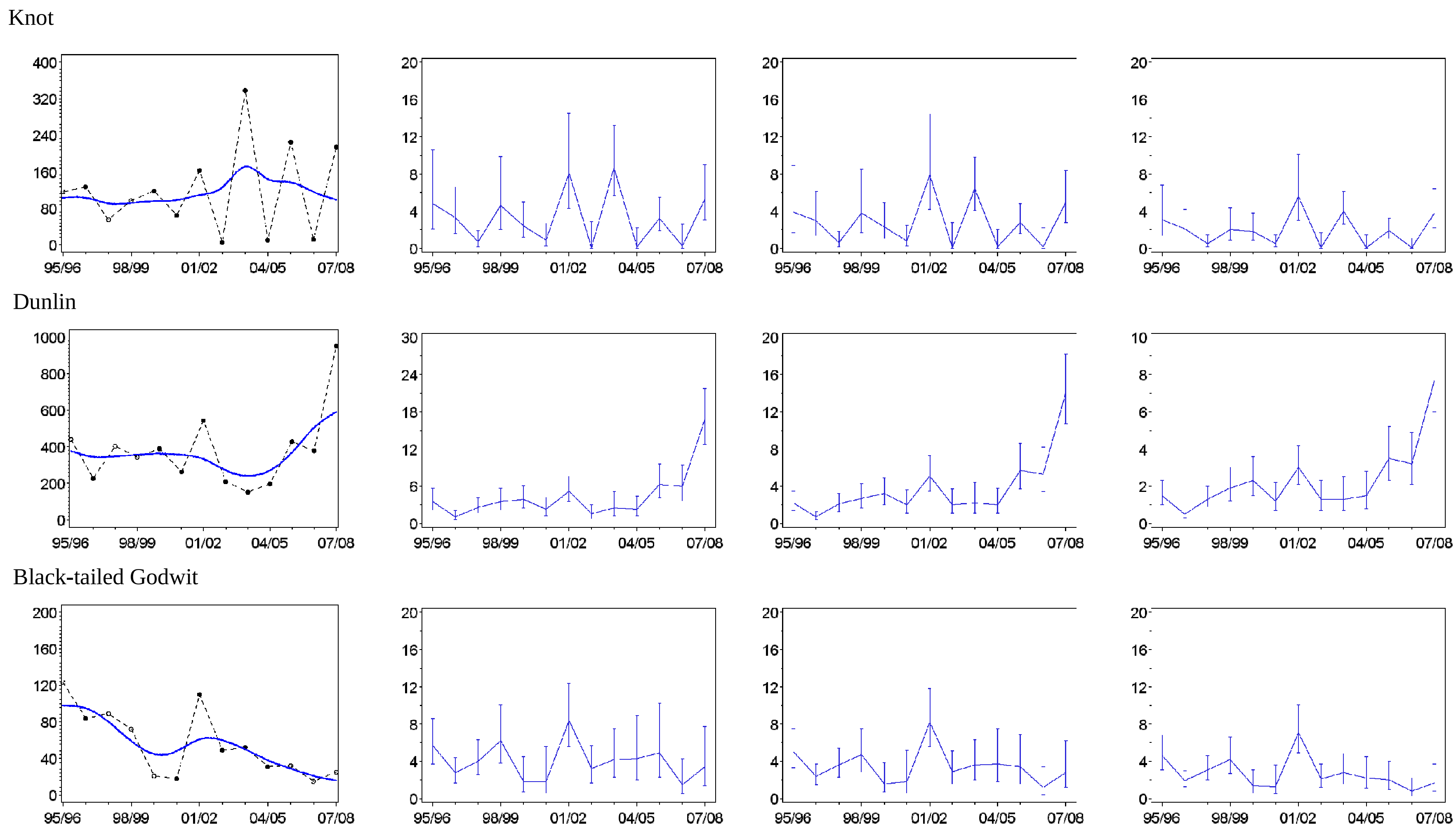


Figure S26. Population trends of each species in Upper Stour sector CU020 (East Mistley to Nether Hall) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

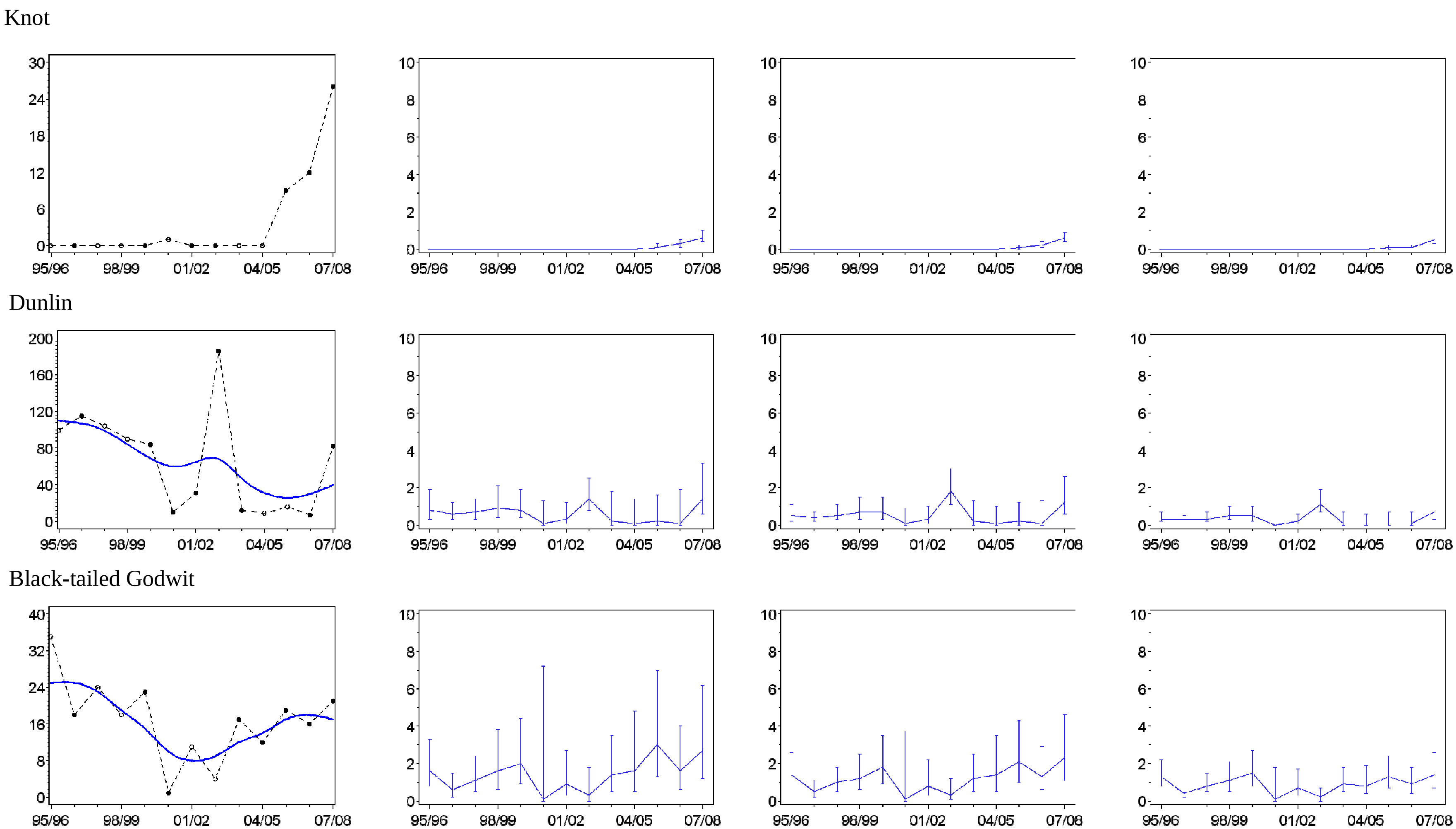
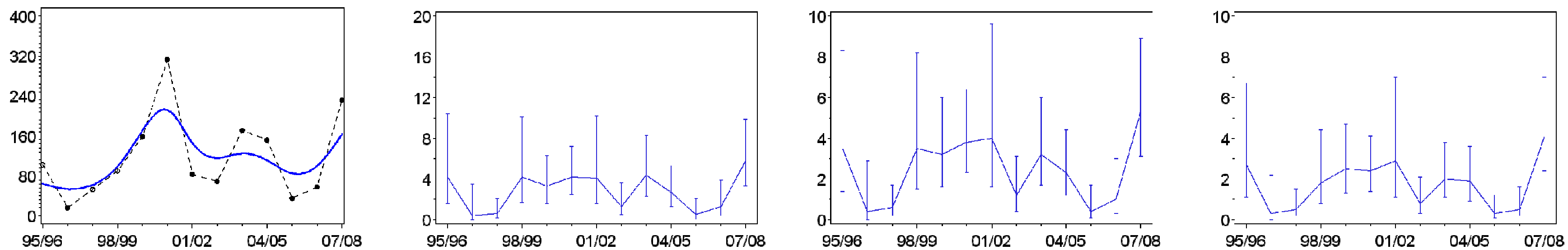
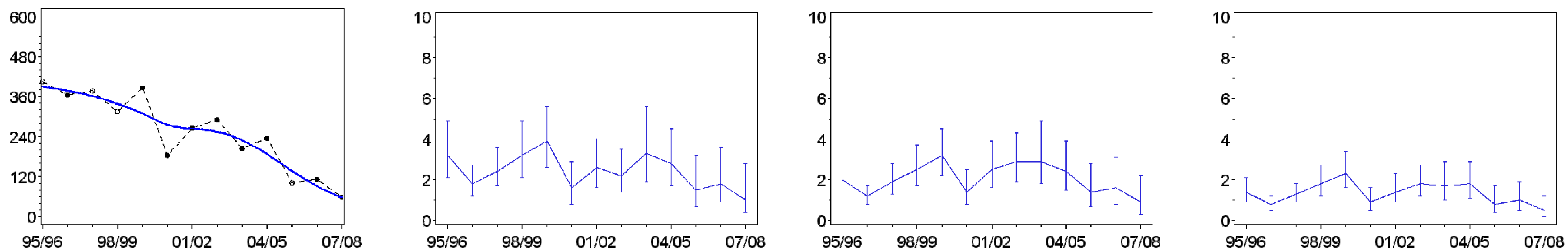


Figure S27. Population trends of each species in Upper Stour sector CU022 (Cattawade to Mistley Quay) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

Knot



Dunlin



Black-tailed Godwit

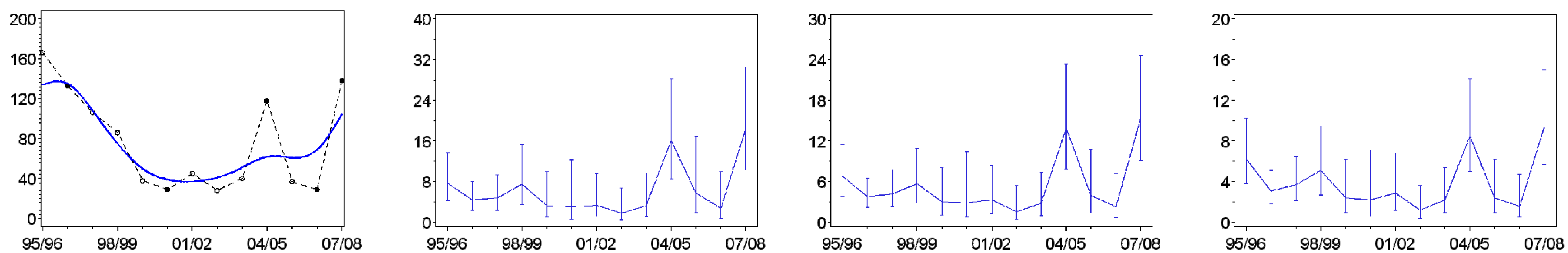


Figure S28. Population trends of each species in Upper Stour sector CU023 (Cattawade to Mistley Quay) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

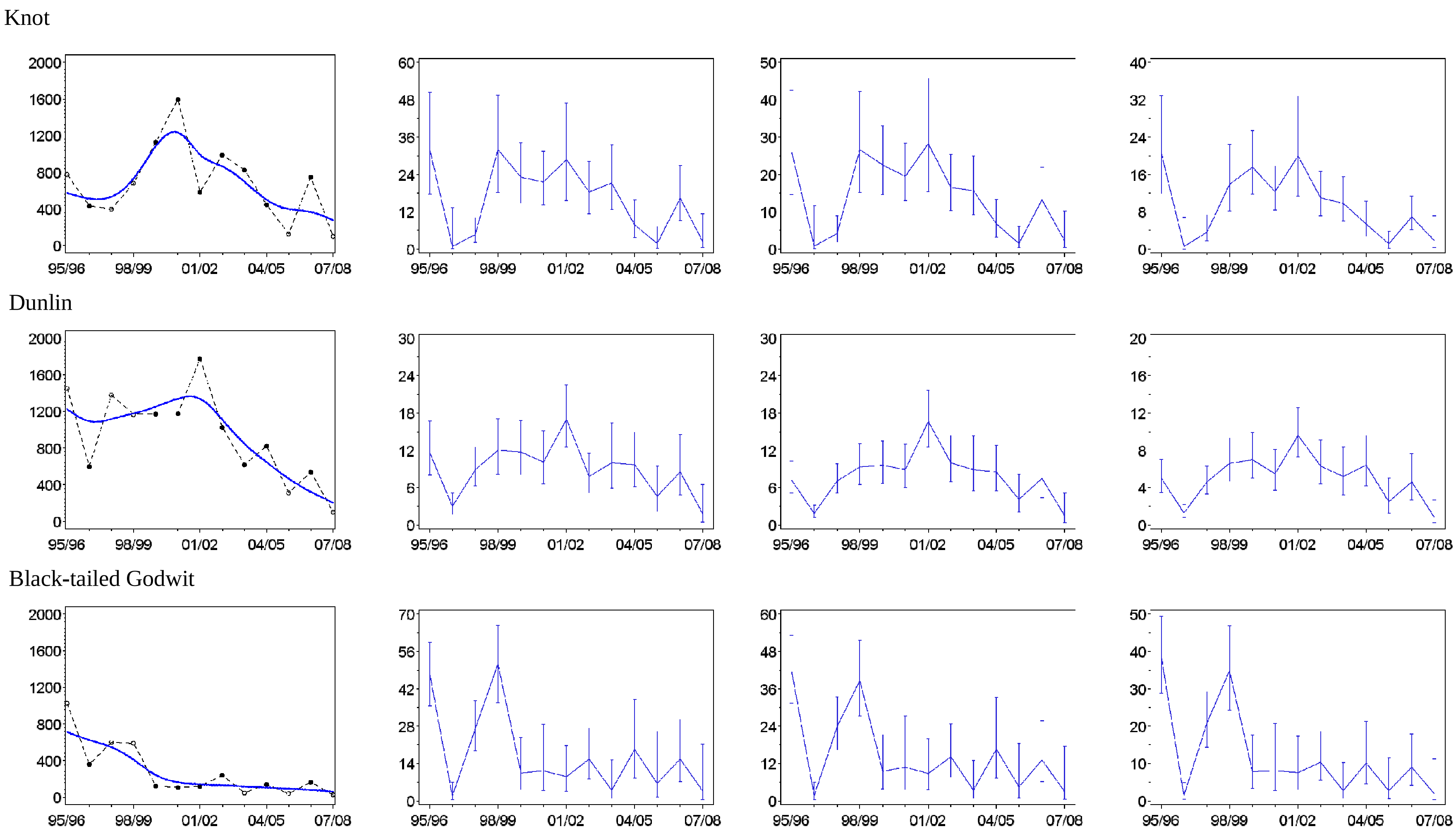


Figure S29. Population trends of each species in Upper Stour sector CU025 (Seafield Bay from South Shore) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

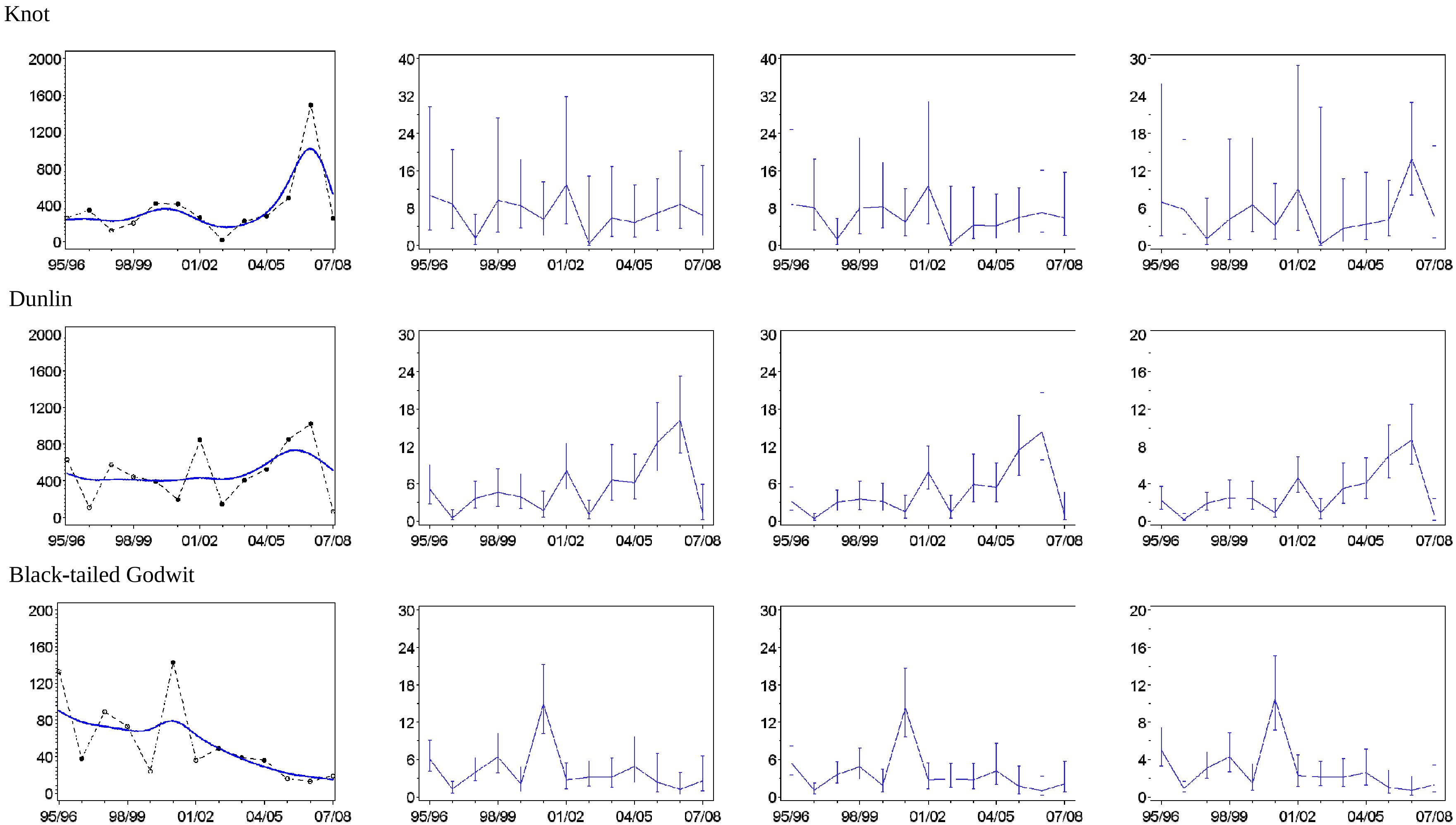


Figure S30. Population trends of each species in Upper Stour sector CU026 (Seafield Bay from North Shore) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

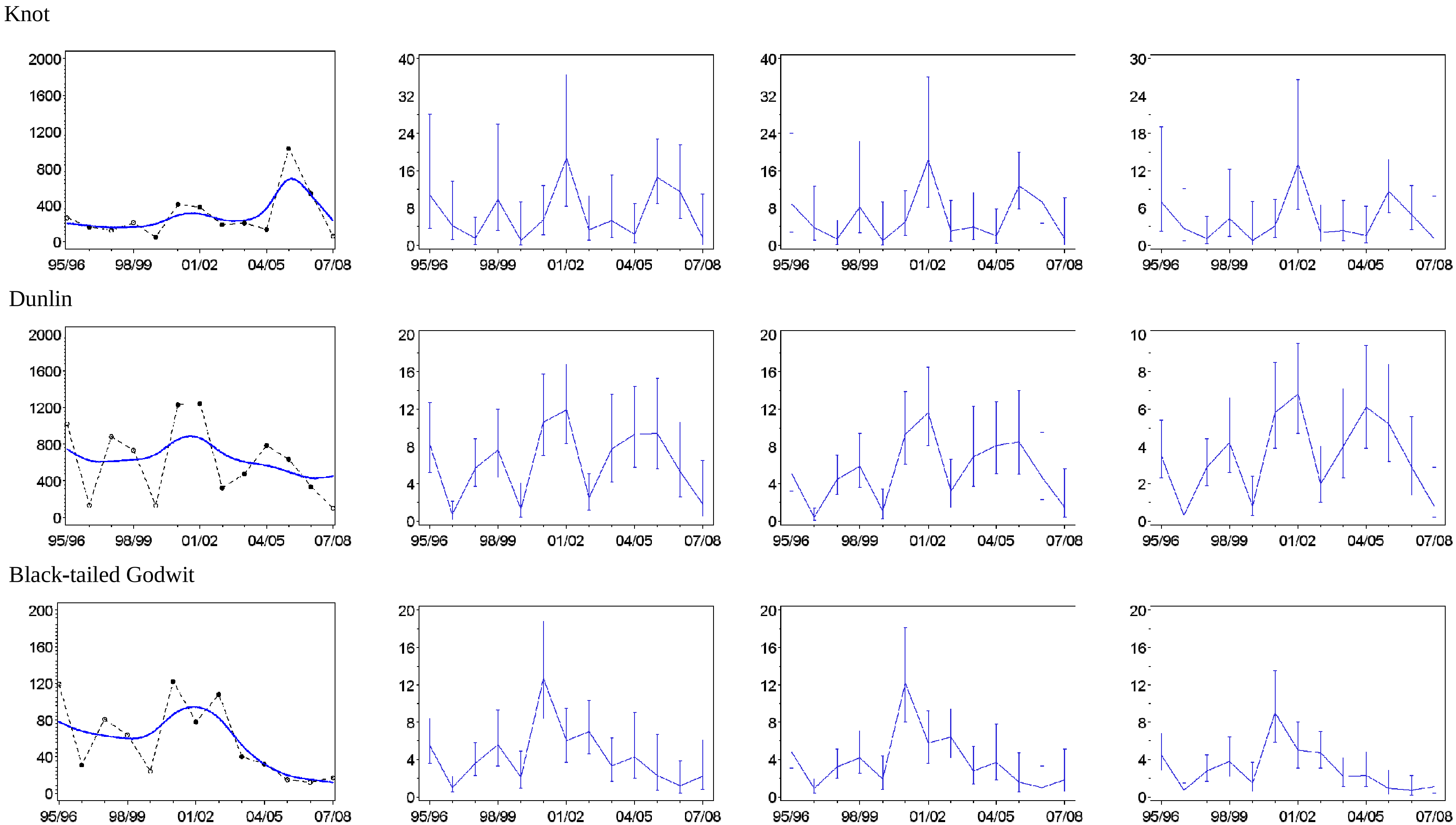


Figure S31. Population trends of each species in Upper Stour sector CU027 (Seafield Bay from North Shore) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

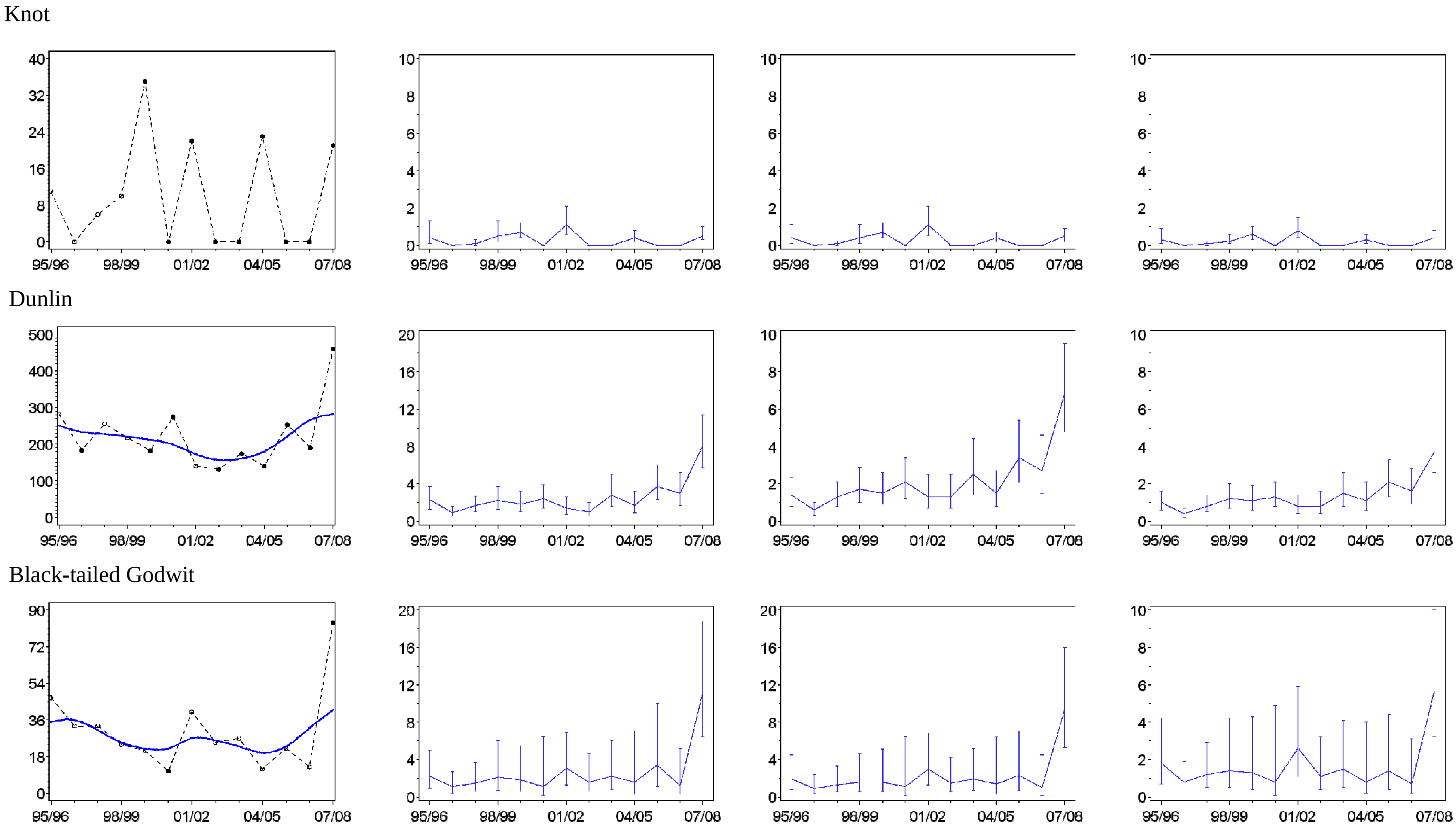


Figure S32. Population trends of each species in Upper Stour sector CU028 (Newmill Creek to Stutton Ness) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

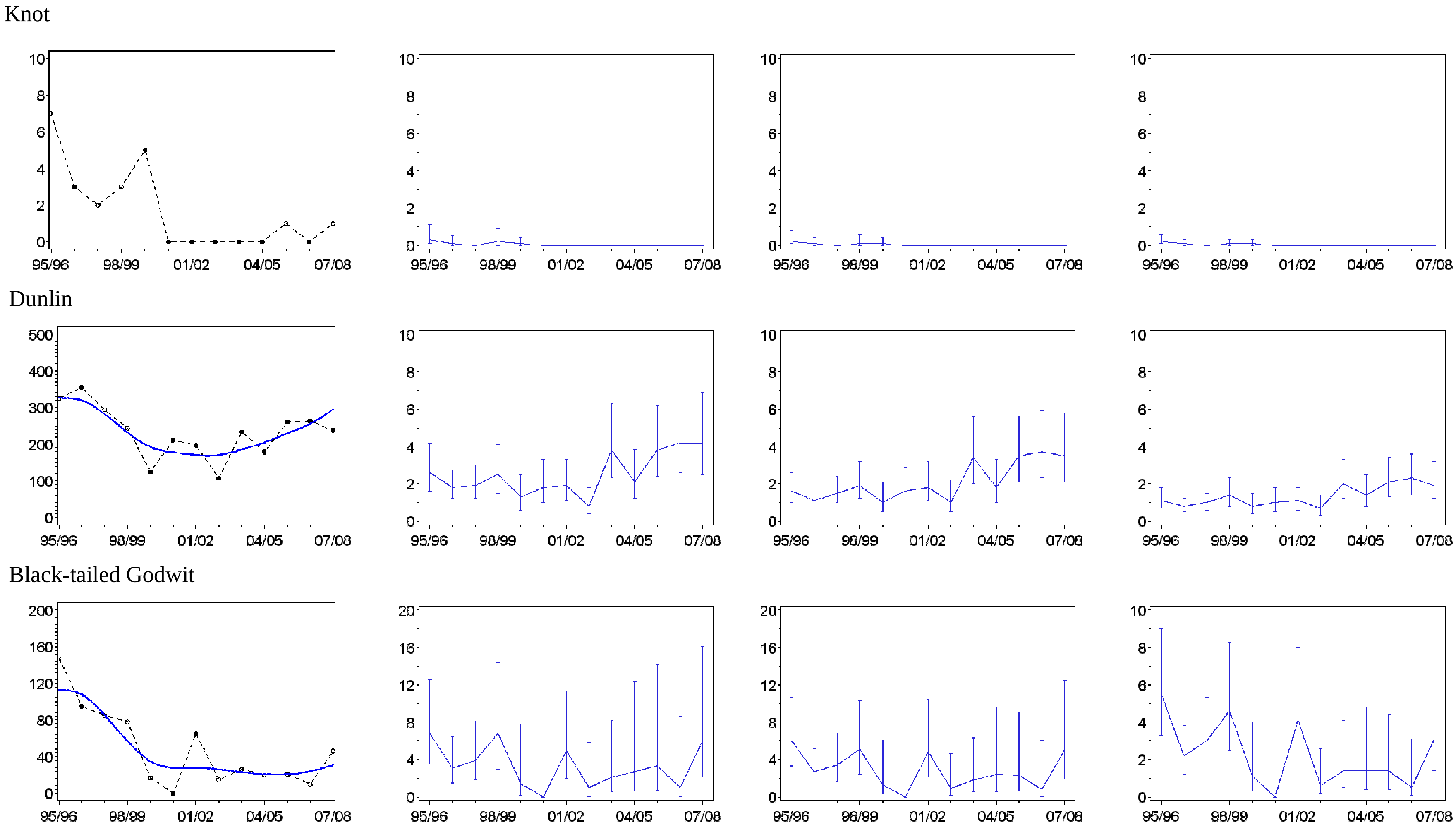


Figure S33. Population trends of each species in Upper Stour sector CU029 (Newmill Creek to Stutton Ness) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

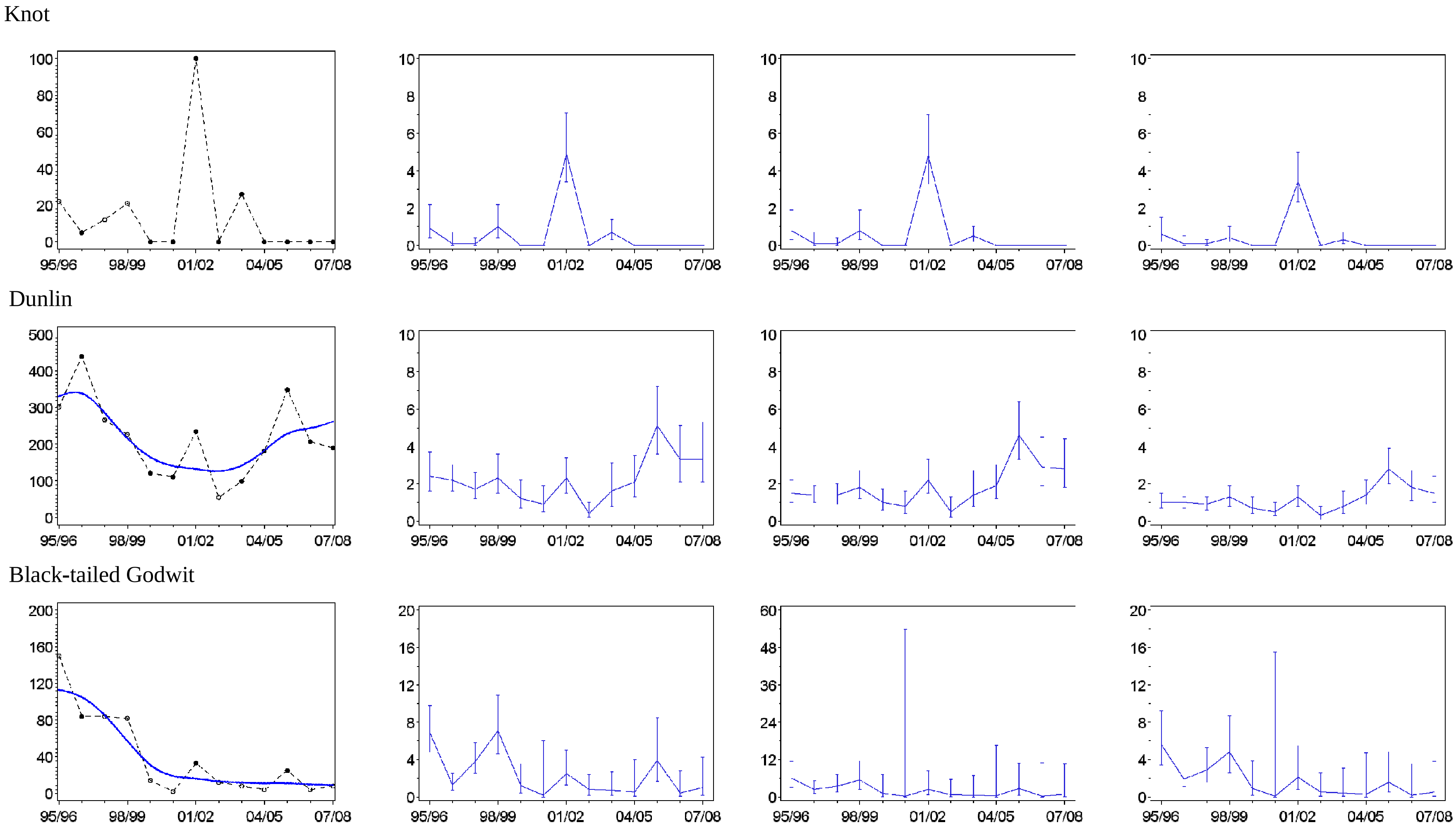


Figure S34. Population trends of each species in Upper Stour sector CU030 (Newmill Creek to Stutton Ness) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

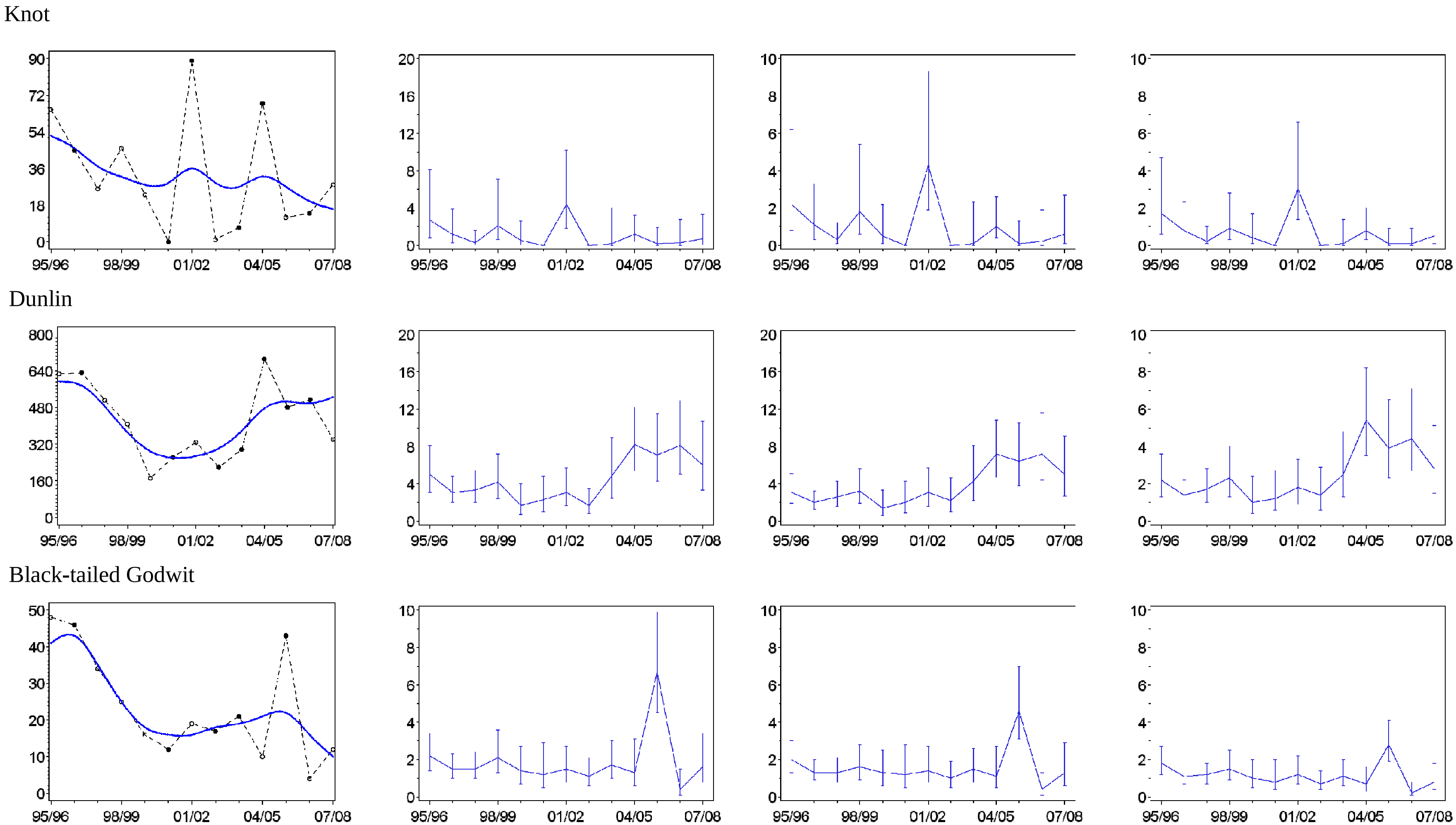


Figure S35. Population trends of each species in Upper Stour sector CU031 (Stutton Ness to Holbrook Creek) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

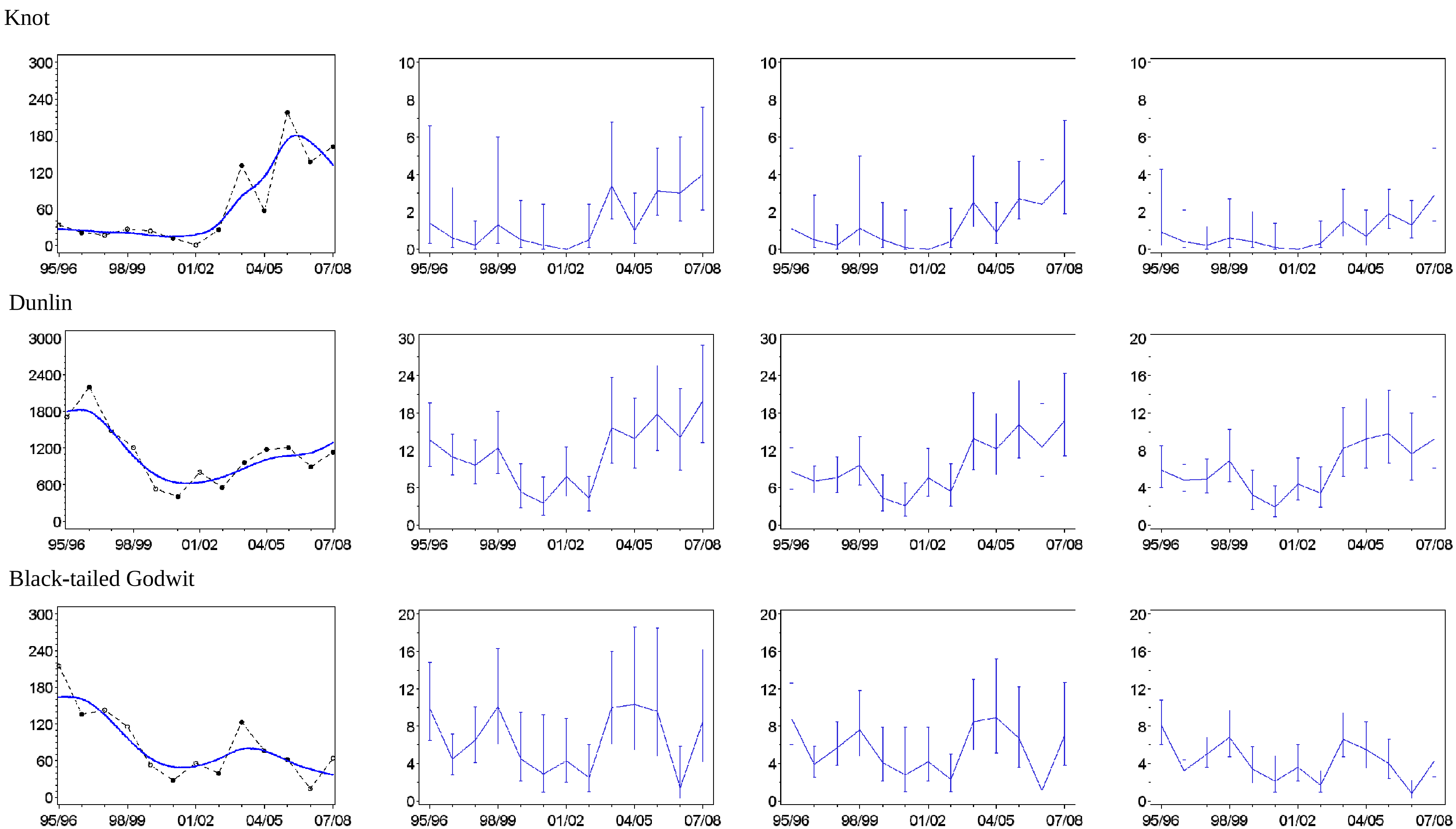


Figure S36. Population trends of each species in Upper Stour sector CU032 (Stutton Ness to Holbrook Creek) (left-hand graphs), and the proportional population found in this sector per year relative to the Stour, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined, respectively.

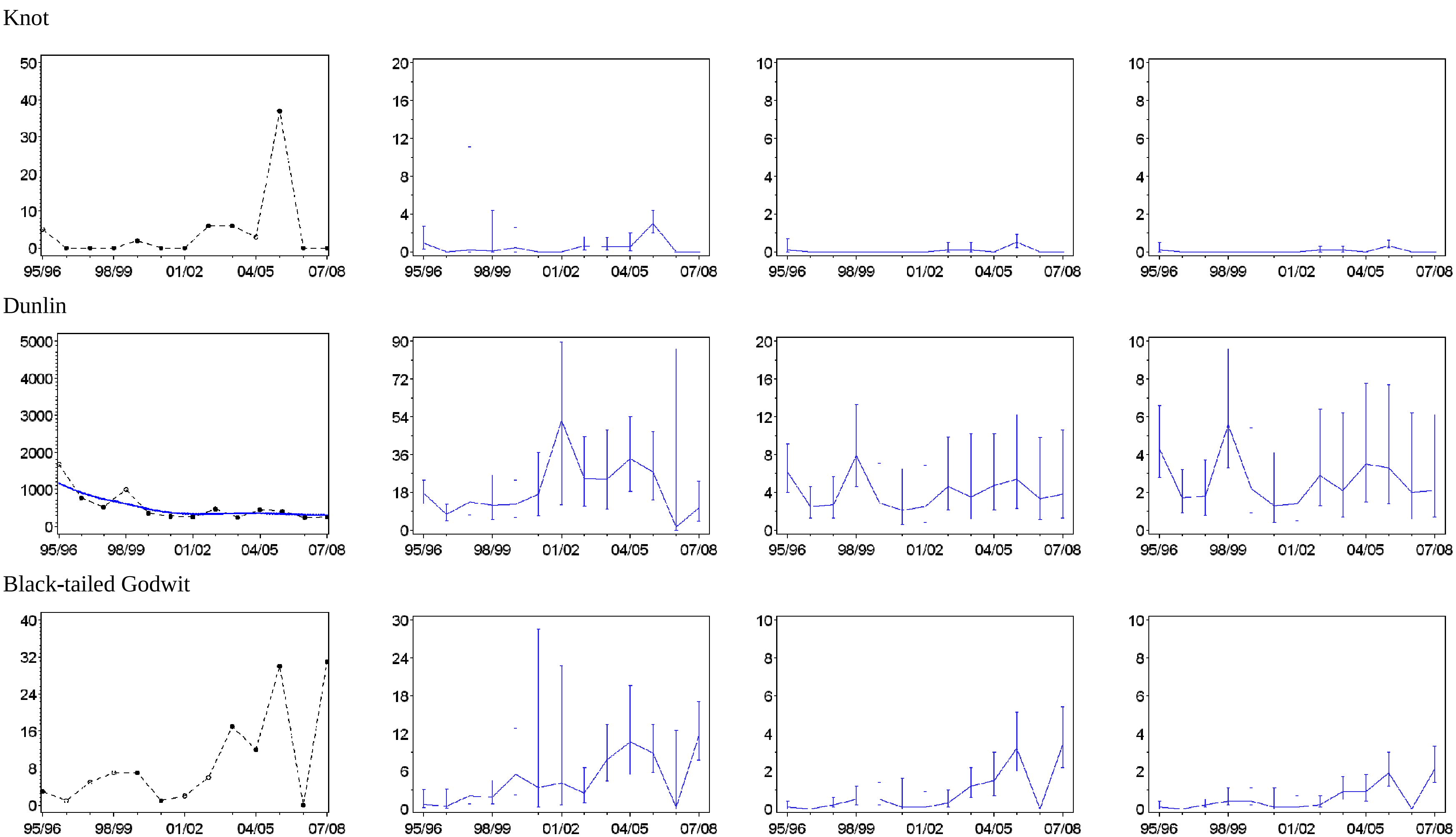


Figure O1. Population trends of each species in Lower Orwell sector EW011 (Thorpe Bay) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

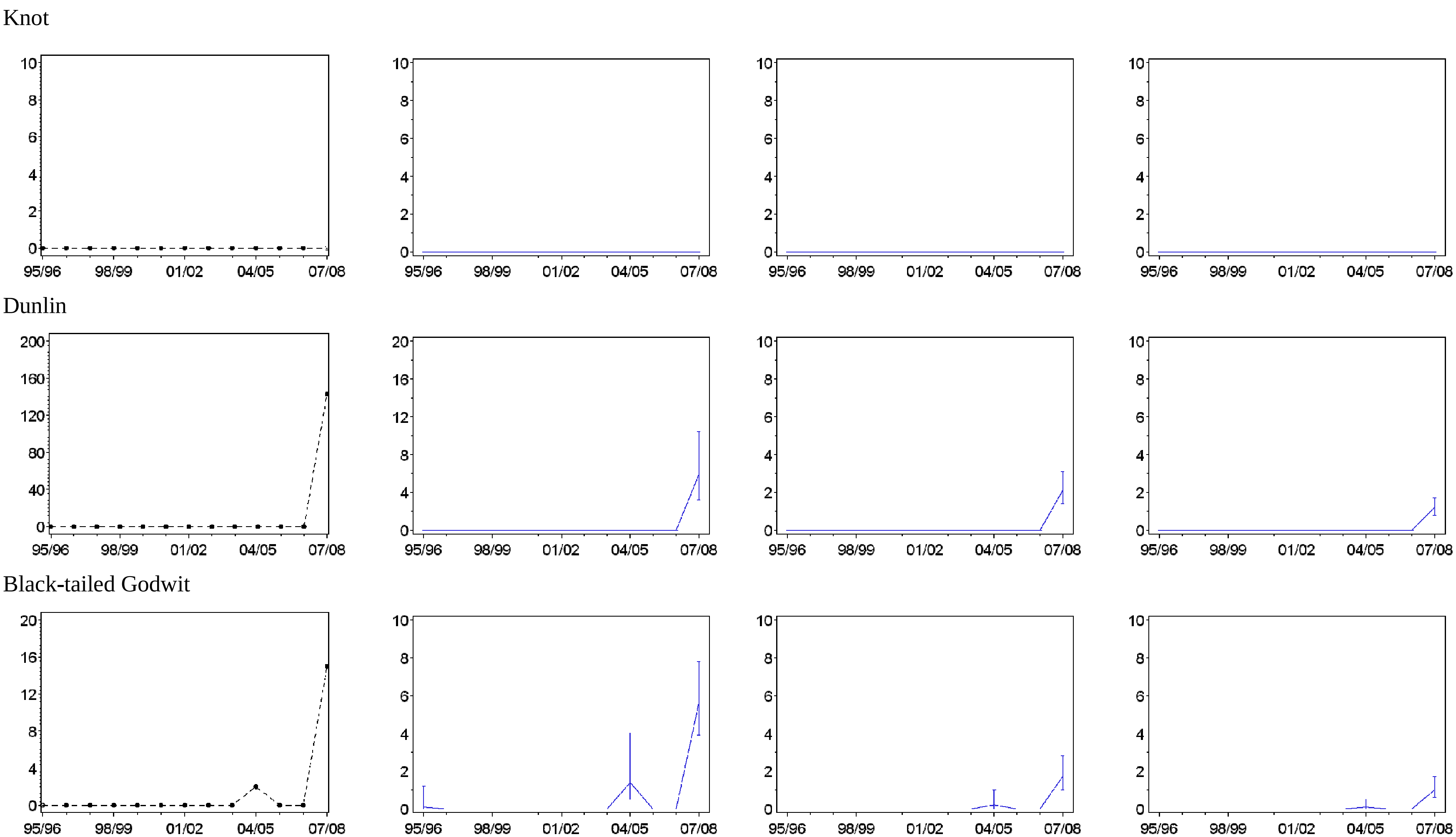


Figure O2. Population trends of each species in Lower Orwell sector EW012 (Loompit Lake) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

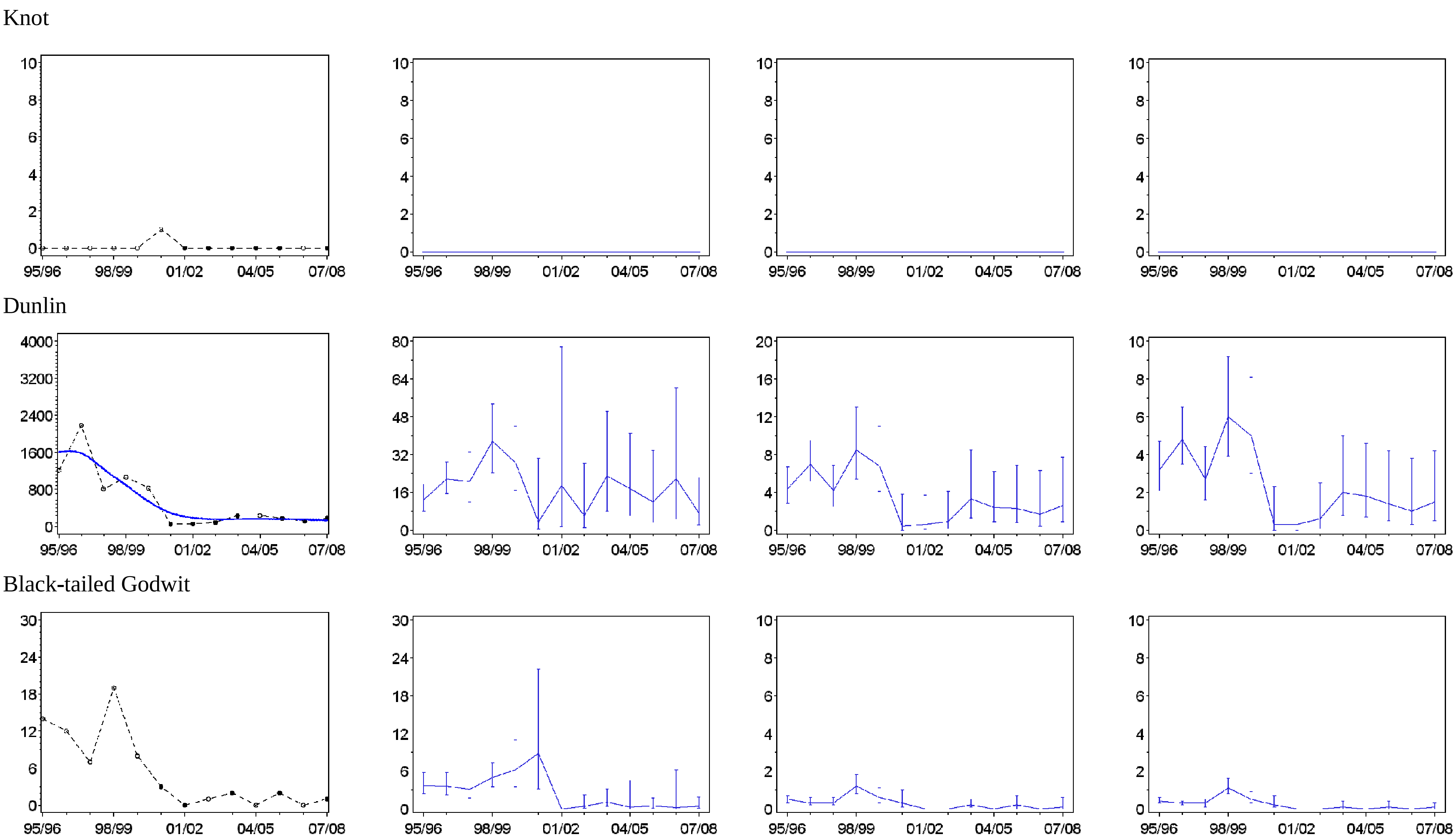


Figure O3. Population trends of each species in Lower Orwell sector EW030 (Shotley Shoreline, River and Saltings) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

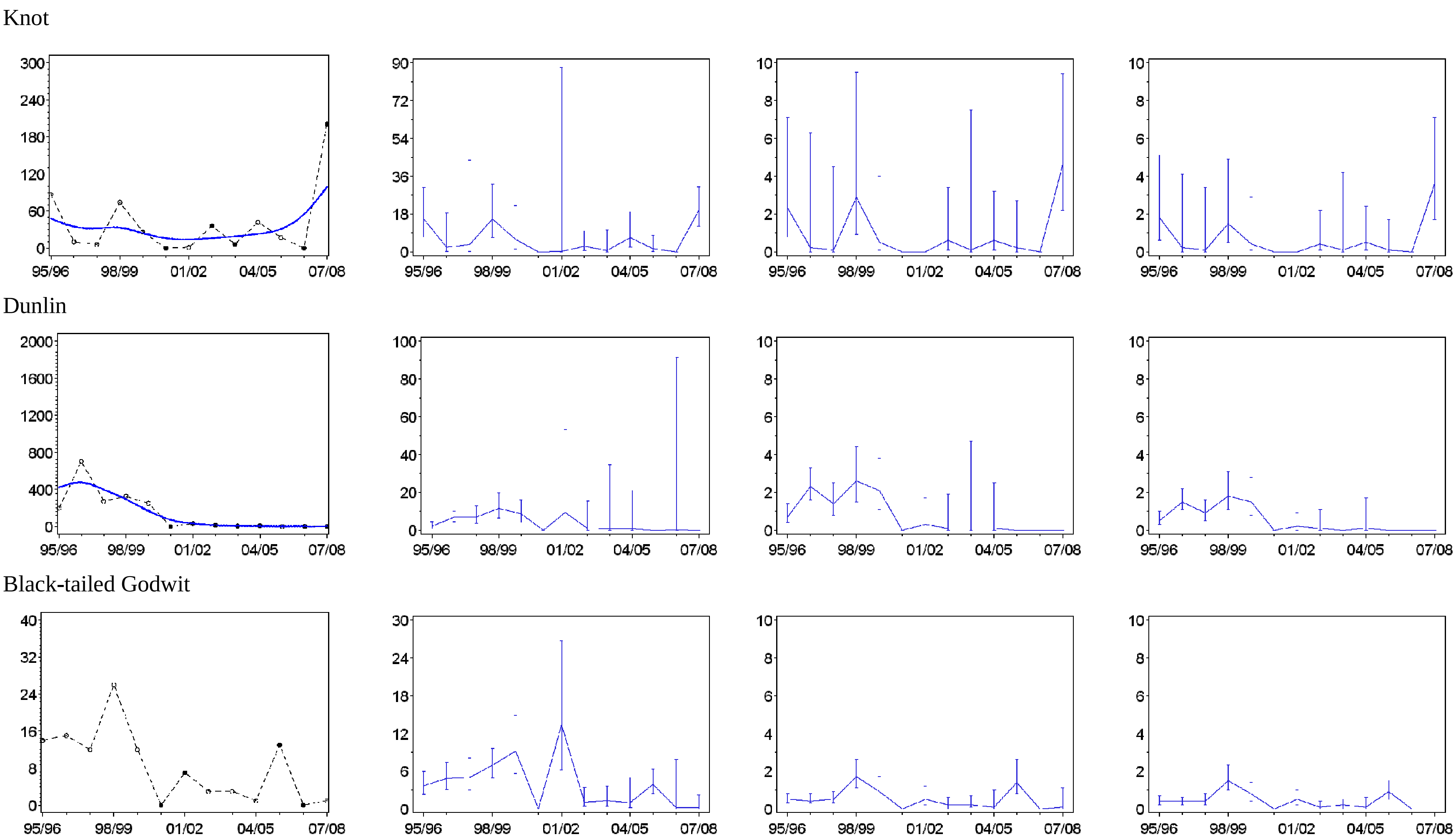


Figure O4. Population trends of each species in Lower Orwell sector EW031 (Trimley Retreat Area) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

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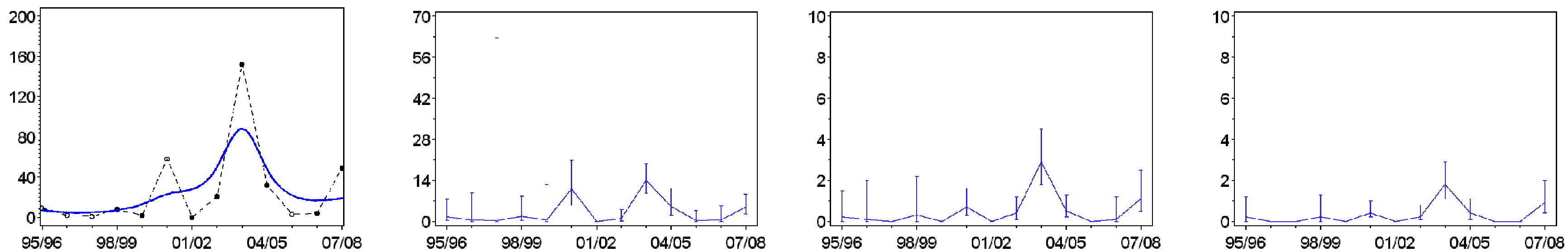

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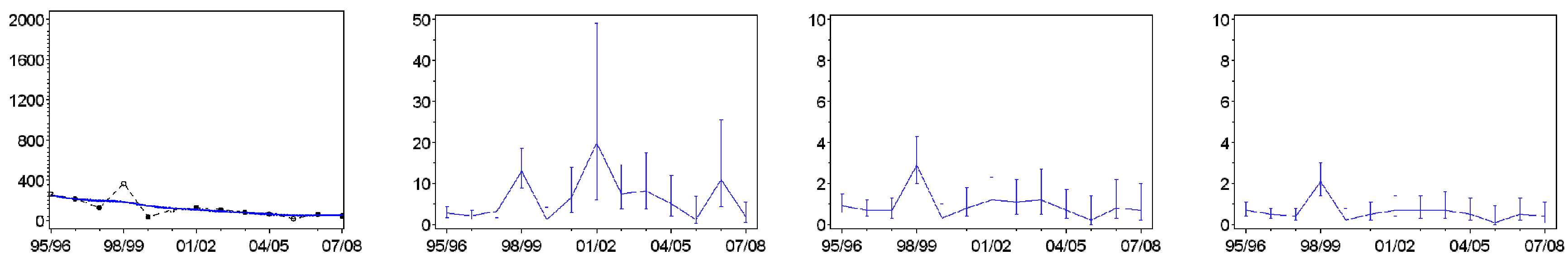

Black-tailed Godwit

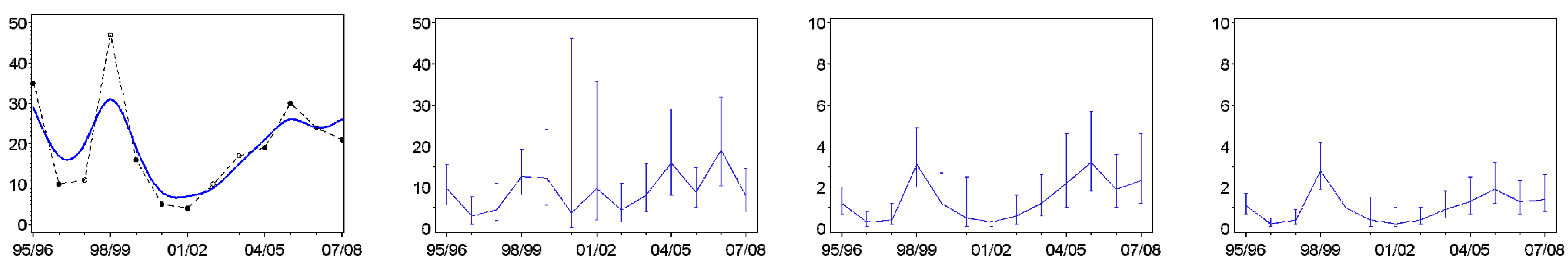

Figure O5. Population trends of each species in Mid Orwell sector EW006 (Woolverstone) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

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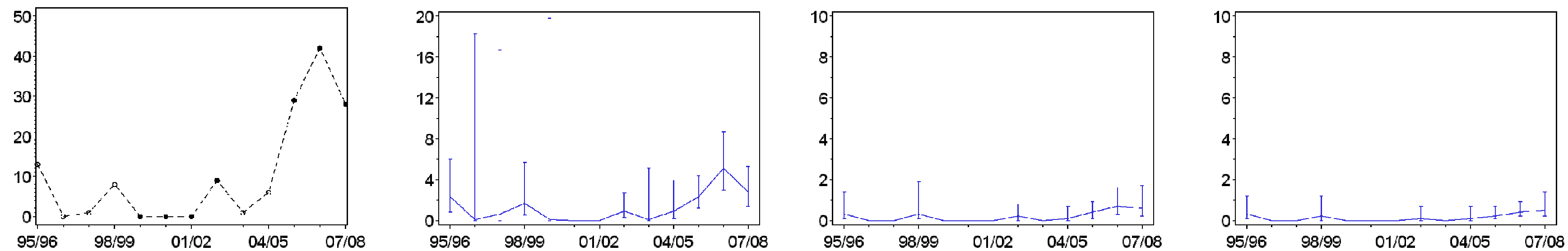

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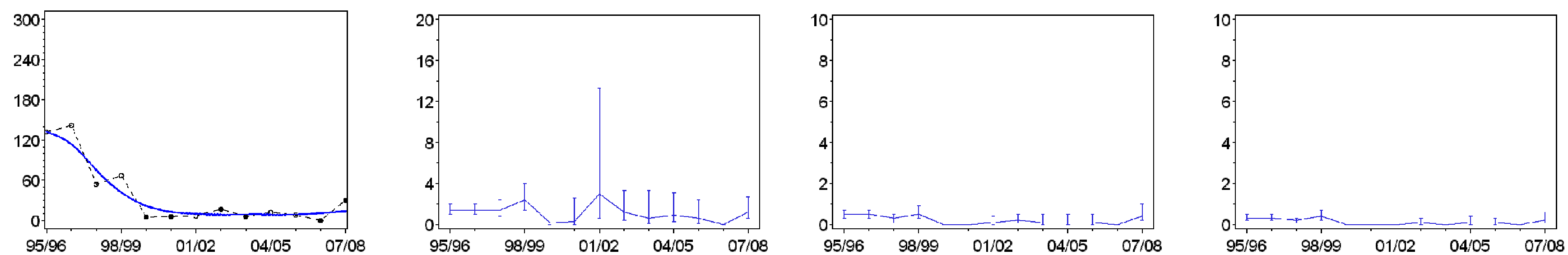

Black-tailed Godwit

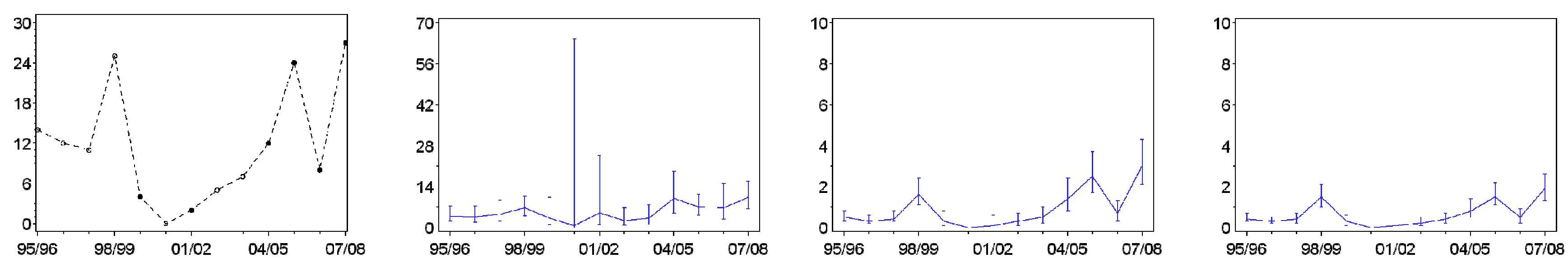

Figure O6. Population trends of each species in Mid Orwell sector EW019 (Pin Mill Shoreline, River and Saltings) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

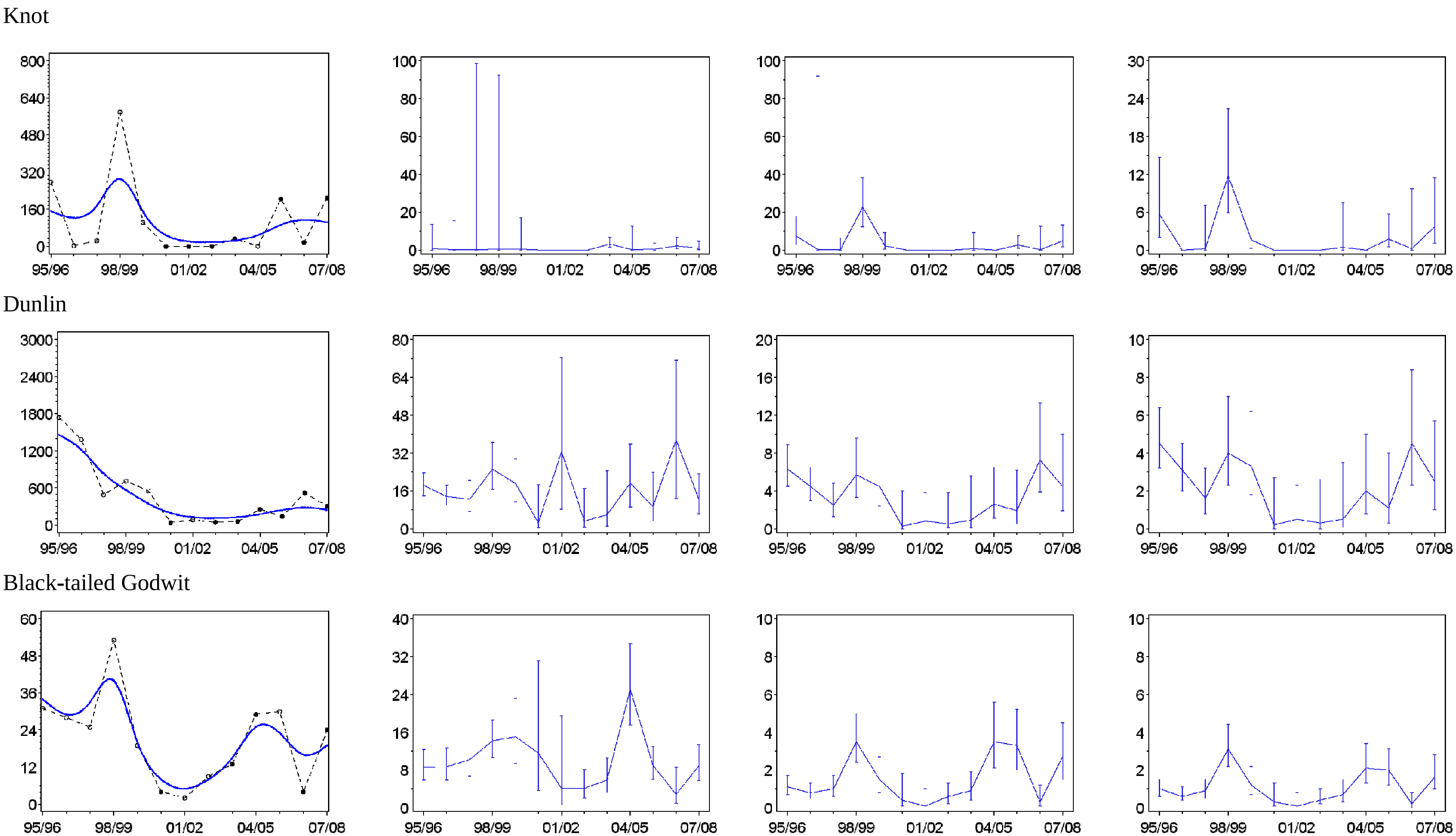

Figure O7. Population trends of each species in Mid Orwell sector EW026 (Collimer Point Shoreline, River and Saltings) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

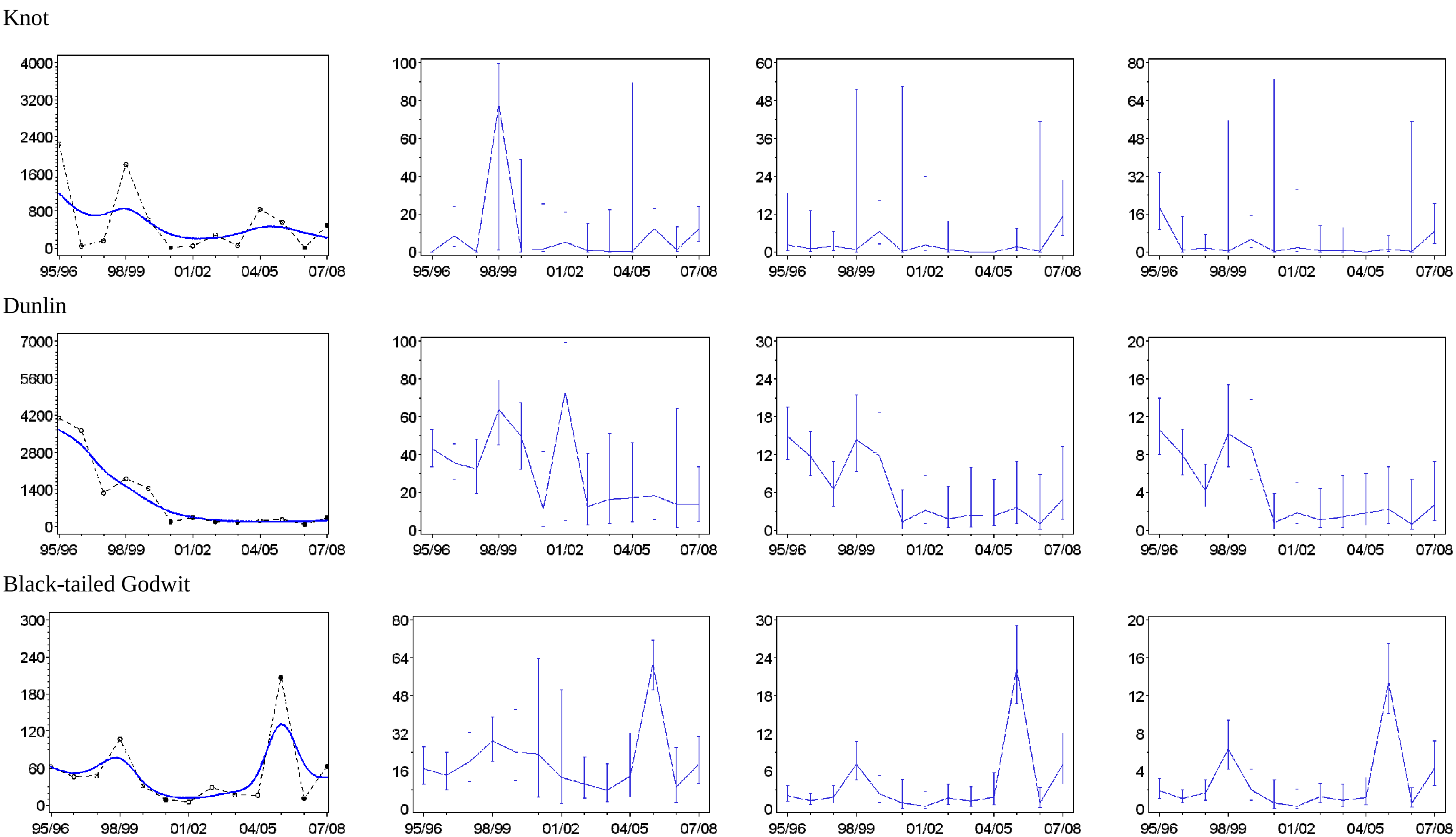

Figure O8. Population trends of each species in Mid Orwell sector EW037 (Levington Creek Shoreline, River and Saltings) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

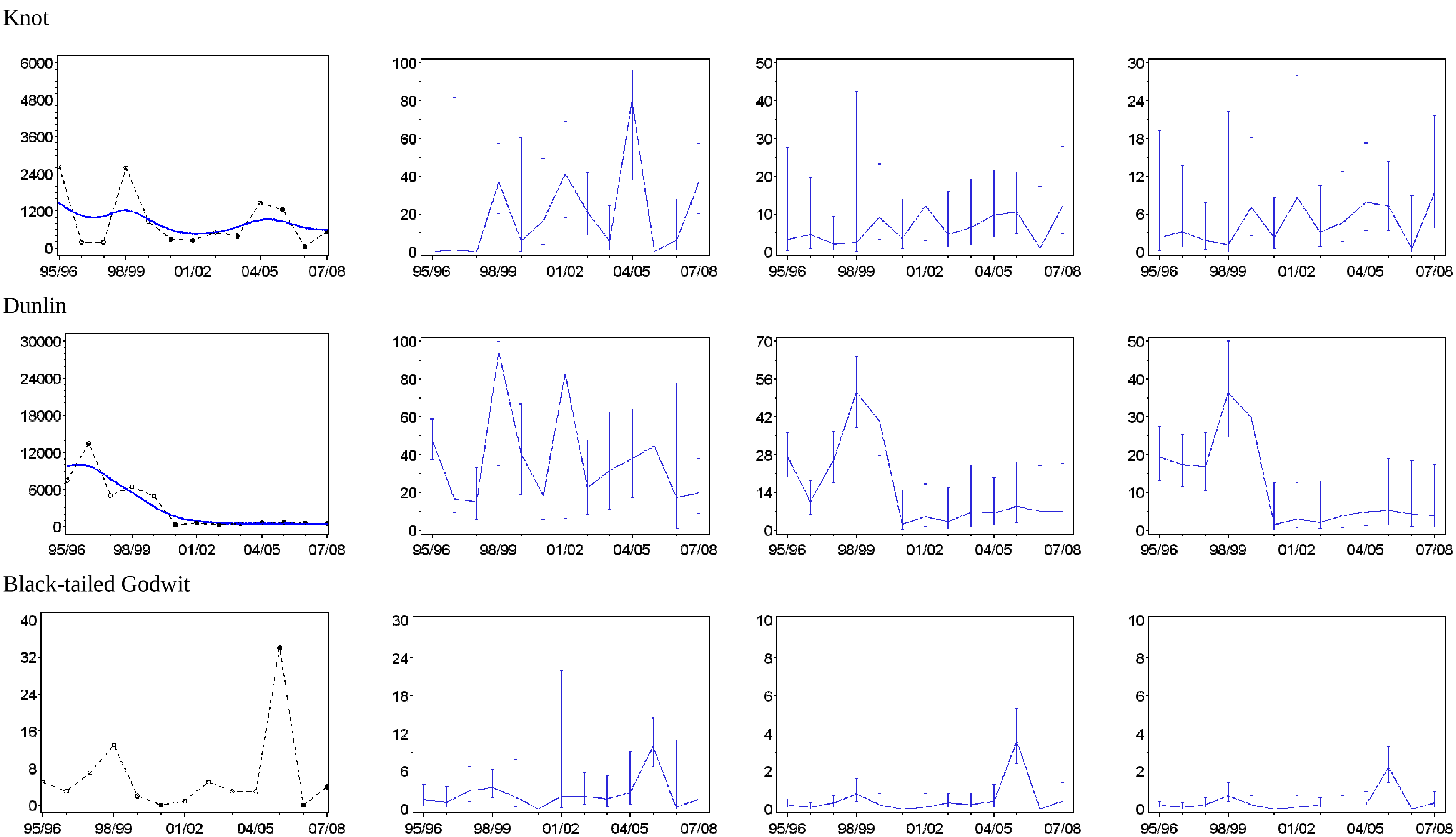

Figure O9. Population trends of each species in Mid Orwell sector EW038 (Nacton Shore) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

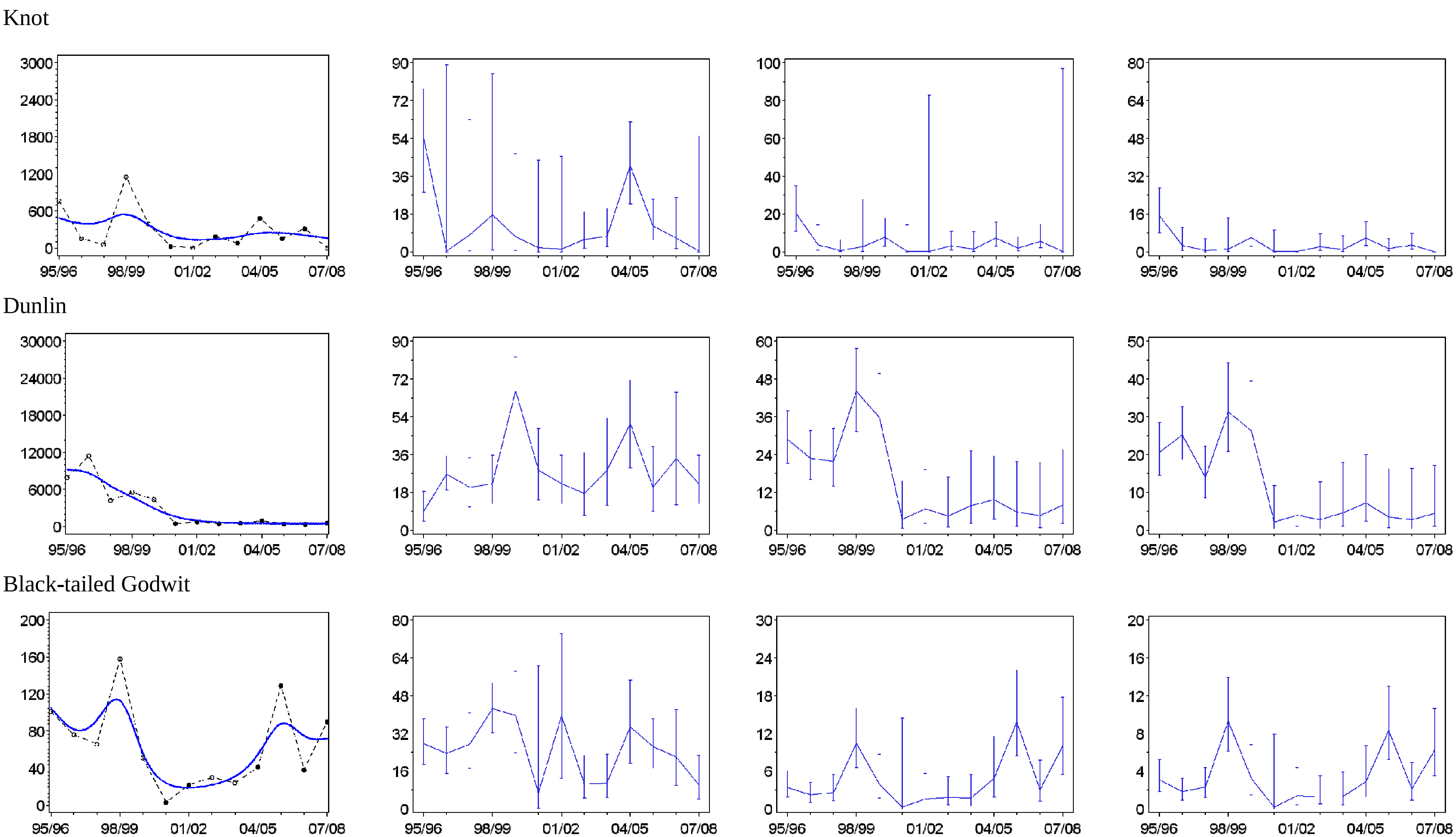

Figure O10. Population trends of each species in Mid Orwell sector EW041 (Nacton Quay Shoreline, River and Saltings) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

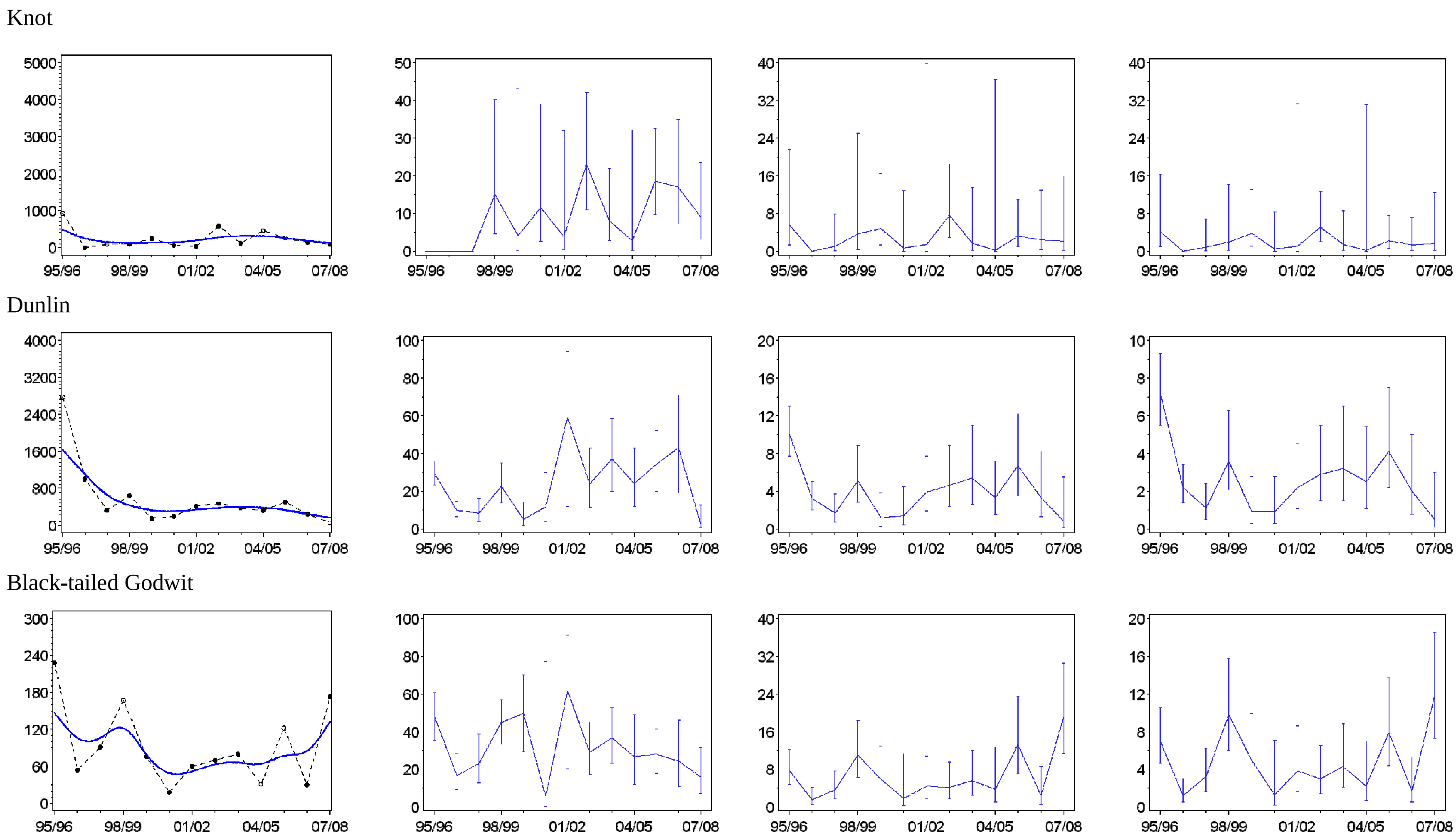

Figure O11. Population trends of each species in Upper Orwell sector EW005 (Freston) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

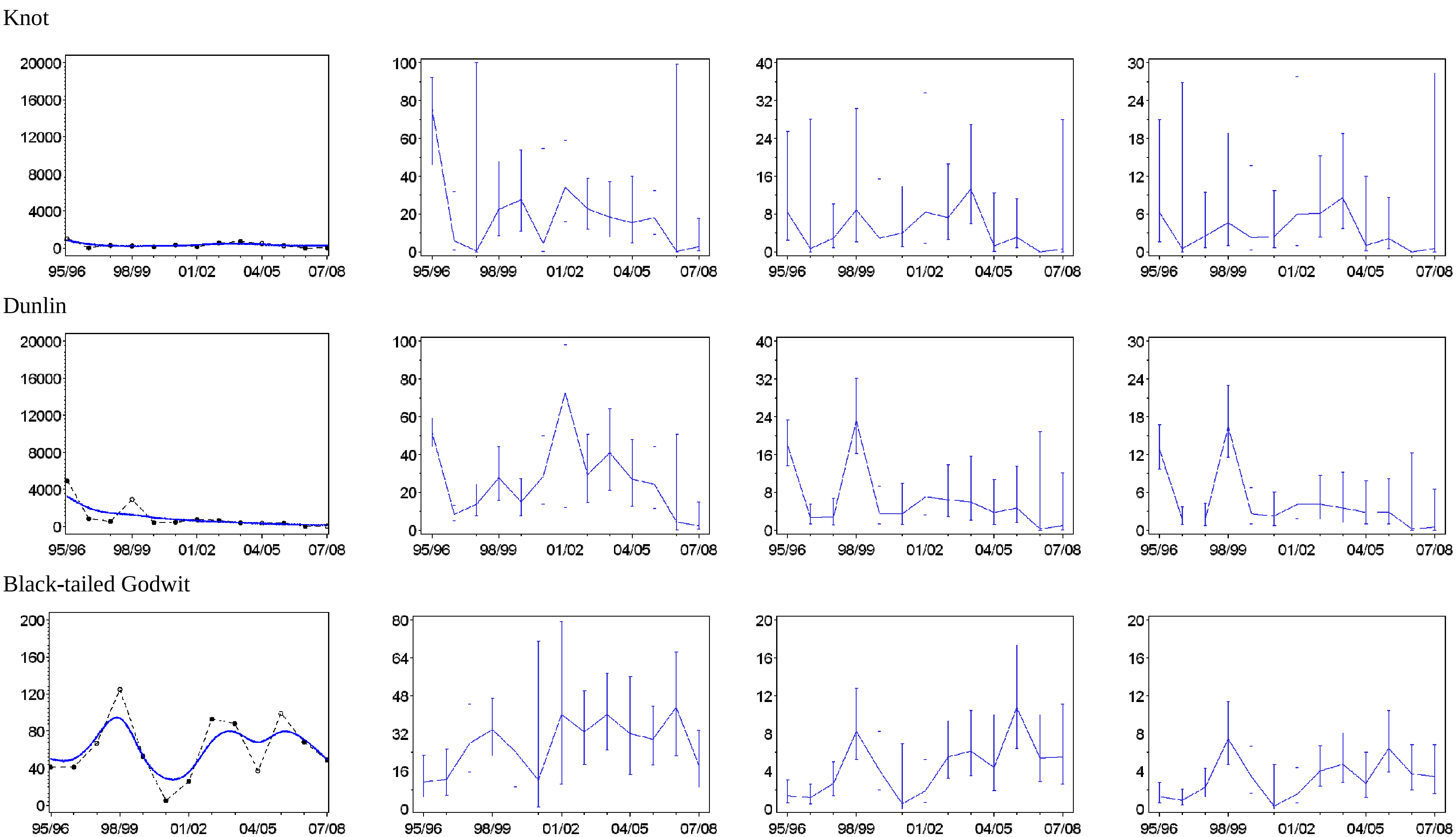

Figure O12. Population trends of each species in Upper Orwell sector EW017 (Black & Pond Ooze) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

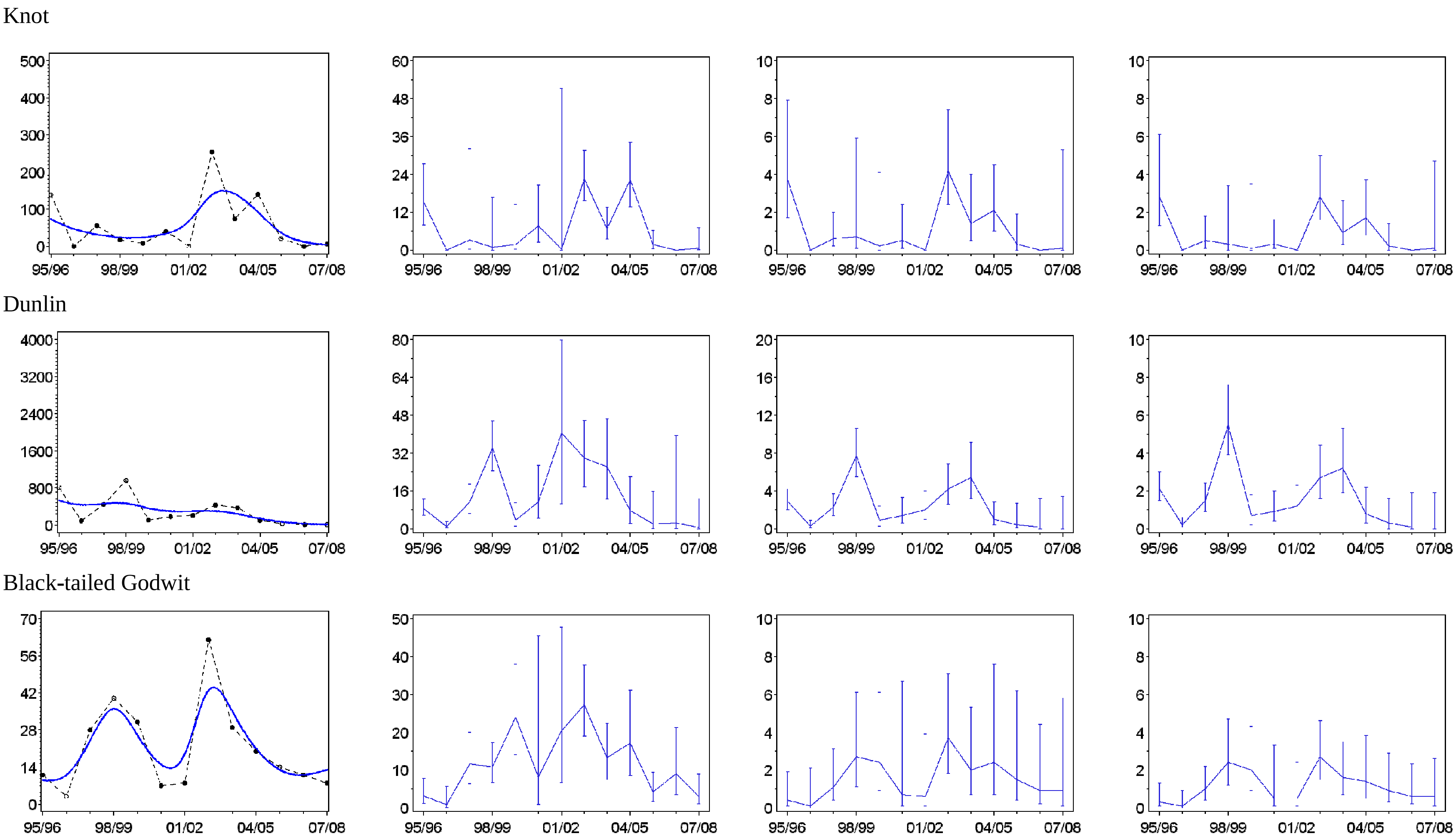

Figure O13. Population trends of each species in Upper Orwell sector EW018 (Black Ooze) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.

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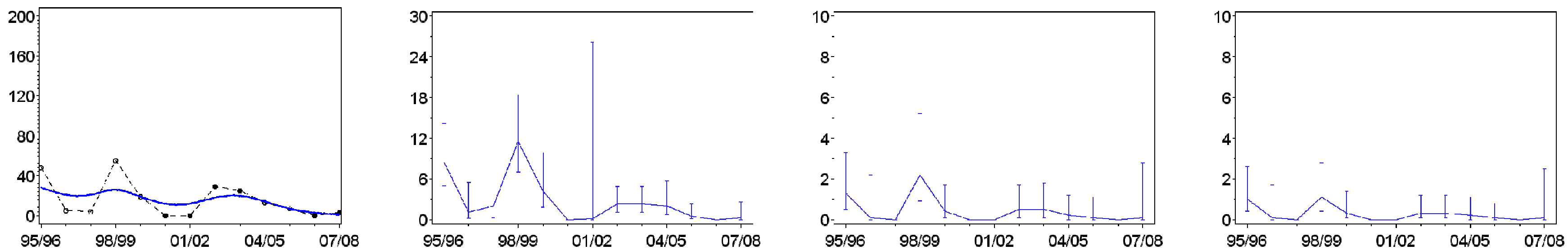

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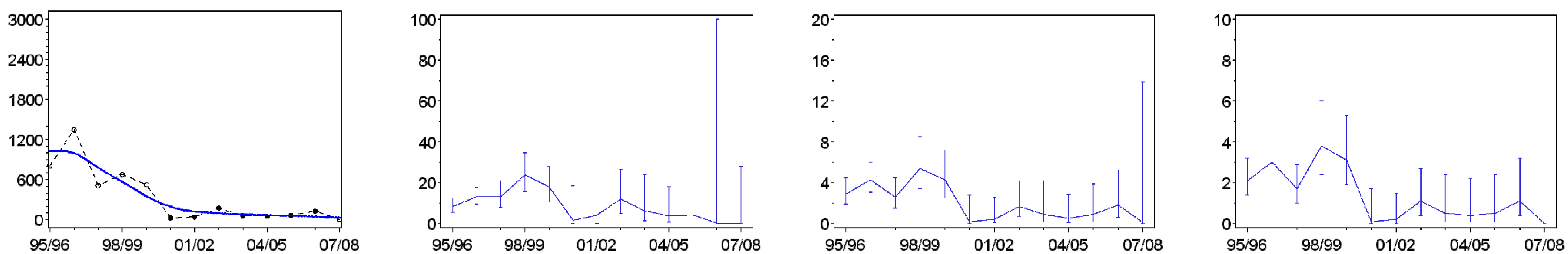

Black-tailed Godwit

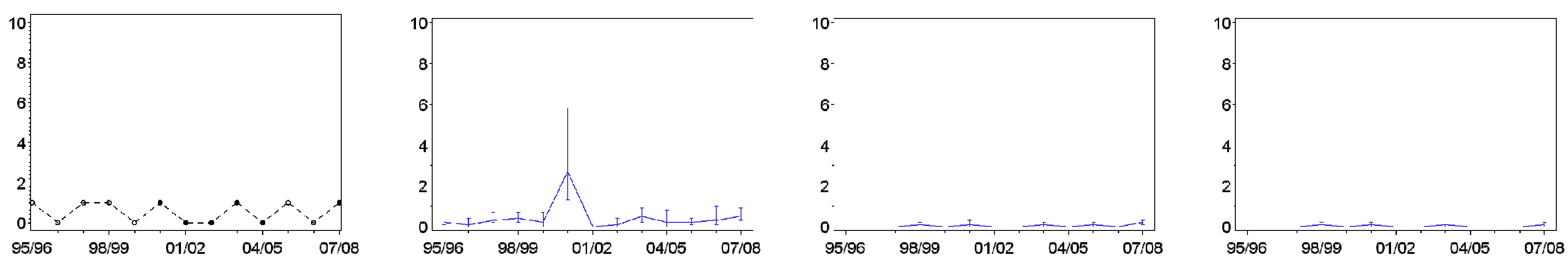

Figure O14. Population trends of each species in Upper Orwell sector EW022 (Strand shoreline, River and Saltings) (left-hand graphs), and the proportional population found in this sector per year relative to the Orwell, the Stour and Orwell combined and the Stour, Orwell, Deben and Hamford Water combined respectively.9