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Declines in over-wintering diving ducks at Lough Neagh and Lough Beg: comparisons of within site, regional, national and European trends

Authors

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CONTENTS

Page No.

List of Figures

Page No.

Page No.

Page No.

EXECUTIVE SUMMARY

1. The Lough Neagh and Lough Beg Special Protection Area (SPA) is the most important site for diving ducks in Great Britain and Ireland. In the late 1980s and early 1990s, the site hosted an estimated 40,000 Pochard, 30,000 Tufted Duck, 5,000 Scaup and 14,000 Goldeneye.

2. Since the early 1990s, there have been substantial declines in the numbers of three of these species. In the winter of 2003/04, the site hosted an estimated 8,000 Pochard, 9,000 Tufted Duck, 2,600 Scaup and 4,000 Goldeneye. Scaup numbers have since recovered and are now present in higher numbers than at any time since the mid-1980s. The declines occurred on all parts of the site and thus do not appear to be related to a factor specific to one part of the Lough Neagh and Lough Beg SPA.

3. The declines in the number of Pochard, Tufted Duck and Goldeneye on the site are an order of magnitude greater than declines occurring at any other site in Great Britain or Ireland over the same period and do not parallel trends in other regions of Great Britain and Ireland, nor those of any other European region.

4. There was a general downturn in the number of Scaup at a number of other sites in Great Britain and Ireland over the same period, for example the Tralee Bay complex in Kerry and the Solway Firth. Even greater declines have occurred at the IJsselmeer in The Netherlands and along the Baltic Coast of Germany, concurrent with the declines at Lough Neagh and Lough Beg. This could be due to site related issues, but may equally be indicative of a downturn in the breeding population of this species.

5. The causes of declines at the Lough Neagh and Lough Beg SPA are not known with certainty, but the balance of evidence suggests that site related issues are primarily responsible. Previous work has suggested that high levels of nutrient input have caused hyper-trophic conditions, with detrimental effects on the chironomid larvae that constitute the major dietary component for all four of the diving duck species. The results of this study lend some support to this theory, but further work assessing how diving duck may have been impacted by any changes in chironomid larvae that have occurred would need to be undertaken before this could be established with certainty.

6. It is possible that the ducks have been able to respond to these changes by relocating to sites elsewhere in Great Britain or Ireland. Pochard have increased at Lough Corrib, Tufted Duck at Rutland Water, Scaup at Belfast Lough and Goldeneye at several inland sites in England. However, the magnitude of increases at these sites is considerably smaller than the decreases that have occurred at Lough Neagh and Lough Beg and at the same time there have been decreases at other sites in the UK.

7. Pochard, Tufted Duck and Goldeneye have increased in the Baltic-Nordic Region and in Central Europe. These increases are most probably due to climate change. It is possible that the recent spate of milder winters, which has rendered sites further east more favourable, has facilitated relocation from Lough Neagh and Lough Beg. At this stage, this suggestion cannot be confirmed, but it is perhaps more likely that the increases in those regions are due to influxes from closer by.

1. INTRODUCTION

The Lough Neagh and Lough Beg system (hereafter referred to as Lough Neagh) is one of the most important sites for wintering wildfowl in Europe. Parts of the site have been designated as a series of Areas of Special Scientific Interest (ASSIs) and National Nature Reserves (NNRs) and the entire site is designated as a Ramsar Site and Special Protection Area (SPA) (Stroud *et al.* 2001; BirdLife International 2004). Four species in particular: Pochard (*Aythya ferina*), Tufted Duck (*A. fuligula*), Scaup (*A. marila*) and Goldeneye (*Bucephala clangula*) occur in internationally important numbers and are identified as key features of the site. In recent years however, these species have declined considerably. Between the early 1990s and the winter of 2003/04, Pochard decreased in number from a peak of more than 40,000 to less than 8,000. Similarly Tufted Duck decreased from almost 30,000 to less than 9,000 and Goldeneye from almost 14,000 to less than 4,000. Scaup have been somewhat less affected, having declined from almost 5,000 to c. 2,600 (Kirby *et al.* 1991; BirdLife International 2004; Collier *et al.* 2005).

The causes of decline are not known with certainty. It has been suggested that changes in the chironomid larvae community in response to changes in nutrient levels have caused a large-scale re-distribution of the wintering populations of these species. All four species of diving duck feed predominantly on these larvae, with Scaup favouring larger larvae found in deeper water (Allen *et al.* 2004a, 2004b). Lough Neagh is highly eutrophic and despite phosphate stripping at tertiary sewage plants, phosphate levels have increased due to agricultural run-off (Allen *et al.* 2004a. 2004b). Although eutrophic conditions generally benefit chironomid larvae, hyper-trophic conditions lead to reduced dissolved oxygen concentrations and increased pH, which is detrimental to some species of chironomid, particularly those occurring in shallower water and courser sediments (Allen *et al.* 2004a, 2004b).

However, other causes of re-distribution not linked to site conditions, such as changing climate could also be responsible for the decline. Temperatures have generally increased in Europe (see results). It is thus conceivable that the over-wintering population has re-distributed towards colder regions in a similar fashion to the shifts occurring in over-wintering populations of waders (Austin and Rehfisch 2005; Maclean *et al.* in review). Furthermore, the possibility that significant mortality has occurred or that birds reach their breeding ground in poorer condition and are thus less productive cannot be ruled out. The purpose of this report is to provide analyses of within-site changes in numbers of the four diving duck species and compare these with regional, national and international trends. In so doing, it is intended that insight will be gained as to whether the declines are due to factors operating on the site or at a wider scale.

2. METHODS

2.1 Temperature Changes

To help determine whether Europe-wide changes in diving duck numbers and distributions may have been driven by climate, temperature trends across Europe were calculated using a 10' resolution dataset of monthly surface mean temperature for the period 1900-2000, obtained from the Climatic Research Unit at the University of East Anglia, Norwich (Mitchell *et al.* 2003). Mean monthly temperatures in December, January and February and in winter (mean of December, January and February) over the whole of Europe in each year were calculated.

2.2 Bird Data

Analyses primarily used data from the UK Wetland Bird Survey (WeBS) and Irish Wetland Bird Survey (I-WeBS). Additional data used to understand trends elsewhere in Europe are collected as part of various national schemes that are similar in methodology to WeBS and I-WeBS and are collated by Wetlands International (Gilissen *et al.* 2002). The UK Wetland Bird Survey (Collier *et al.* 2005) is a joint scheme of the British Trust for Ornithology (BTO), the Wildfowl and Wetlands Trust (WWT), Royal Society for the Protection Birds (RSPB) and the Joint Nature Conservancy Council (JNCC) that aims to monitor non-breeding waterbirds. Monthly counts are conducted, mainly by volunteers, principally from September to March, with fewer observations during the summer months. Data have been collected for WeBS and its predecessors, the Birds of Estuaries Enquiry and National Wildfowl Counts, since the 1960s; for this report, data were available up to the winter of 2003/04.

The aims and methods of I-WeBS (Crowe 2005) closely resemble those of WeBS; the scheme is organised by BirdWatch Ireland, the National Parks & Wildlife section of the Department of Environment, Heritage and Local Government and WWT, supported by the Heritage Council. In Ireland (including Northern Ireland), indices of Pochard numbers are calculated using November to February I-WeBS counts, Tufted Duck indices using October to March counts, Scaup indices using September to March counts and Goldeneye using December to march counts. In Great Britain, Pochard indices are calculated using November to January counts, Tufted Duck indices using November to February counts, Scaup indices using September to March counts and Goldeneye indices using February counts. In Great Britain, the months selected for indexing are based on analyses undertaken by Kirby *et al.* 1995). Mean totals in this report were calculated using the same suite of months as these indices.

Totals refer to the total number of birds counted as part of any given survey in any given region, but include imputed missing or incomplete counts. Counts are imputed using the Underhill method (Underhill & Prŷs-Jones 1994), provided the site has been counted on at least half of all winter (index) months during the study period. Sites with less than 50% coverage are excluded from analyses and thus are not incorporated into totals. It is important to note therefore, that all totals refer to the totals (including imputed values) that are counted in a region and not to the total wintering numbers of that species. In some instances, coverage may be relatively low, in which case the reported total represents only a fraction of the actual total likely to be found in that region during winter. Smoothed trends were calculated using General Additive Models (GAMs) with 0.3 x n degrees of freedom (rounded down to the nearest integer) (Hastie & Tibshirani 1990; Fewster *et al.* 2000; Atkinson *et al.* 2006).

In accordance with standard WeBS and I-WeBS methodologies (Kirby *et al.* 1995; Collier *et al.* 2005, Maclean *et al.* 2005; Crowe 2005; Atkinson *et al.* 2006), as well as that used across Europe (Delany *et al.* 1999; Gilissen *et al.* 2002; van Roomen *et al.* 2005), the trends in this report are generated using counts averaged across indexing months rather than peak annual counts.

2.2.1 Site-level changes

WeBS core counts have been made annually at Lough Neagh since the winter of 1986/87. To analyse changes within the site, data for each of the four species were obtained for 115 sectors of the site (Fig. 2.2.1). For each of these sectors, five-year peak means (i.e. the peak count for each year averaged over 5 years) and five-year means (mean of all counts within five year period) were calculated for each of the four species. To estimate missing or incomplete counts, the expected proportion of the Lough Neagh totals for each species hosted by that sector was estimated by averaging the 15 counts nearest in time to the date in question, while controlling for seasonal trends by restricting those counts to the previous, current and following calendar months and comparing these averages to the site total. For each five-year period density maps were produced using ArcView (ESRI, Redlands).

To further examine within site changes, the 115 sectors were amalgamated into 19 larger sectors and changes in numbers plotted as a function of year for each of these larger sectors (Fig 3.5.1). The boundaries of these larger sectors were selected by examining sector density plots and amalgamating sectors in which changes in densities across all four species appeared to follow a consistent pattern, while also ensuring that a sufficiently fine geographical resolution was retained.

Logistic plots indicating the proportion of the site total hosted by each of the larger sectors were also calculated. The confidence intervals on these logistic plots are proportional to between-month variation and inversely proportional to the total numbers recorded on the site. Full details of the methodology used to produce these logistic plots can be found in Maclean *et al.* (2005) and Austin *et al.* (in press).

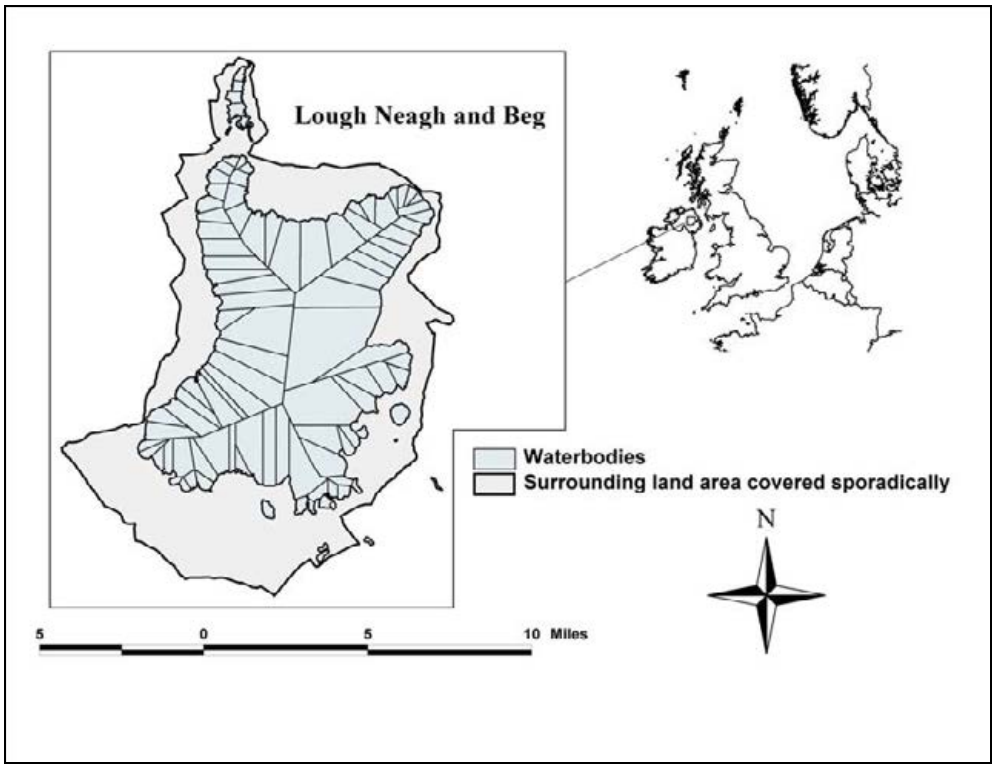


Figure 2.2.1 The Lough Neagh and Beg system showing the individual waterbody sectors counted (pale blue). The area surrounding the Loughs (pale grey) occasionally hosts small numbers of diving duck species, but are predominantly counted as part of WeBS due to the presence of geese and swans.

2.2.2 Comparison with regional, national and European trends

To compare trends at Lough Neagh with those in Northern Ireland as a whole, logistic plots were produced comparing the proportion of the Northern Irish over-wintering WeBS total of each of the four species hosted by Lough Neagh. To determine whether decreases at Lough Neagh have corresponded with increases elsewhere in the British Isles, regional trends in WeBS and/or I-WeBS totals are also presented. WeBS and I-WeBS provide comprehensive annual coverage of more than 2,000 sites across the British Isles (Collier *et al.* 2005; Crowe 2005) and thus provide a reasonable means of indicating population trends. To further establish where increases and decreases have occurred, maps indicating numeric changes during the last five and 10 years were produced using ArcView.

To establish whether the declines at Lough Neagh may have been due to increases elsewhere in Europe, perhaps due to migratory short-stopping, midwinter (January) trends for five regions of Europe (Northwest, Baltic/Nordic, Central, East Mediterranean and West Mediterranean) were obtained from Wetlands International (Wetlands International 2005). Smoothed trends were again calculated by fitting GAMs with 0.3 x n degrees of freedom. However, Scaup trends for all of the European regions and Goldeneye trends for the East and West Mediterranean were not produced as these data were not available at the time of writing, but trends were obtained for Germany (Wahl in lit.) and The Netherlands (van Roomen *et al.* 2005).

3. RESULTS

3.1 Temperature Changes in Northwest Europe

The change in mean December, January, February and winter (mean of Dec, Jan and Feb) temperatures in Europe are shown in Fig. 3.1.1. For the most part, temperatures have increased, though in the mid-1980s, winters were exceptionally cold.

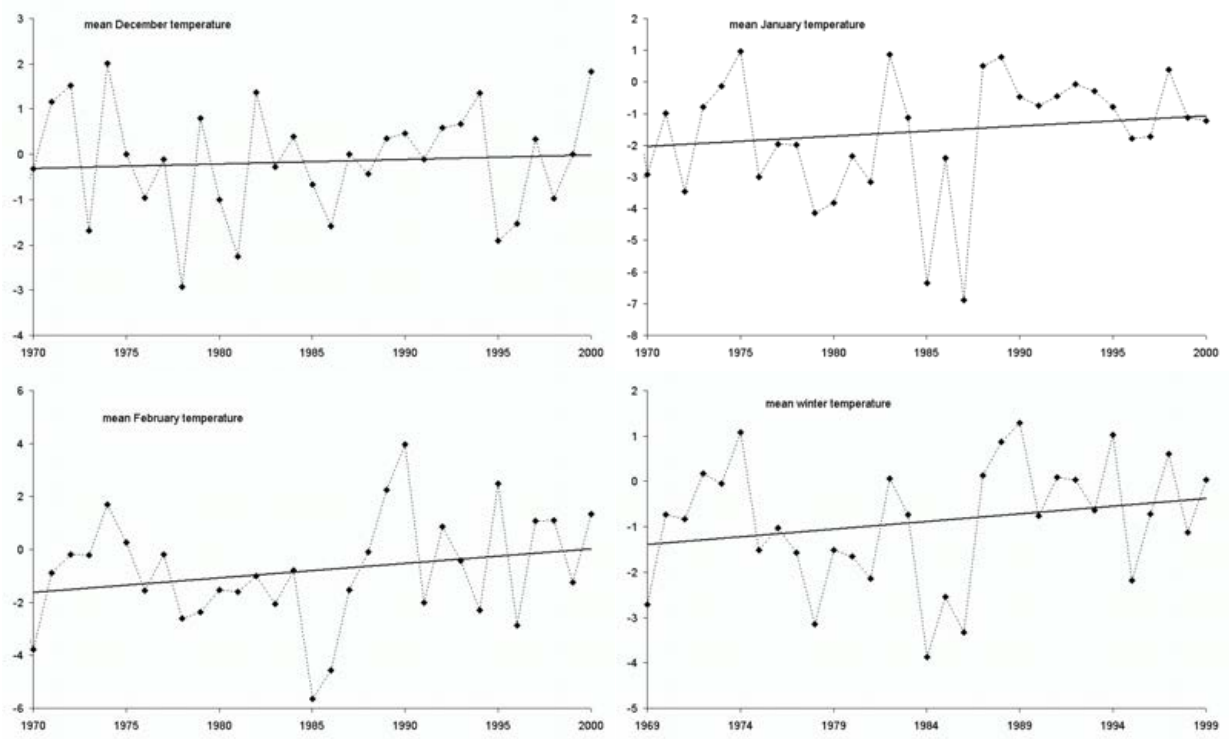


Figure 3.1.1 Change in mean temperature in Europe in December (top-left), January (top-right), February (bottom-left) and for the whole of winter (bottom-right). On the x axis, 1970 = the winter of 1970/71 etc. The black solid line is a linear trend line fitted through the data.

3.2 Site Level Changes at Lough Neagh

The site trends for each of the diving duck species are shown in Fig. 3.2.1. The decline in Pochard started in the winter of 1990/91, but numbers have only declined precipitously since the winter of 1999/2000. Mean numbers peaked at c. 22,000 in the winter of 1990/91 and have since declined to c. 7,000 in the winter of 2003/04. Peak counts reveal an even steeper decline, from 40,928 in the winter of 1990/91 (Kirby *et al.* 1991) to 7,831 in 2003/04 (Collier *et al.* 2005). The trend for Tufted Duck suggest that the decline of this species may be more recent, with the greatest decline in mean counts occurring between 2000/01 and 2003/04 (from c. 19,000 to c. 6,000), peak counts fell from 29,393 in 1989/90 (Kirby *et al.* 1991) to 8,946 in 2003/04 (Collier *et al.* 2005). The trend for Scaup also indicates a recent decline. The species' mean monthly counts peaked in the winter of 1999/2000 at almost 2,000, but fell sharply after the winter of 2001/02 to c. 700 in the winters of 2002/03 and 2003/04. Peak counts fell from a maximum of 4,934 in the winter of 1994/95 (Waters *et al.* 1996) to 2,565 and 2,674 in 2002/03 and 2003/04 respectively (Collier *et al.* 2005). Goldeneye numbers have declined more steadily for a longer period. Mean counts have declined from a maximum of c.10,000 in the winter of 1990/91 to c. 3,000 in the winters of 2002/03 and 2003/04. Peak counts where highest in the winter of 1992/93 at 13,748. Recent counts have been in the order of 4-5,000, with the lowest peak of 3,661 recorded in the winter of 2002/03.

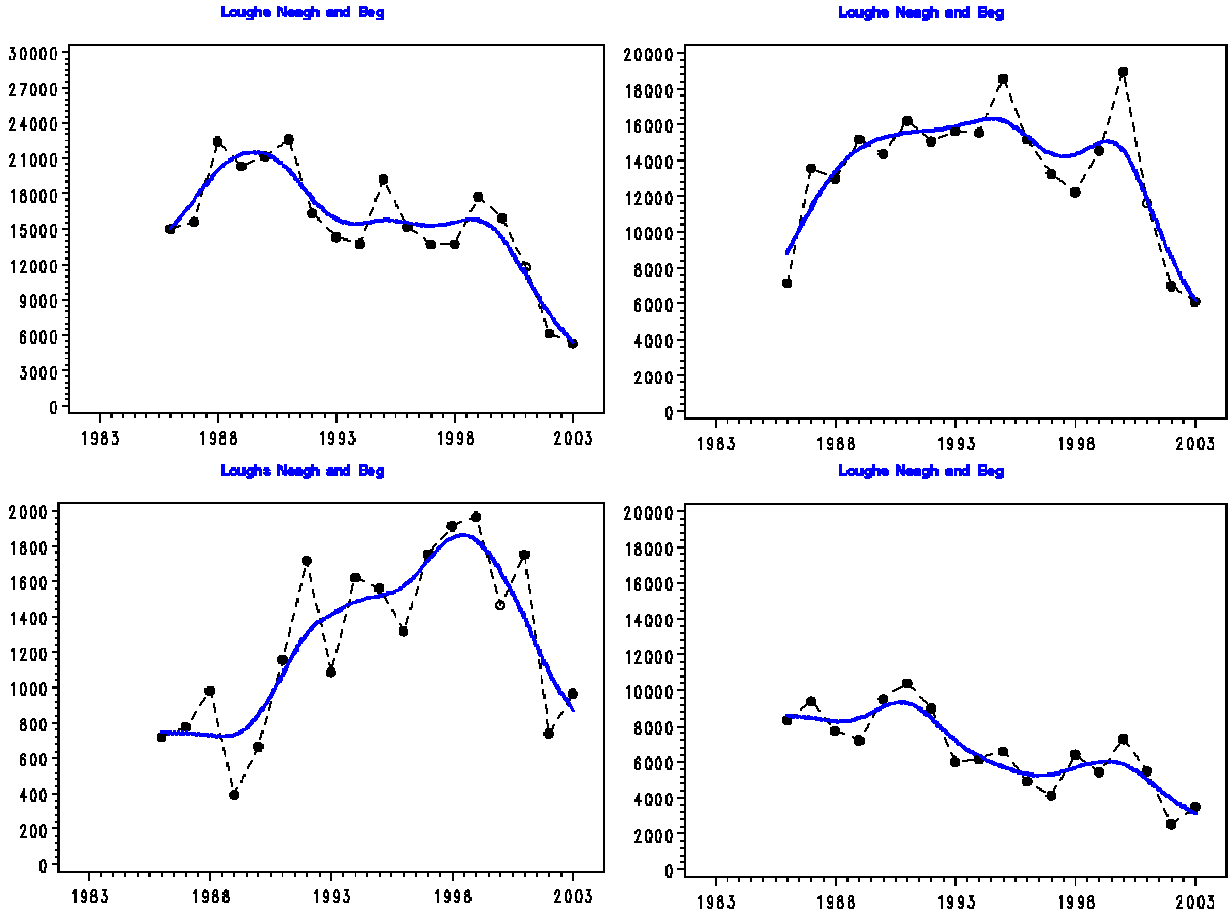


Figure 3.2.1 The trend in numbers of Pochard (top-left), Tufted Duck (top-right), Scaup (bottom-left) and Goldeneye (bottom-right) at the Lough Neagh and Lough Beg SPA. On the x axis, 1986 = the winter of 1986/87 etc. Values on the y-axis refer to average monthly counts during the indexing period.

3.3 Historic Trends at Lough Neagh

WeBS and its predecessor, the National Wildfowl counts, provide coverage of waterbird trends on Lough Neagh since 1986. However, waterfowl counts have been conducted at Lough Neagh since the early 1960s. The following is a synopsis taken from Winfield *et al.* (1989), which provides an overview of long-term trends in the number of waterfowl between the mid-1960s and late 1980s.

Between 1964 and 1986 Pochard show considerable short-term variation in numbers, which makes it difficult to discern long-term changes, although there does appear to have been a decline during the late 1960s and early 1980s and an increase in the mid-1980s. Tufted Duck showed dramatic declines on the site during the early 1980s following a period of stability through the 1960s and probably the 1970s. Overall, the number of Scaup on the site has remained relatively stable, although the pattern is quite variable with occasional large peaks occurring in some years. Goldeneye numbers varied little through the 1960s, 1970s and early 1980s. Historical counts of all of the species should be treated with a degree of caution however, as there have undoubtedly been significant improvements in the availability and performance of optical equipment used during counts and counter efficiency is also thought to have increased due to a greater number of counters. Thus even if numbers had actually remained relatively stable, the trend would probably suggest that an increase had occurred. An apparently stable trend might suggest that numbers have actually decreased.

3.4 Lough Neagh Sector-level Density Changes

Density maps (five-year peak means and five-year means) of Pochard are shown in Figs. 3.4.1 and 3.4.2. The highest densities occur in the southwest sectors of the site. It appears that, in numeric terms, the greatest declines occurred between 1989/90-1993/94 and 1994/95-1998/99 in these southwestern sectors, but a more widespread decline throughout much of the site occurred between 1994/95-1998/99 and 1999/2000-2003/04.

Density maps (five-year peak means and five-year means) of Tufted Duck are shown in Figs. 3.4.3 and 3.4.4. As with Pochard, high densities occur in the southwest sectors of the site, but also in the south-east sectors. A widespread decline appears to have occurred between 1989/90-1993/94 and 1994/95-1998/99 (more evident from peak than mean densities), with a slight increase in peak densities, but little overall change in mean densities between 1994/95-1998/99 and 1999/2000-2003/04.

Density maps (five-year peak means and five-year means) of Scaup are shown in Figs. 3.4.5 and 3.4.6. Both peak and mean densities reveal that the highest concentrations occur in northwestern sectors of the site and declines have been predominantly from these sectors.

Density maps (five-year peak means and five-year means) of Goldeneye are shown in Figs. 3.4.7 and 3.4.8. Goldeneye are not so obviously concentrated in particular parts of the site, being fairly abundant in many sectors, but predominantly sheltered bays. Peak densities, particularly, reveal a widespread decline between 1989/90-1993/94 and 1994/95-1998/99. Between 1994/95-1998/99 and 1999/2000-2003/04 declines continued, particularly in northwestern sectors of the site.

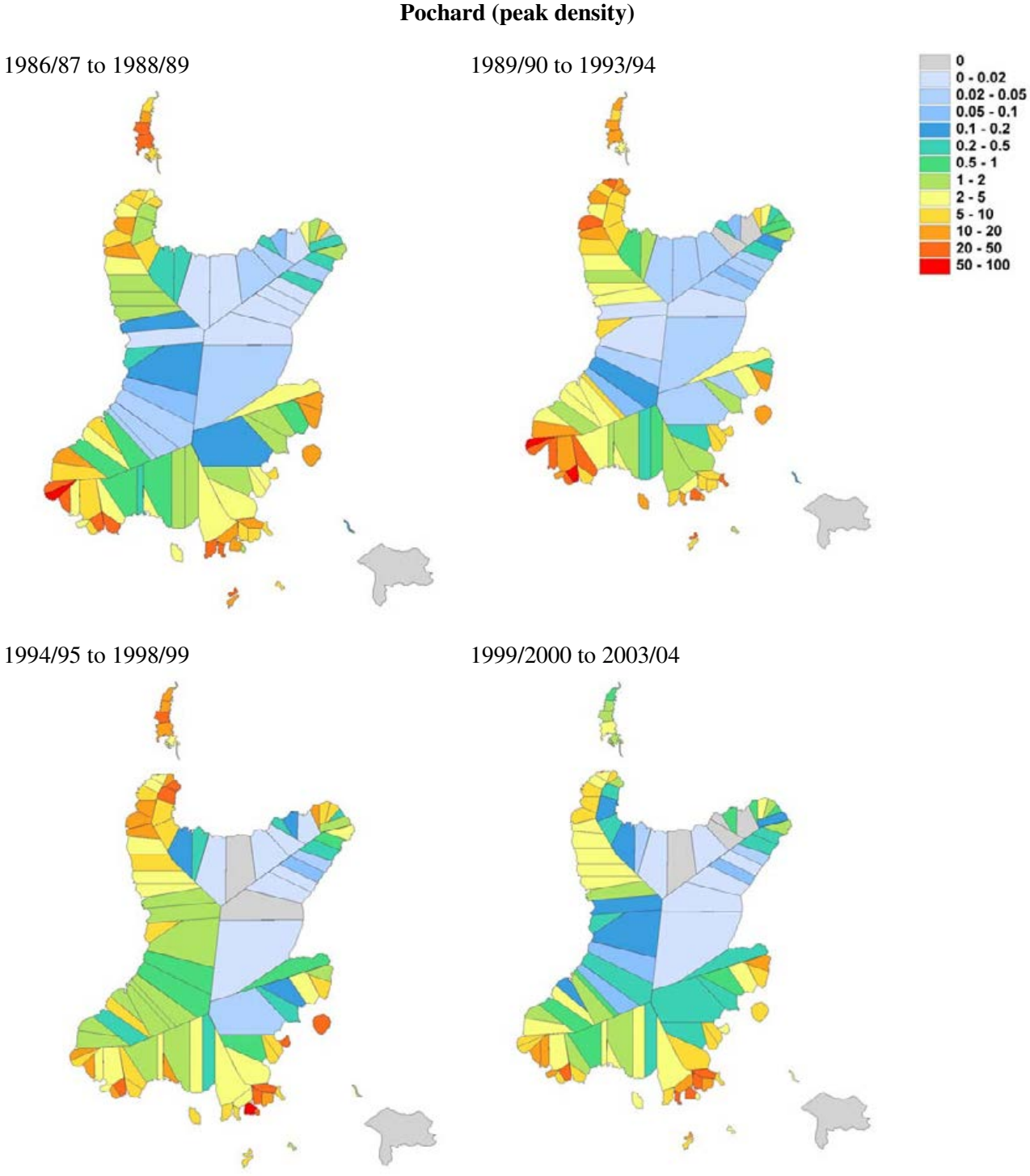


Figure 3.4.1 Five-year peak mean densities (or three year peak mean densities for the period 1986/8 to 1988/89) of Pochard (i.e. the peak count for each year averaged over 5 or 3 years) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) peak mean counts by the area of each sector.

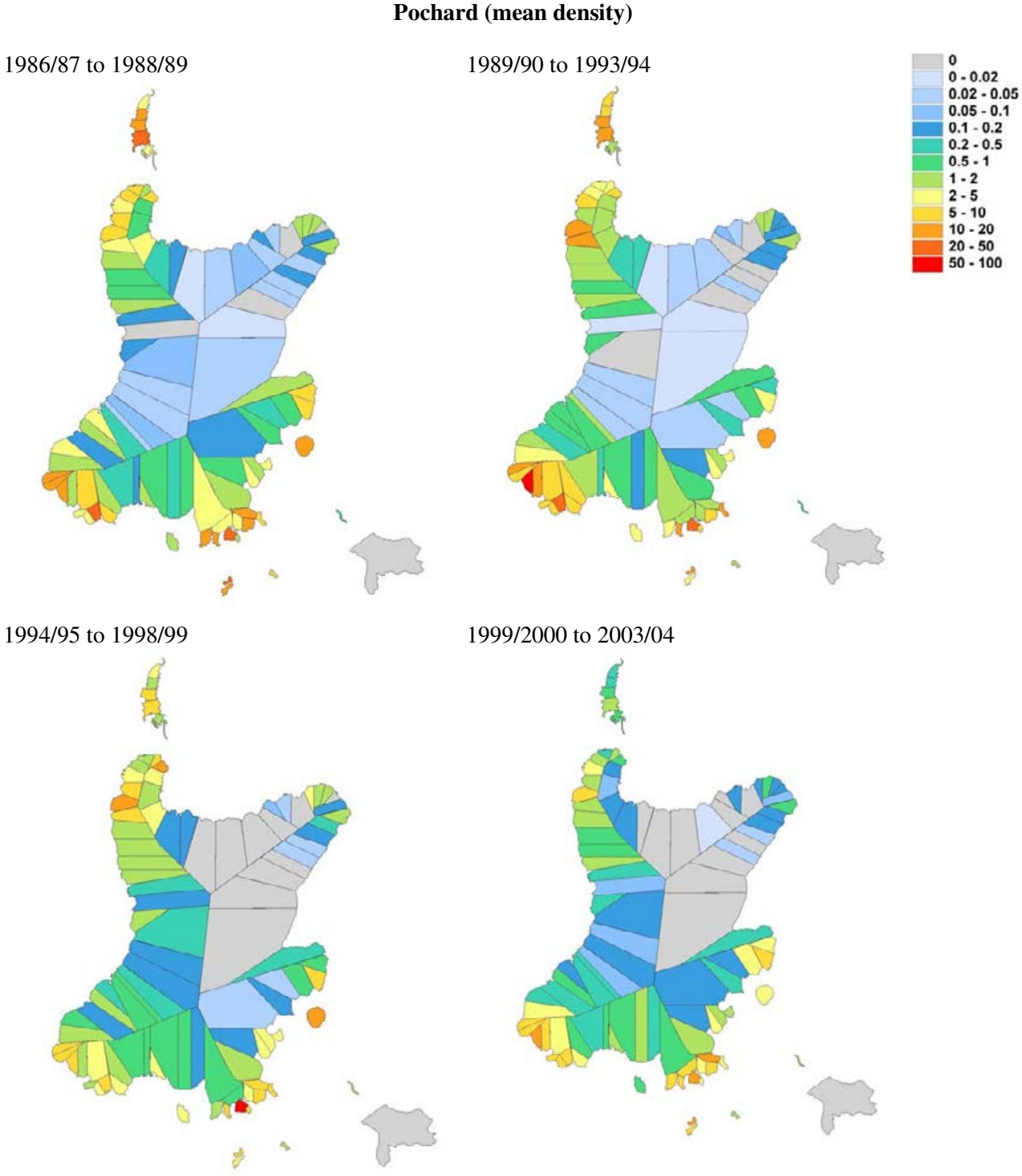


Figure 3.4.2 Five-year mean densities (or 3 year mean densities for the period 1986/8 to 1988/89) of Pochard (i.e. the mean of all counts conducted in each year period) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) mean counts by the area of each sector.

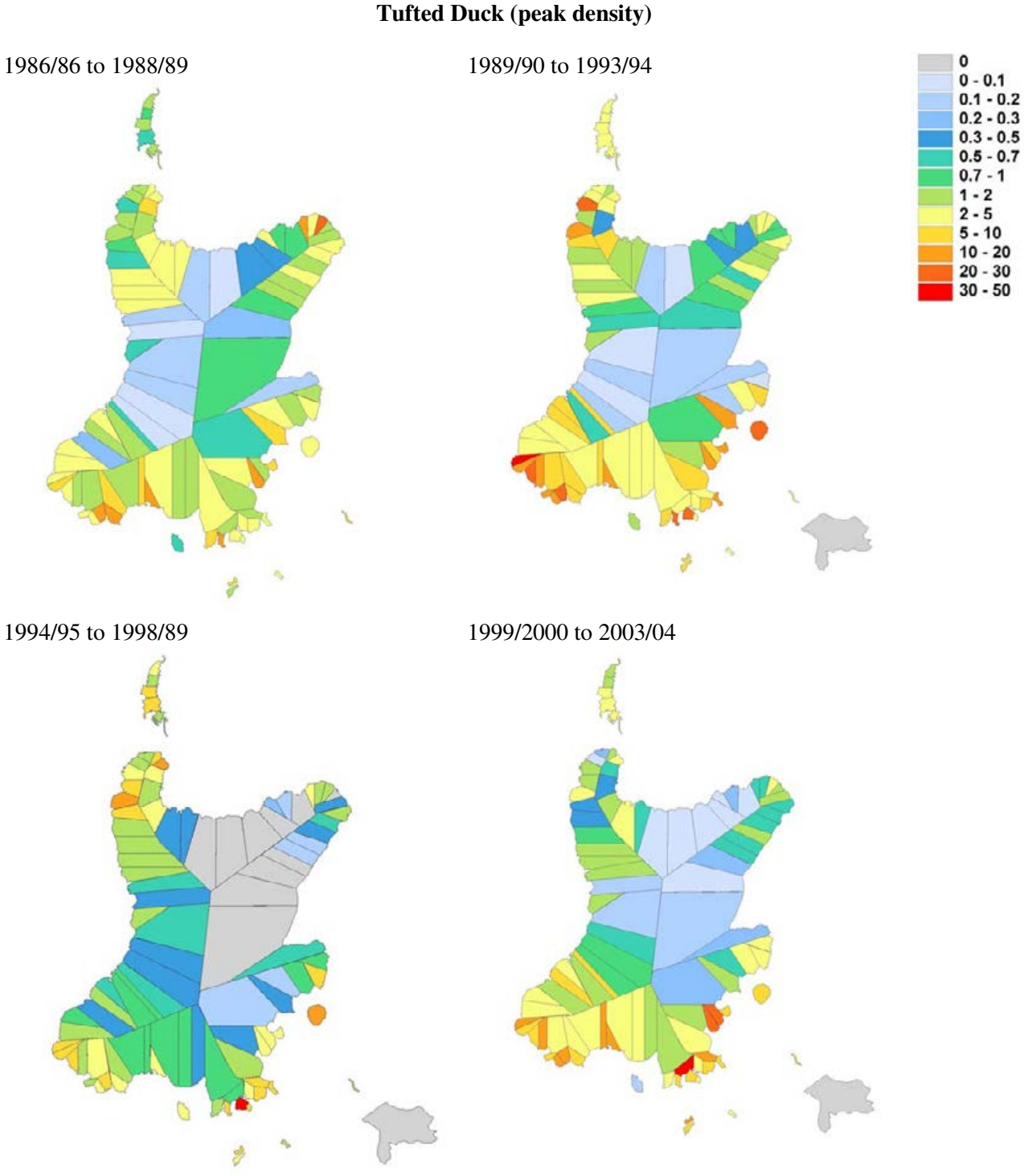


Figure 3.4.3 Five-year peak mean densities (or three year peak mean densities for the period 1986/8 to 1988/89) of Tufted Duck (i.e. the peak count for each year averaged over 5 or 3 years) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) peak mean counts by the area of each sector.

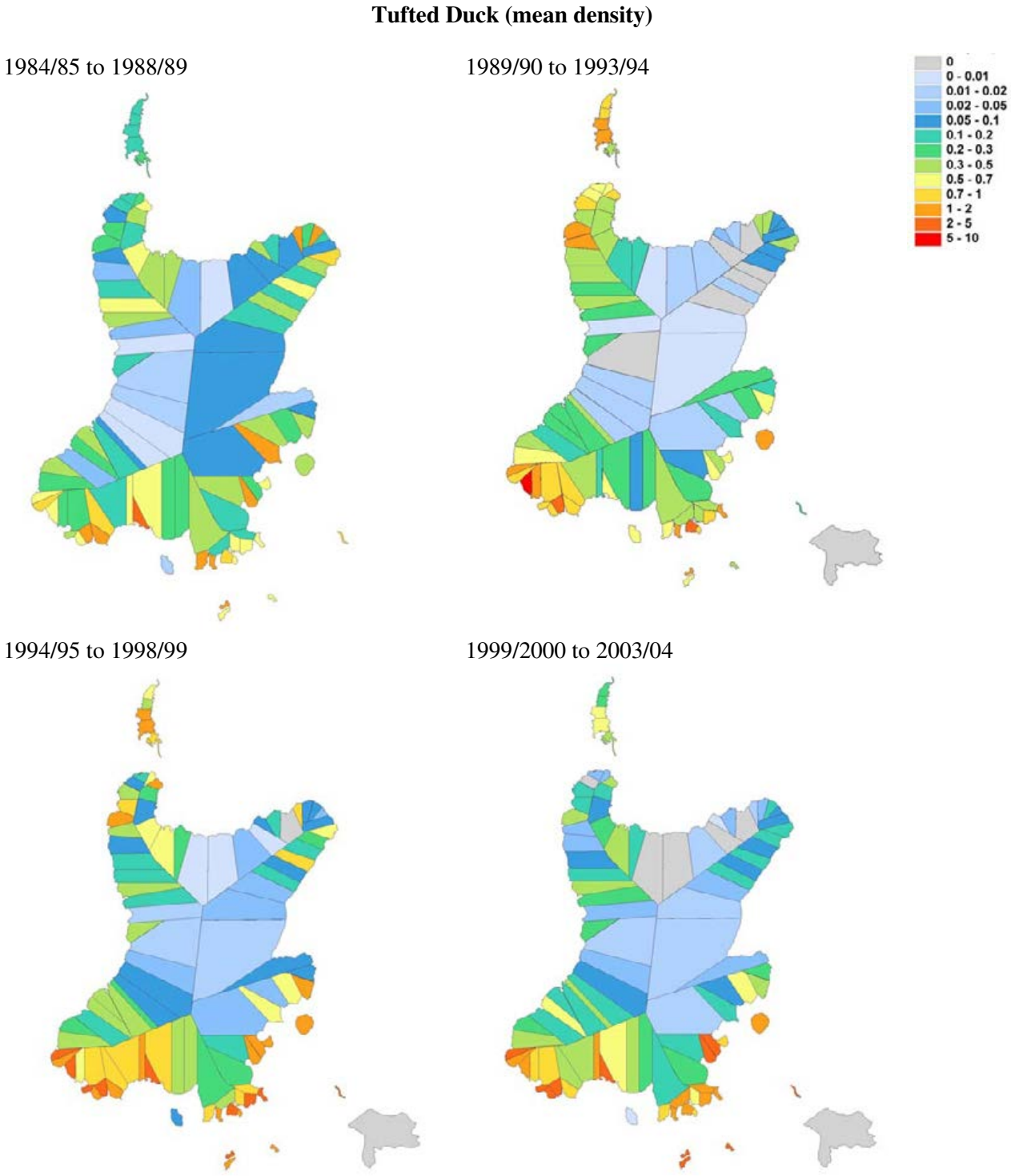


Figure 3.4.4 Five-year mean densities (or 3 year mean densities for the period 1986/8 to 1988/89) of Tufted Duck (i.e. the mean of all counts conducted in each year period) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) mean counts by the area of each sector.

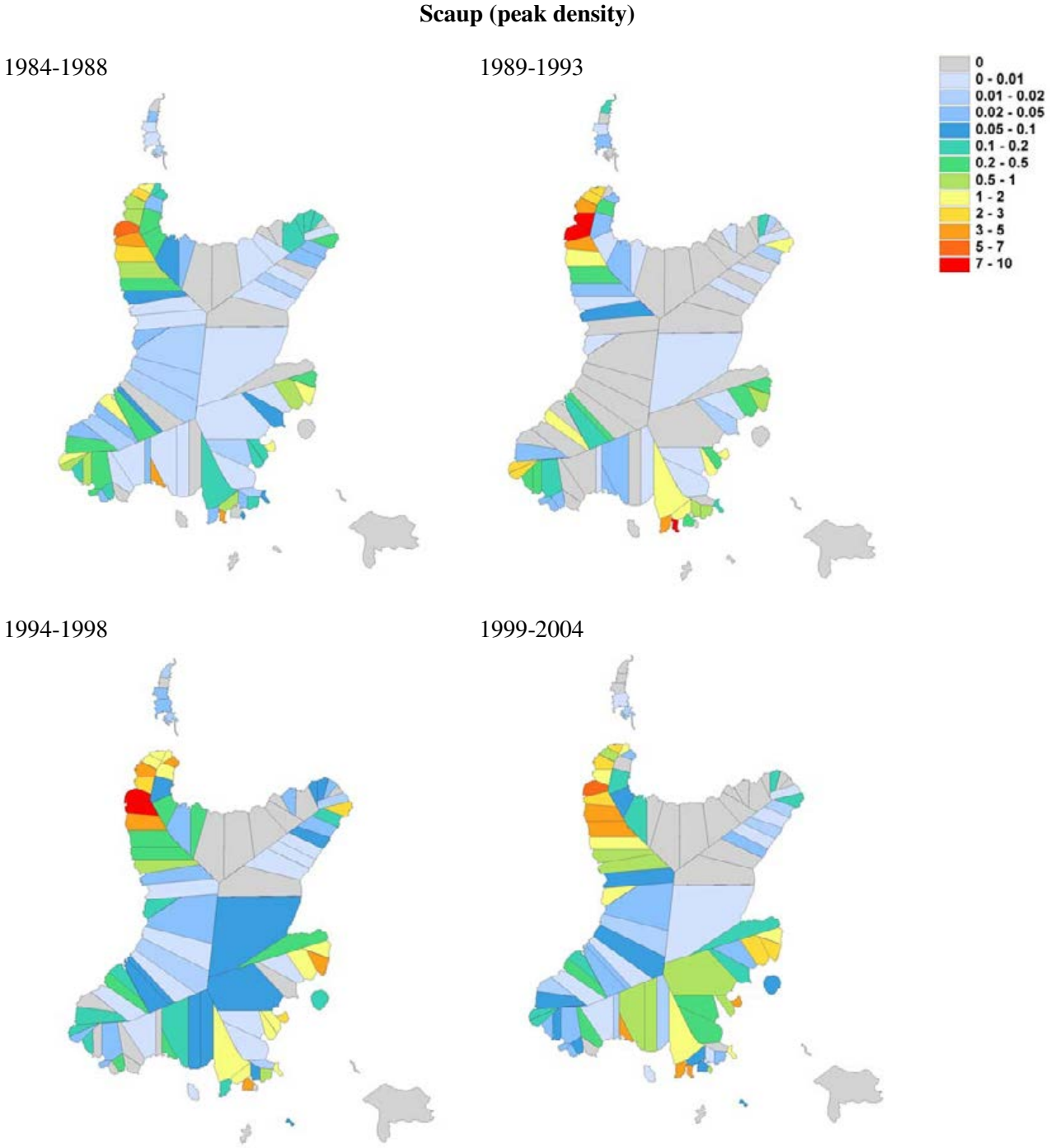


Figure 3.4.5 Five-year peak mean densities (or three year peak mean densities for the period 1986/8 to 1988/89) of Scaup (i.e. the peak count for each year averaged over 5 or 3 years) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) peak mean counts by the area of each sector.

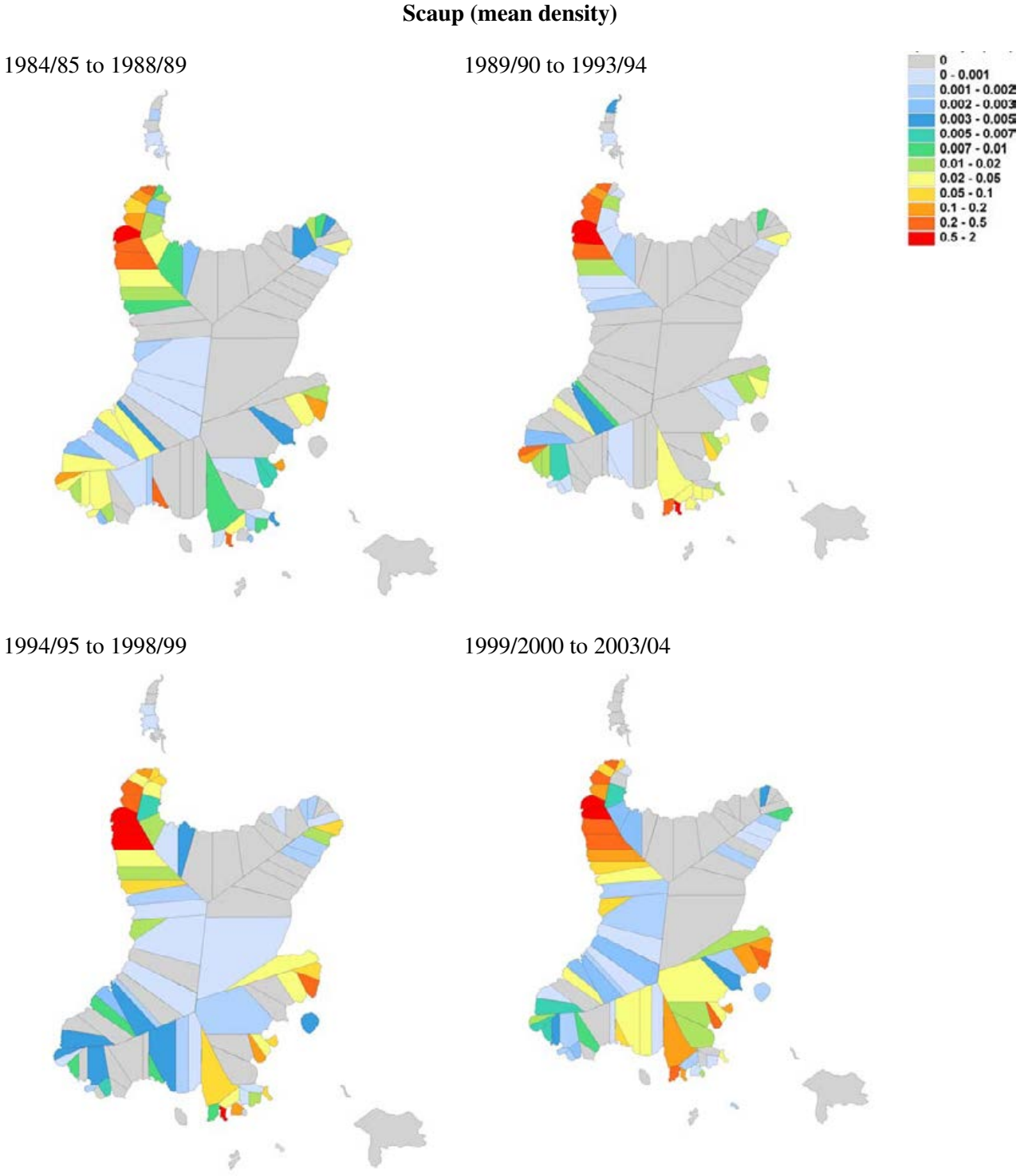


Figure 3.4.6 Five-year mean densities (or 3 year mean densities for the period 1986/8 to 1988/89) of Scaup (i.e. the mean of all counts conducted in each year period) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) mean counts by the area of each sector.

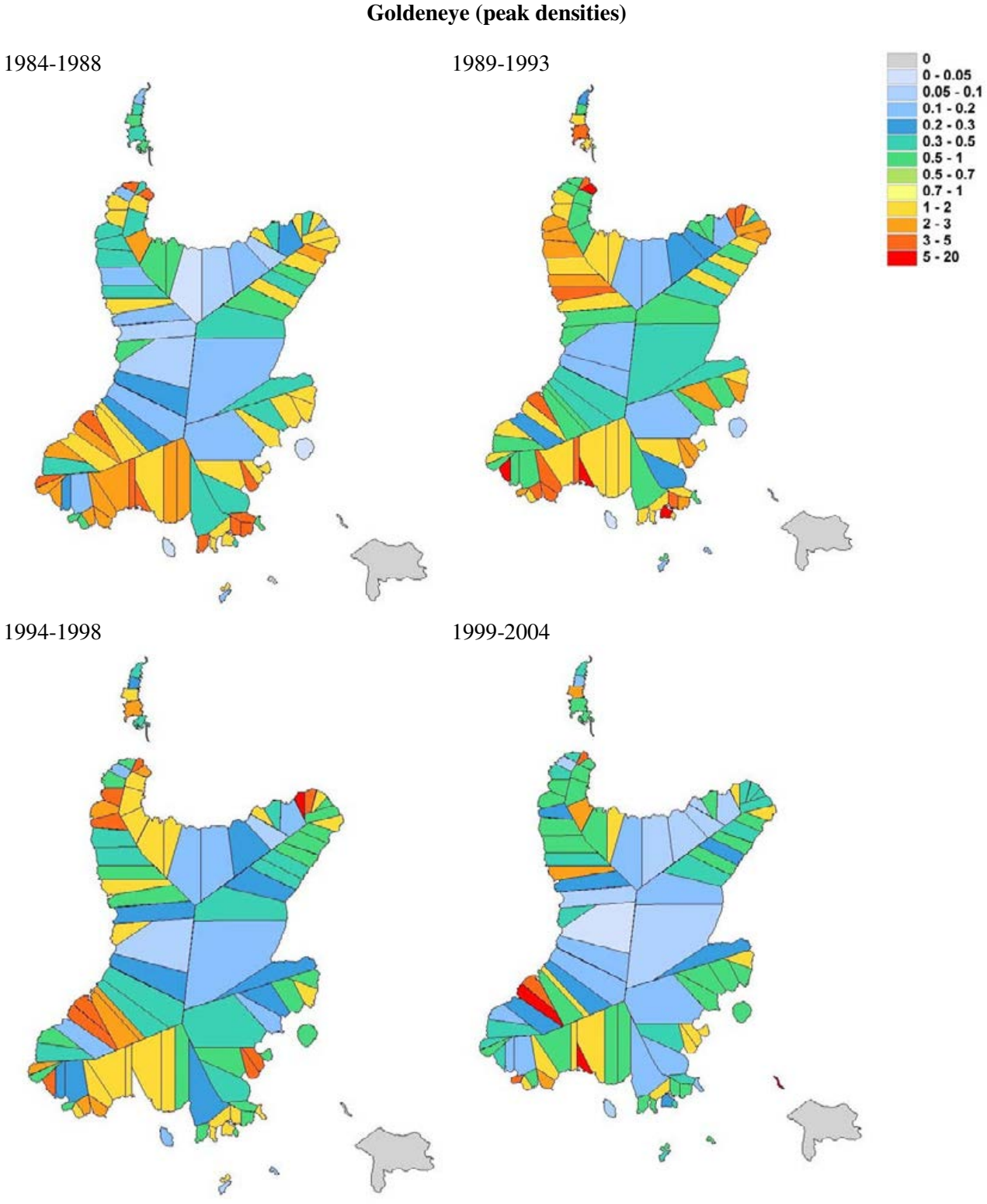


Figure 3.4.7 Five-year peak mean densities (or three year peak mean densities for the period 1986/8 to 1988/89) of Goldeneye (i.e. the peak count for each year averaged over 5 or 3 years) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) peak mean counts by the area of each sector.

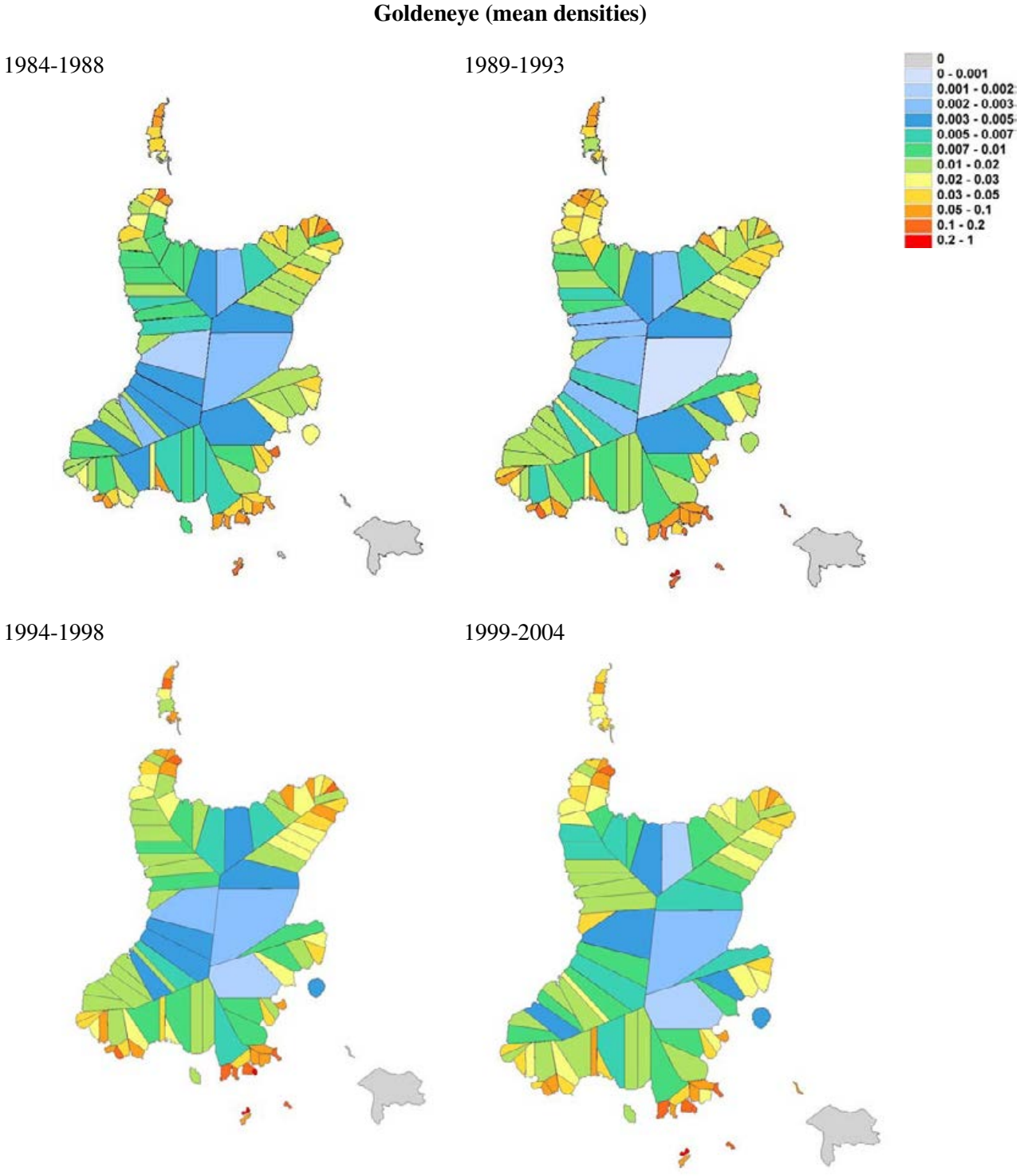


Figure 3.4.8 Five-year mean densities (or 3 year mean densities for the period 1986/8 to 1988/89) of Goldeneye (i.e. the mean of all counts conducted in each year period) in each of the sectors counted as part of WeBS core-counts. Densities were calculated by dividing the five-year (or three year) mean counts by the area of each sector.

3.5 Lough Neagh Sector-level Trends

The amalgamation of the 155 sectors into 19 larger sectors is shown in Fig. 3.5.1. Changes in numbers (raw values and smoothed trends) for each of these sectors, except Swan Fields (as this sector only sporadically hosts a few individuals of the diving duck species) are shown in Figs. 3.5.2-3.5.5. Changes in the proportions of numbers over-wintering on Lough Neagh / Beg hosted by each of the sectors are shown in Figs. 3.5.6-3.5.9.

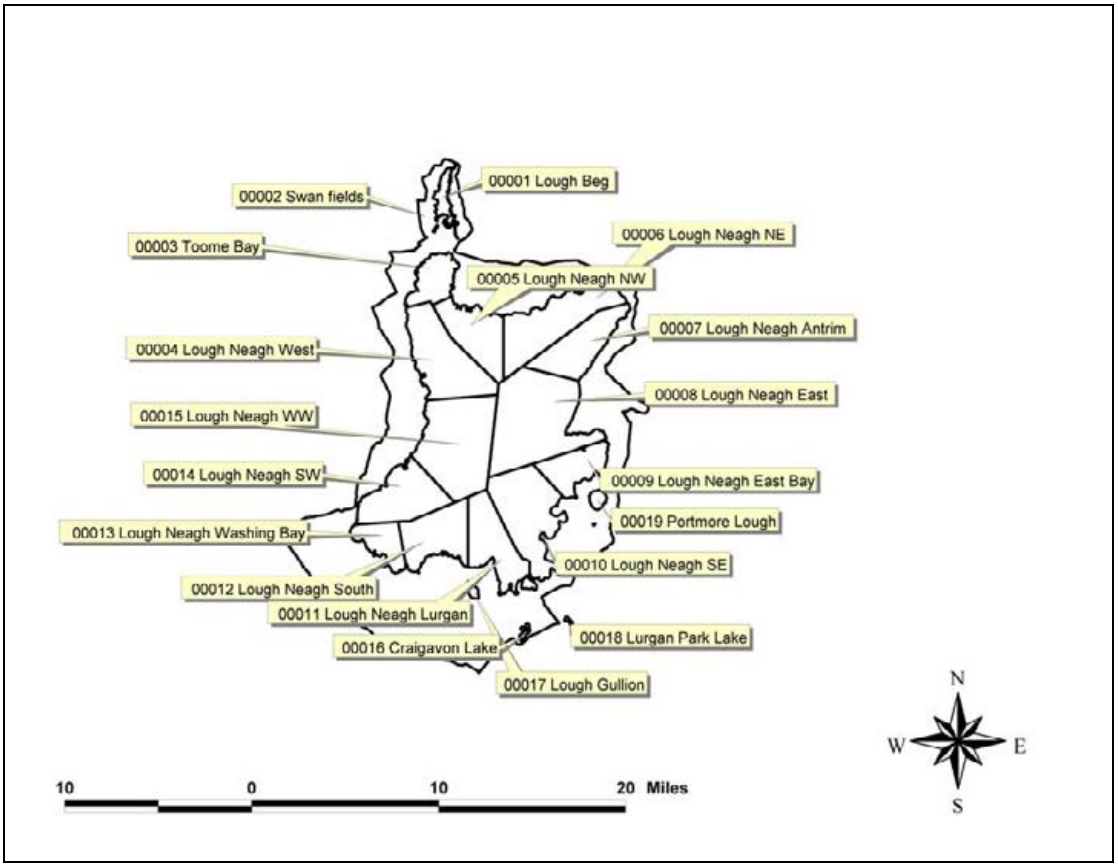


Figure 3.5.1 The geographical boundaries of the amalgamated larger sectors.

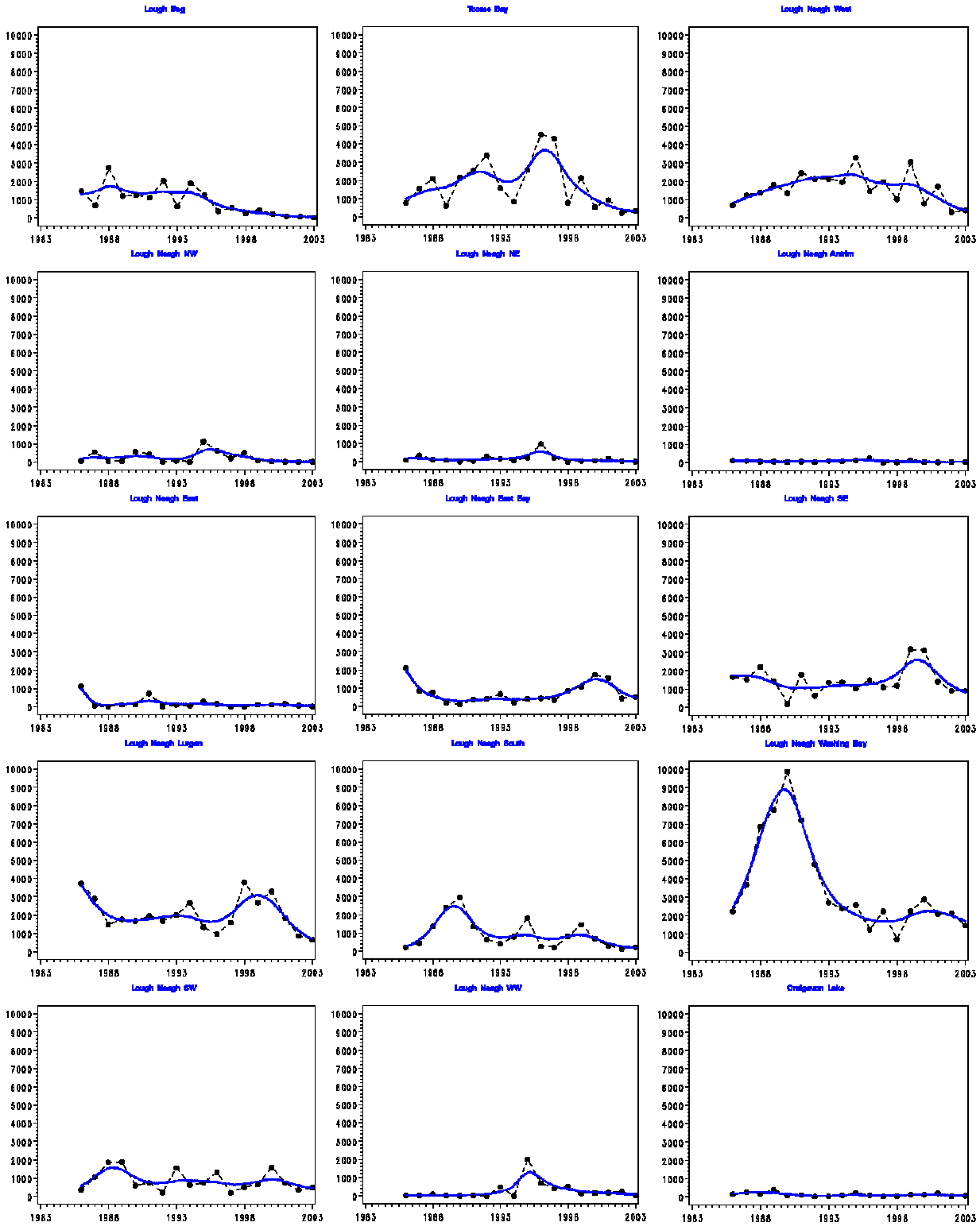
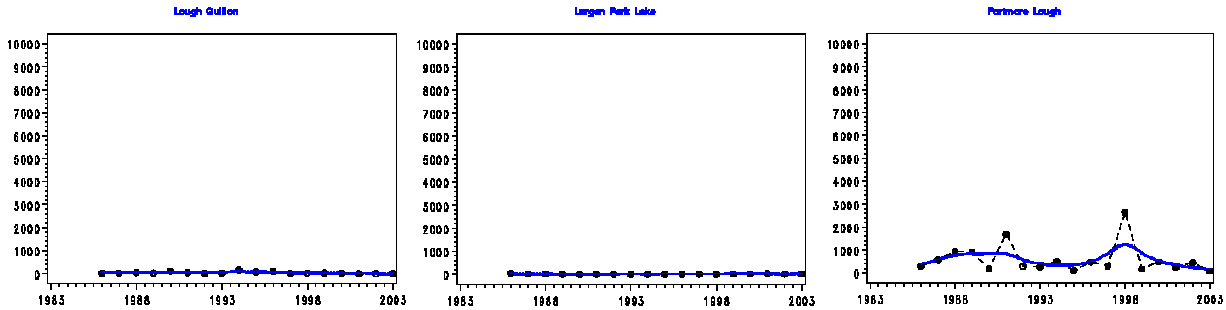


Figure 3.5.2 Changes in the number of Pochard on each of the 18 sectors identified in Fig. 3.5.1. Closed circles represent complete counts and open circles represent imputed estimates. Where possible, smoothed trends have been fitted using General Additive Models with 6 degrees of freedom.



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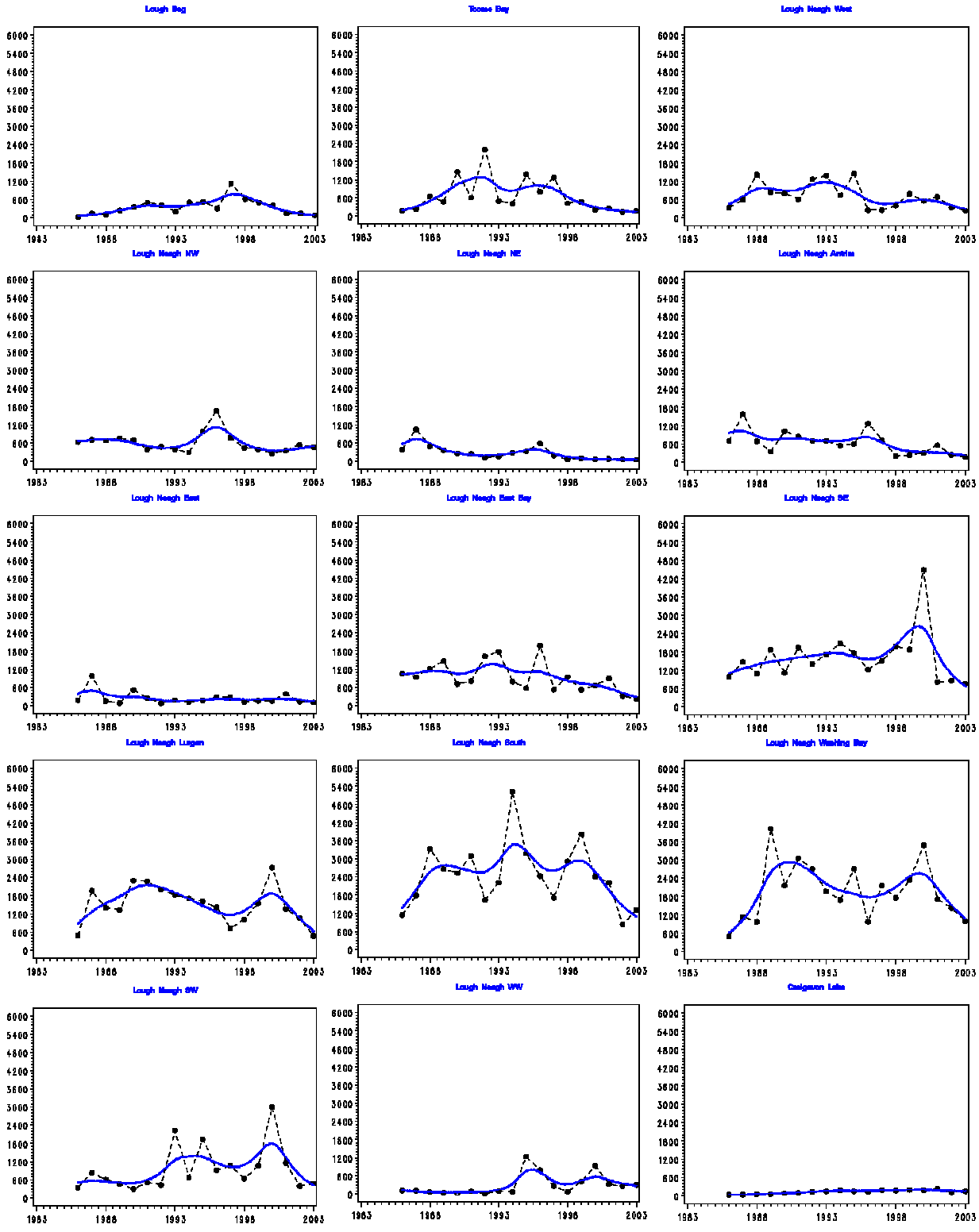

Figure 3.5.3 Changes in the number of Tufted Duck on each of the 18 sectors identified in Fig. 3.5.1. Closed circles represent complete counts and open circles represent imputed estimates. Where possible, smoothed trends have been fitted using General Additive Models with 6 degrees of freedom.

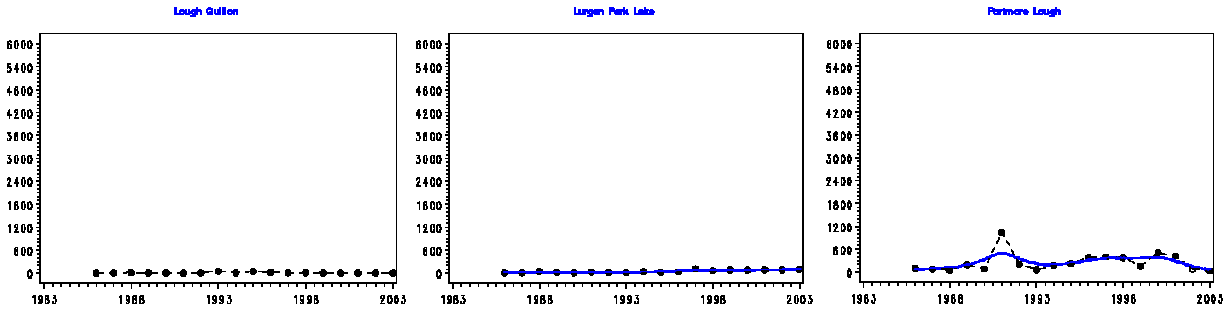

Figure 3.5.3 Continued.

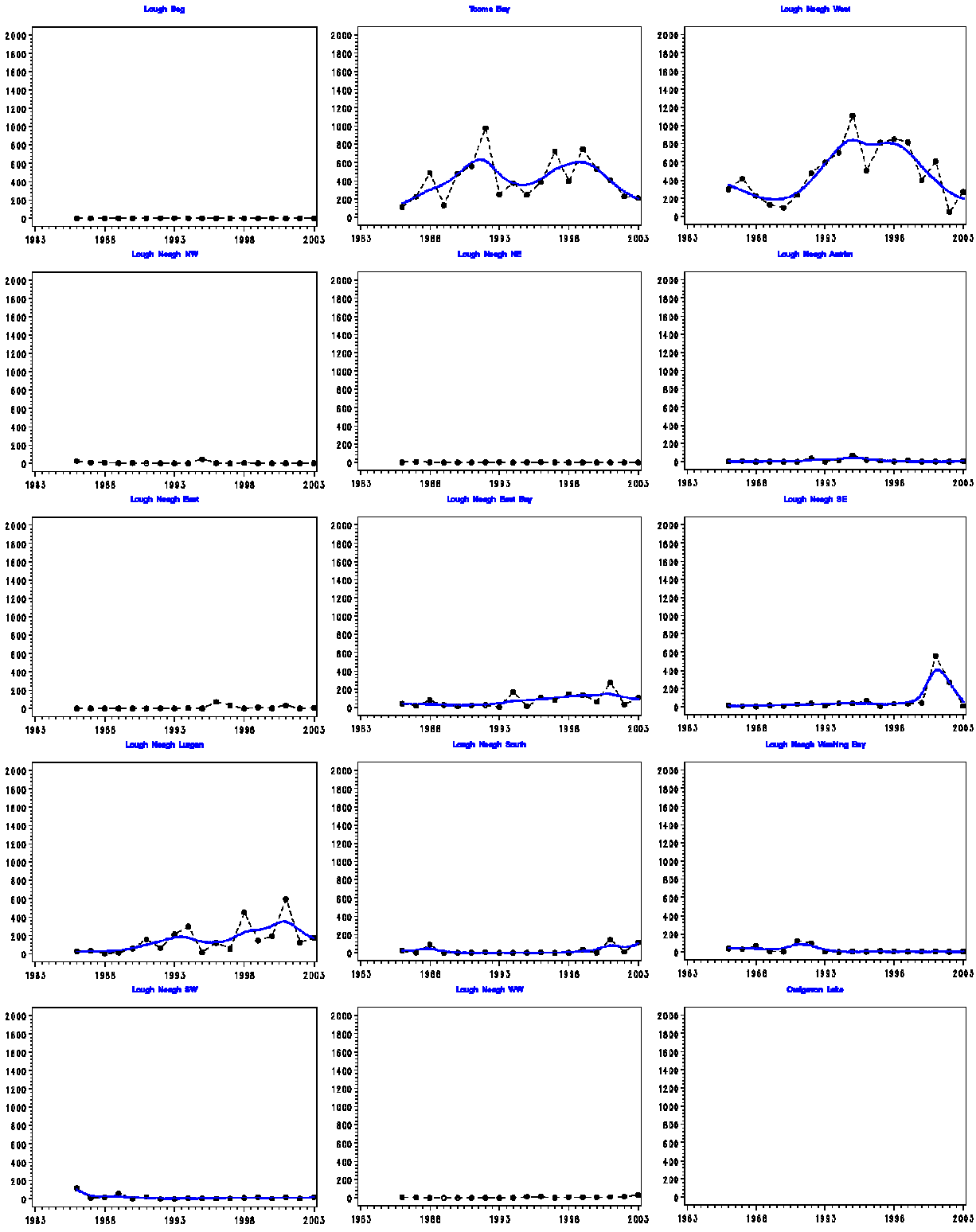

Figure 3.5.4 Changes in the number of Scaup on each of the 18 sectors identified in Fig. 3.5.1. Closed circles represent complete counts and open circles represent imputed estimates. Where possible, smoothed trends have been fitted using General Additive Models with 6 degrees of freedom.

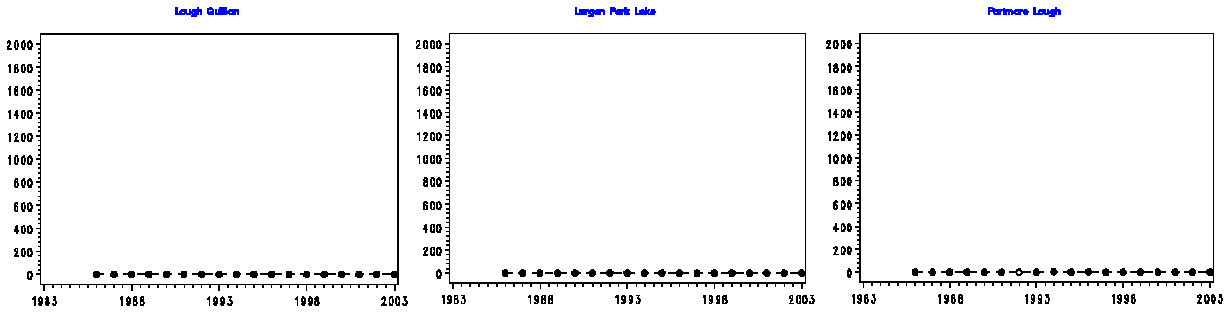

Figure 3.5.4 Continued.

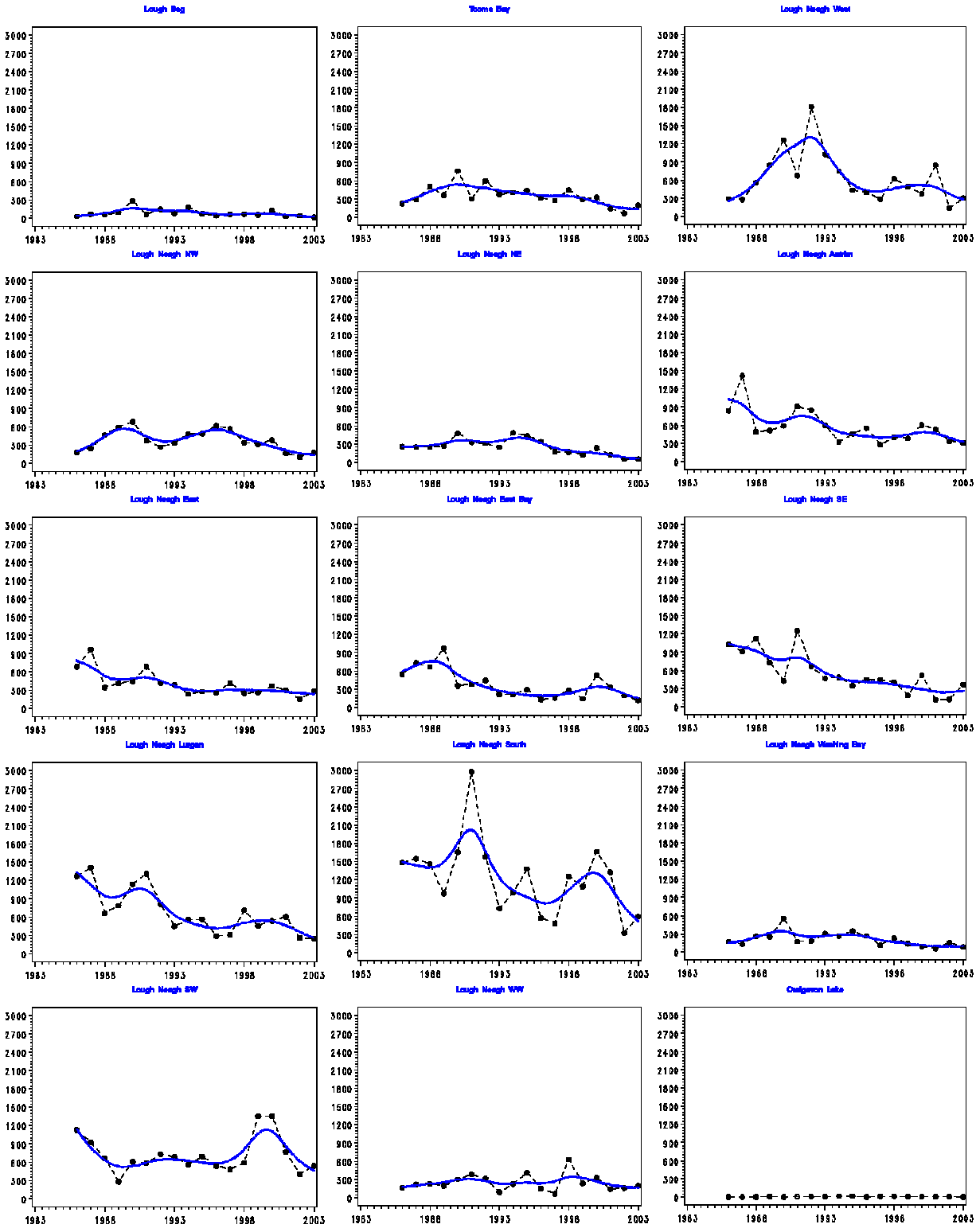

Figure 3.5.5 Changes in the number of Goldeneye on each of the 18 sectors identified in Fig. 3.5.1. Closed circles represent complete counts and open circles represent imputed estimates. Where possible, smoothed trends have been fitted using General Additive Models with 6 degrees of freedom.

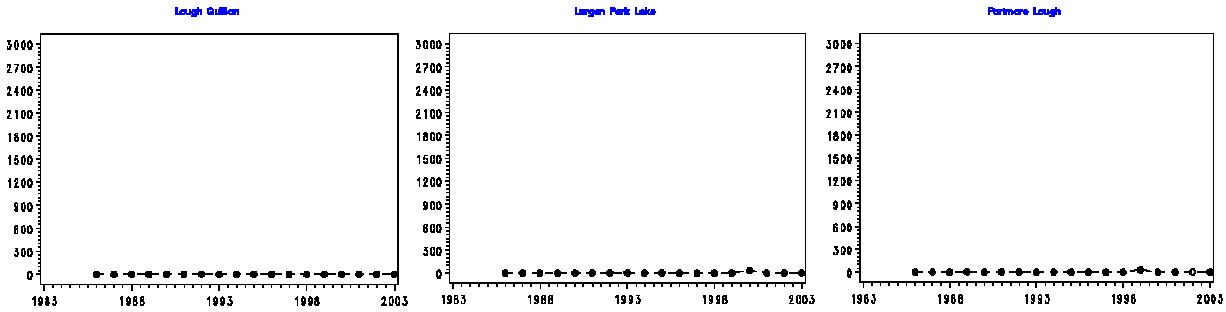

Figure 3.5.5 Continued.

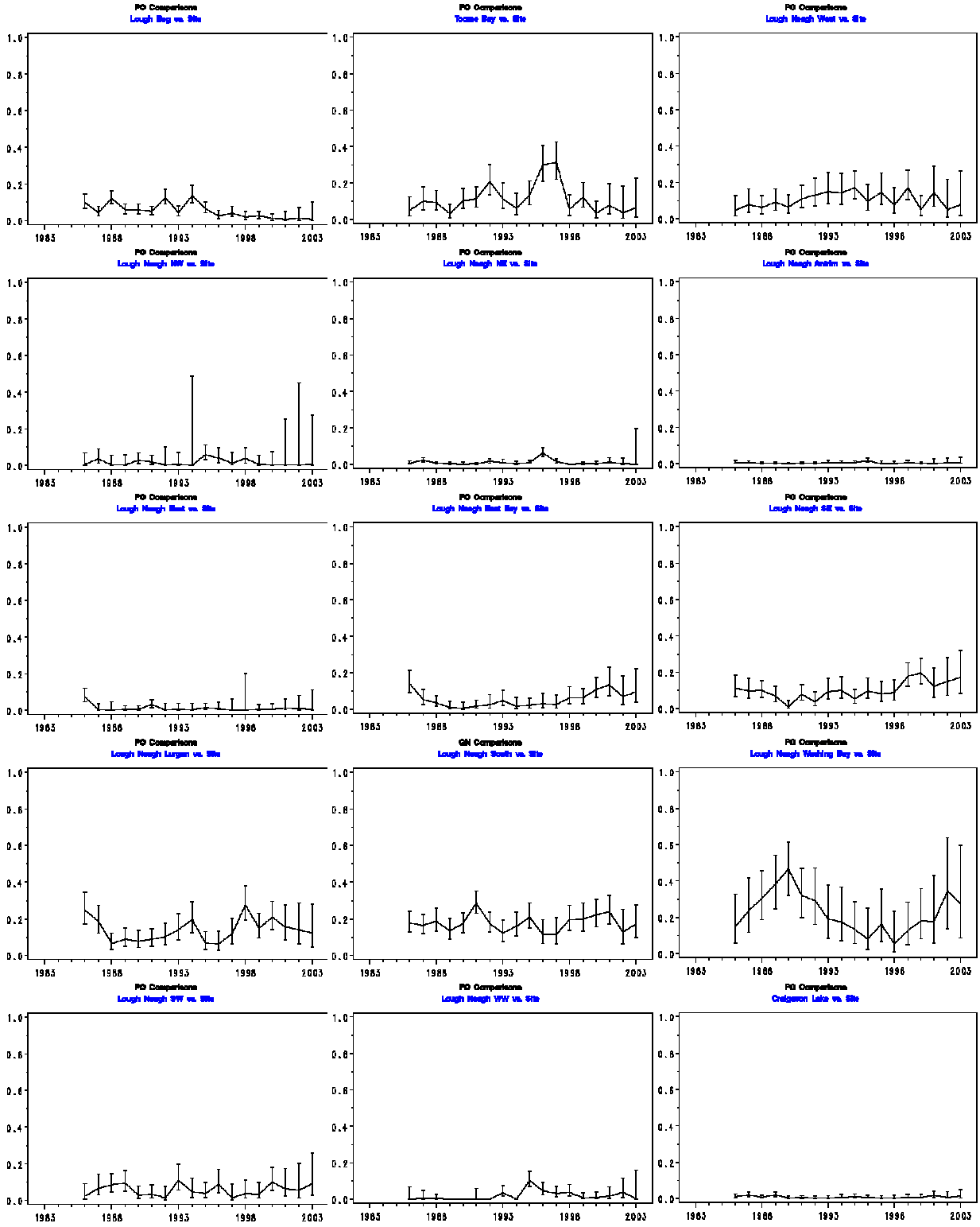

Figure 3.5.6 Changes in the proportion of the number of Pochard on Lough Neagh / Beg hosted by each of the 18 sectors identified in Fig. 3.5.1.

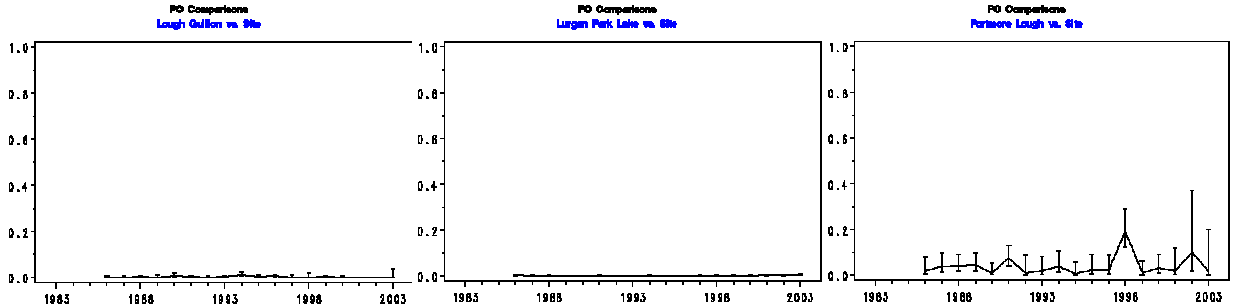

Figure 3.5.6 Continued.

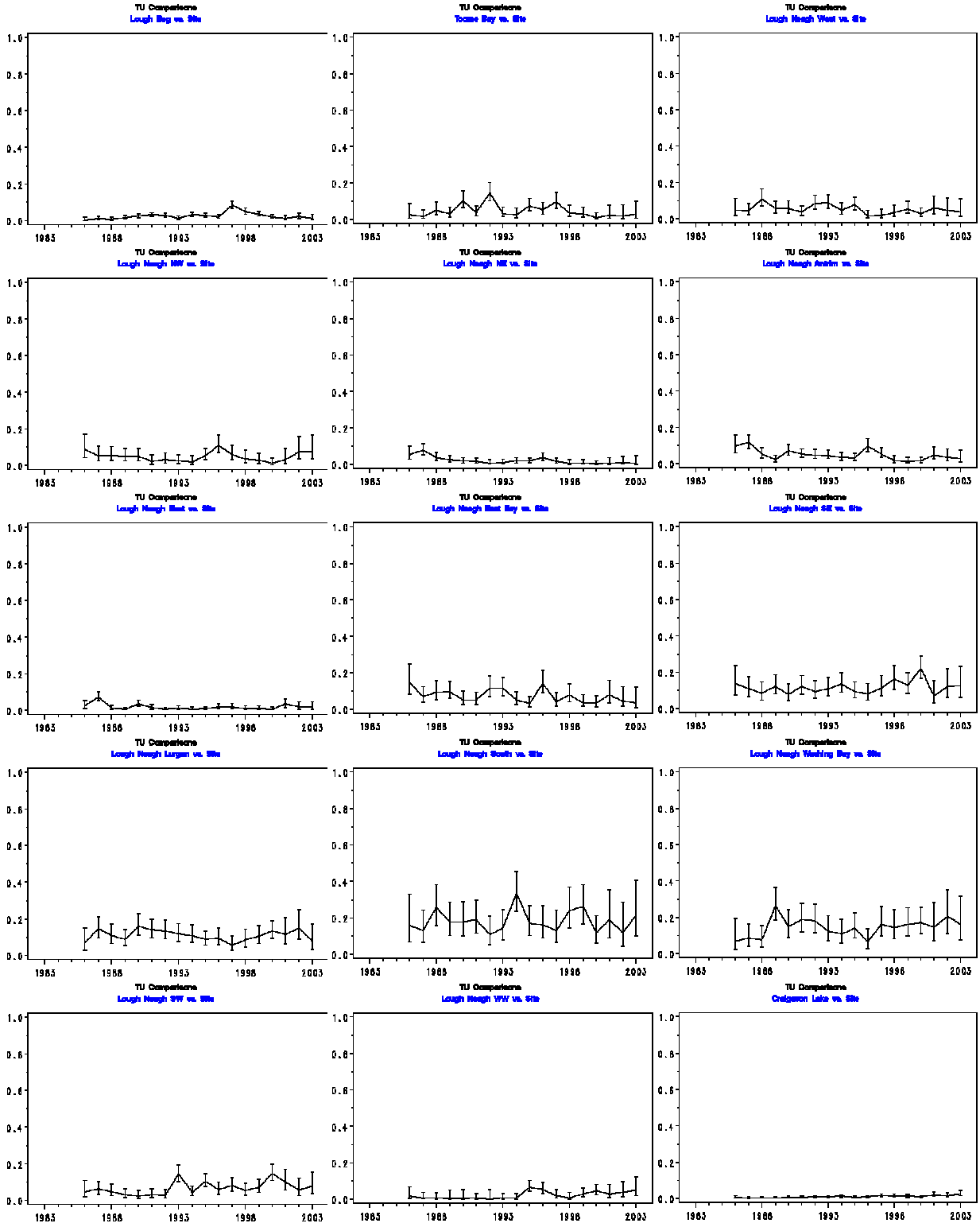

Figure 3.5.7 Changes in the proportion of the number of Tufted Duck on Lough Neagh / Beg hosted by each of the 18 sectors identified in Fig. 3.5.1.

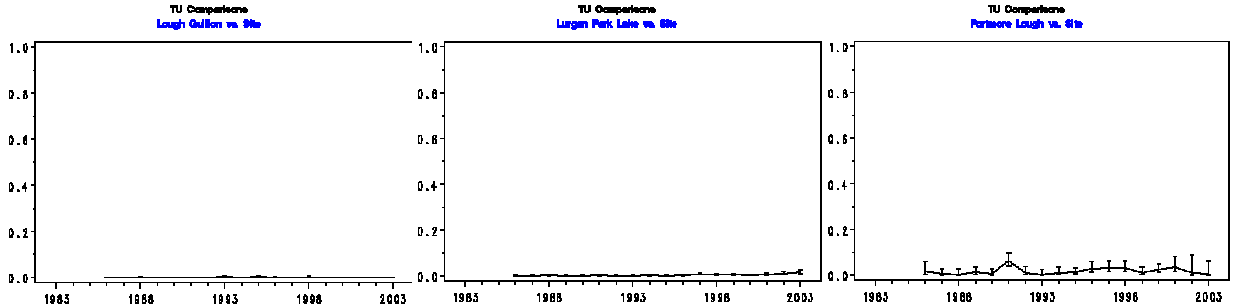

Figure 3.5.7 Continued.

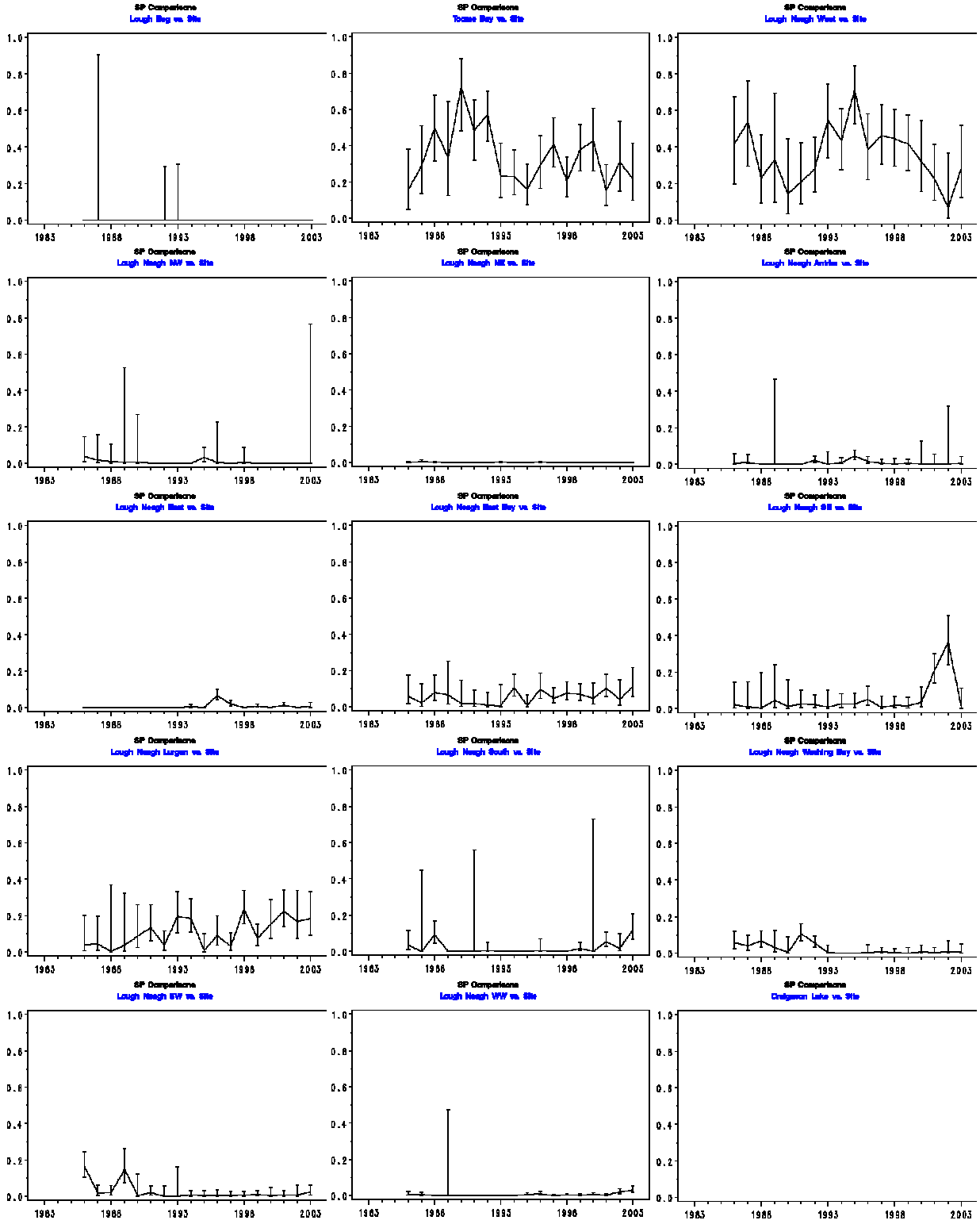

Figure 3.5.8 Changes in the proportion of the number of Scaup on Lough Neagh / Beg hosted by each of the 18 sectors identified in Fig. 3.5.1.

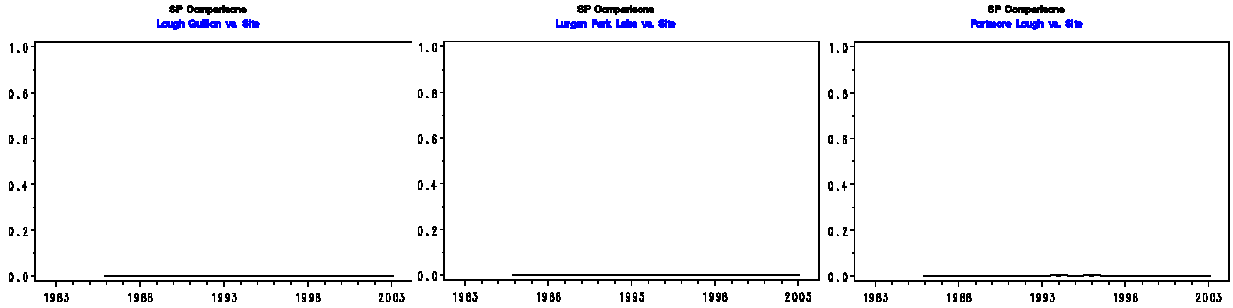

Figure 3.5.8 Continued.

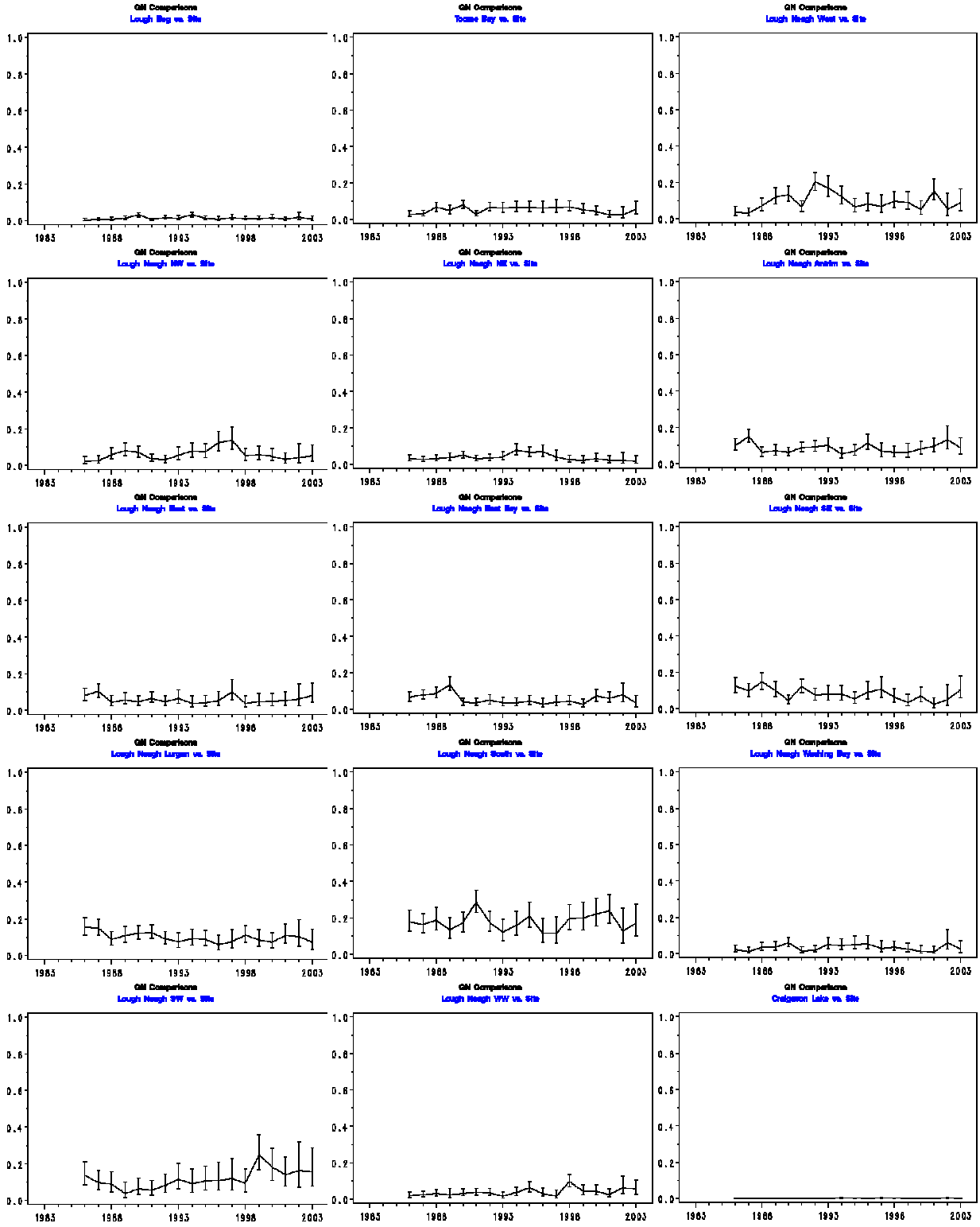

Figure 3.5.9 Changes in the proportion of the number of Goldeneye on Lough Neagh / Beg hosted by each of the 18 sectors identified in Fig. 3.5.1.

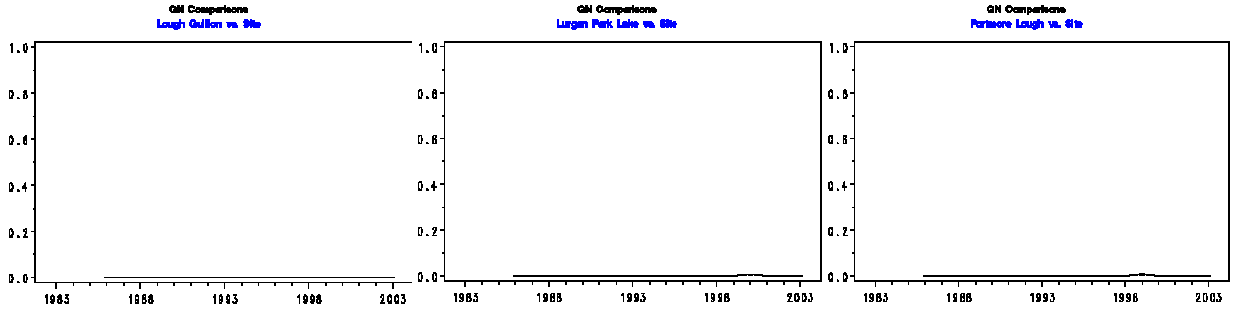

Figure 3.5.9 Continued.

3.6 Numeric Changes in the United Kingdom and Ireland

A geographical overview of changes in the number of Pochard on sites throughout the British Isles is shown in Fig. 3.6.1. Similar overviews are also presented for Tufted Duck (Fig. 3.6.2), Scaup (Fig. 3.6.3) and Goldeneye (Fig. 3.6.4). All sites for which it is possible to assess trends are included for each species. Declines at Lough Neagh, particularly for Pochard, Tufted Duck and Goldeneye are substantially greater than changes in numbers at any other site.

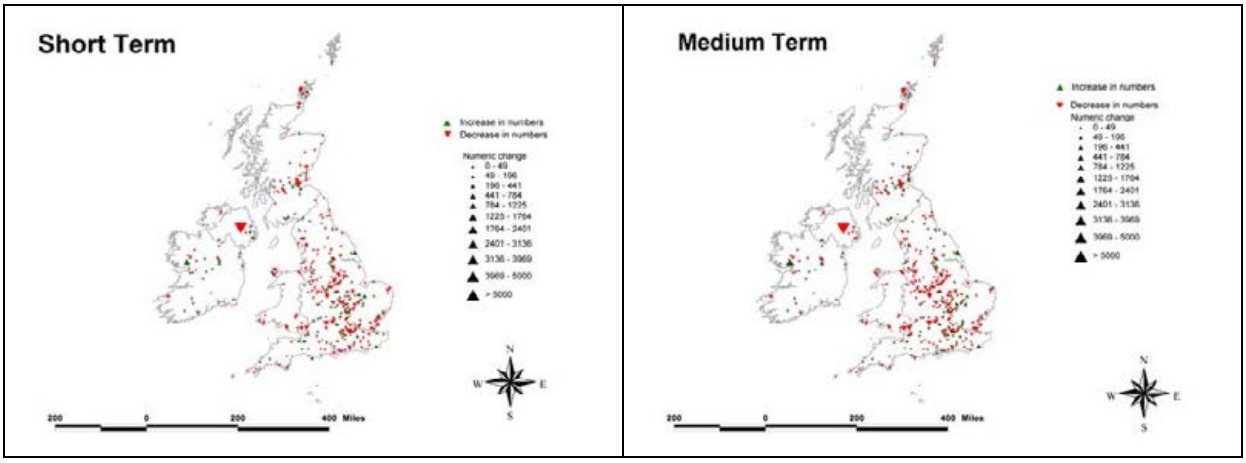

Figure 3.6.1 A geographic overview of short-term (last 5 years) and medium-term (last 10 years) changes in the number of Pochard over-wintering in Great Britain and Ireland.

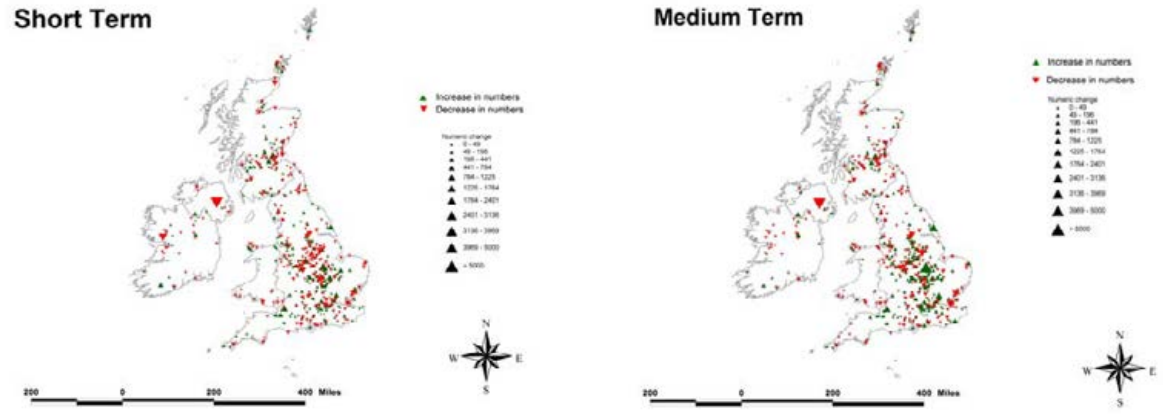

Figure 3.6.2 A geographic overview of short-term (last 5 years) and medium-term (last 10 years) changes in the number of Tufted Duck over-wintering in Great Britain and Ireland.

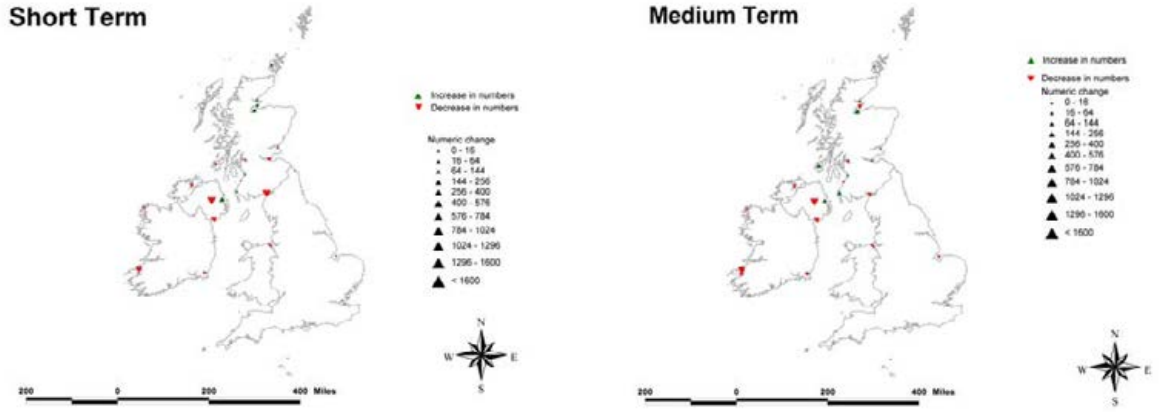

Figure 3.6.3 A geographic overview of short-term (last 5 years) and medium-term (last 10 years) changes in the number of Scaup over-wintering in Great Britain and Ireland.

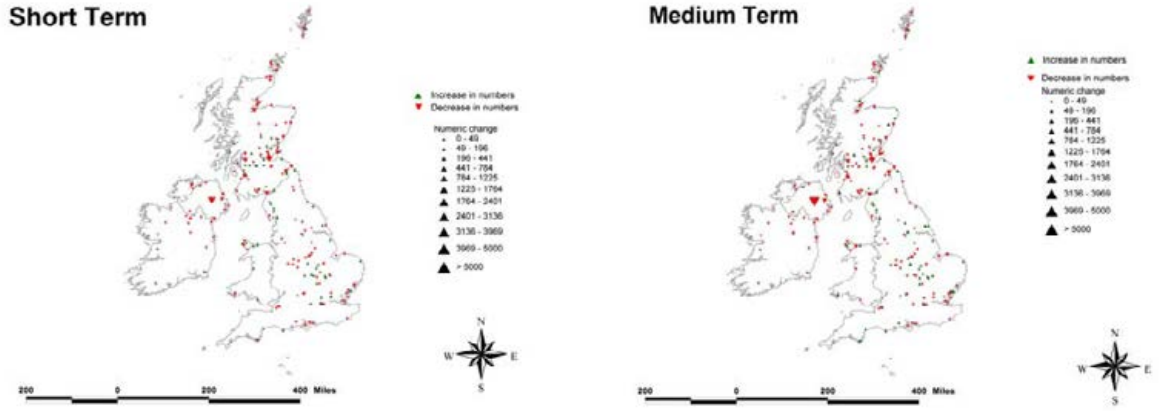

Figure 3.6.4 A geographic overview of short-term (last 5 years) and medium-term (last 10 years) changes in the number of Goldeneye over-wintering in Great Britain and Ireland.

3.7 Regional Trends in Great Britain and Ireland

Changes in numbers and smoothed trends for Lough Neagh and Beg, Environment Agency (EA) and Scottish Environment Protection Agency (SEPA) regions (Fig. 3.7.1), the Channel Islands and the Isle of Man are shown in Figs. 3.7.2-3.7.5. Changes in numbers and smoothed trends for England, Scotland, Wales, Northern Ireland, the Republic of Ireland, Great Britain, all of Ireland and the British Isles are shown in Figs. 3.5.6-3.5.9.

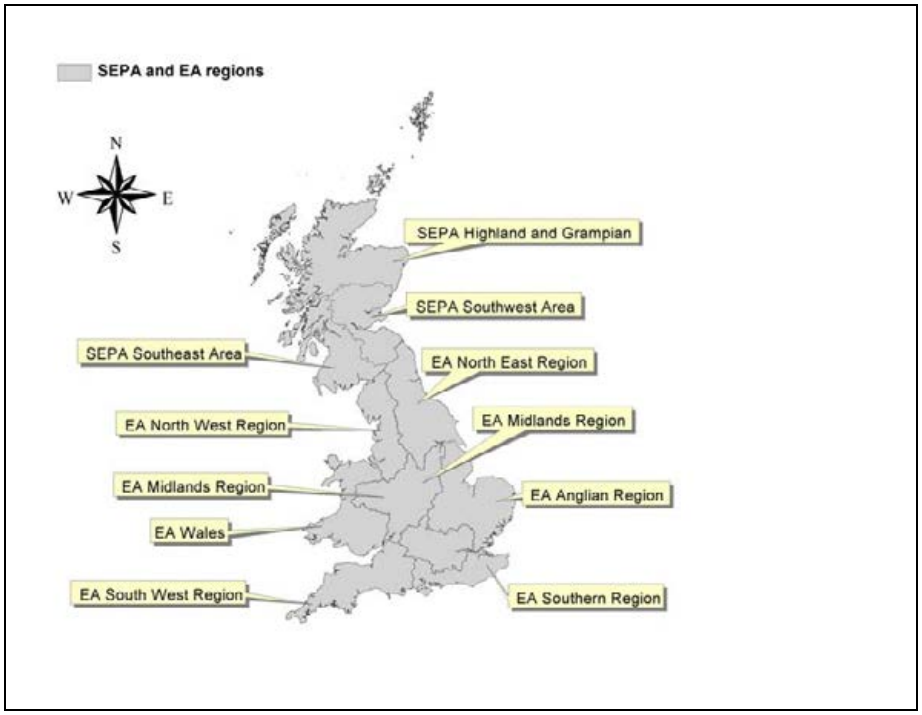

Figure 3.7.1 Environment Agency (EA) and Scottish Environment Protection Agency (SEPA) regions.

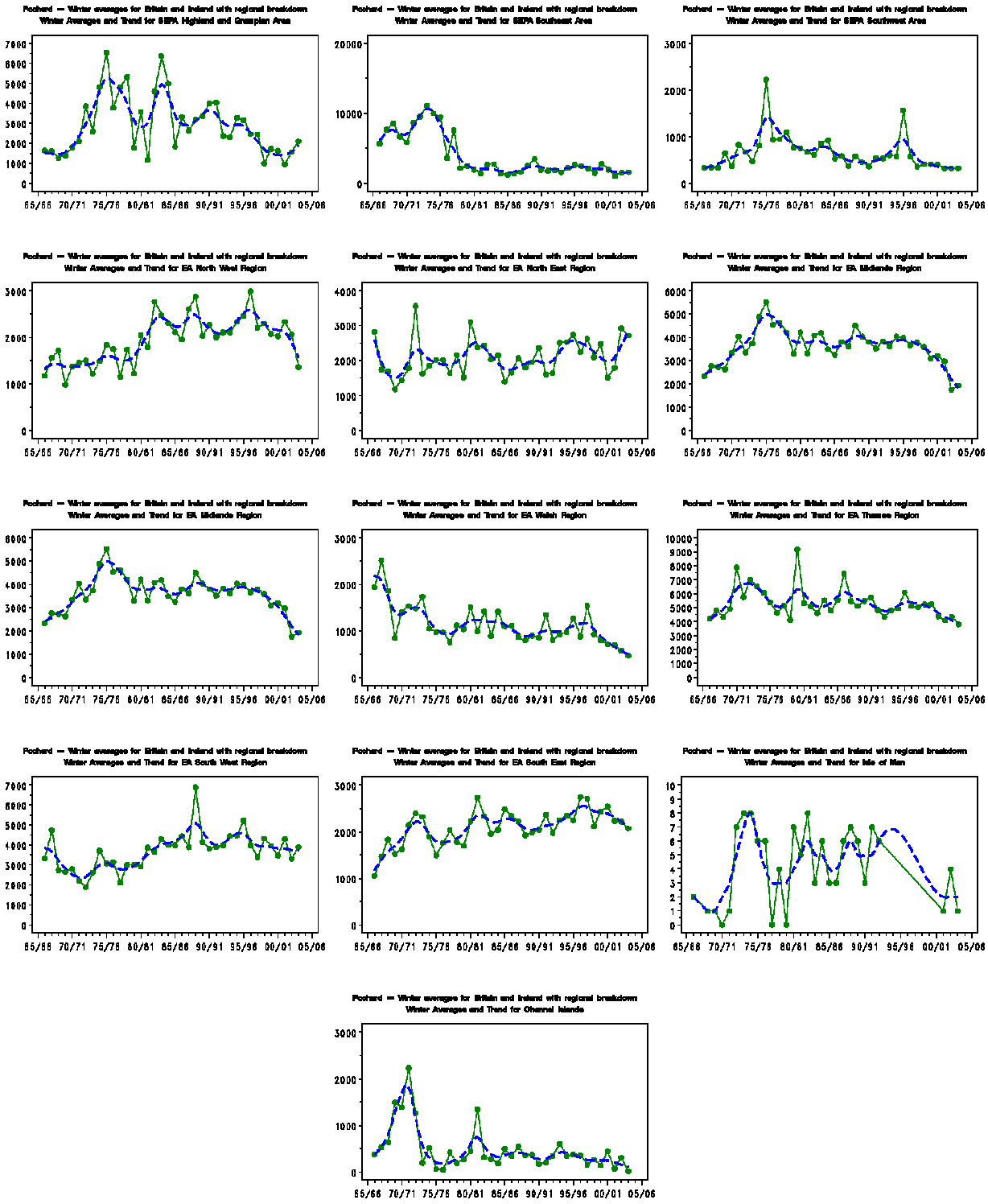

Figure 3.7.2 Smoothed trends and changes in the number of Pochard at Lough Neagh & Beg and in EA and SEPA regions in Great Britain.

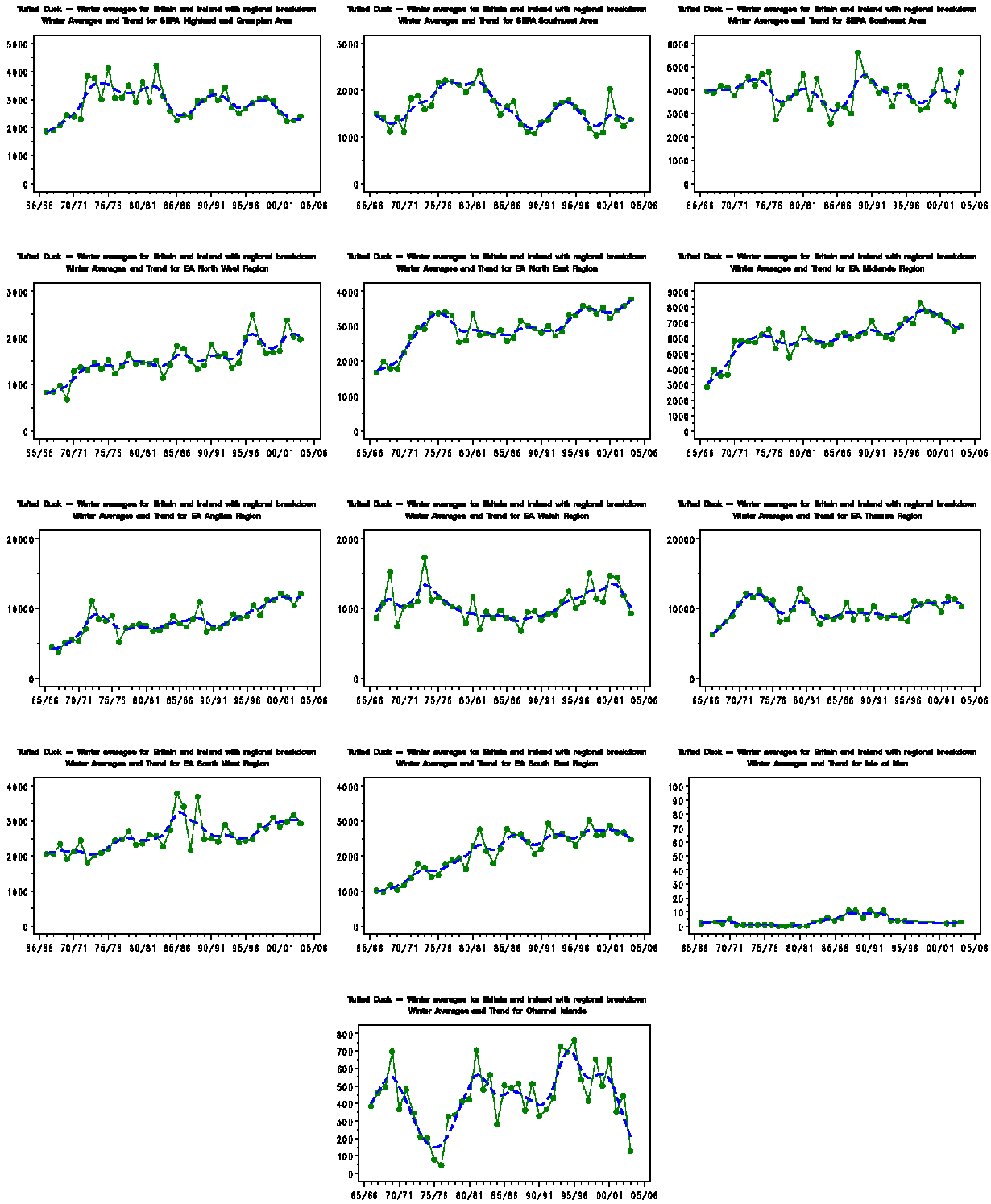

Figure 3.7.3 Smoothed trends and changes in the number of Tufted Duck at Lough Neagh & Beg and in EA and SEPA regions in Great Britain.

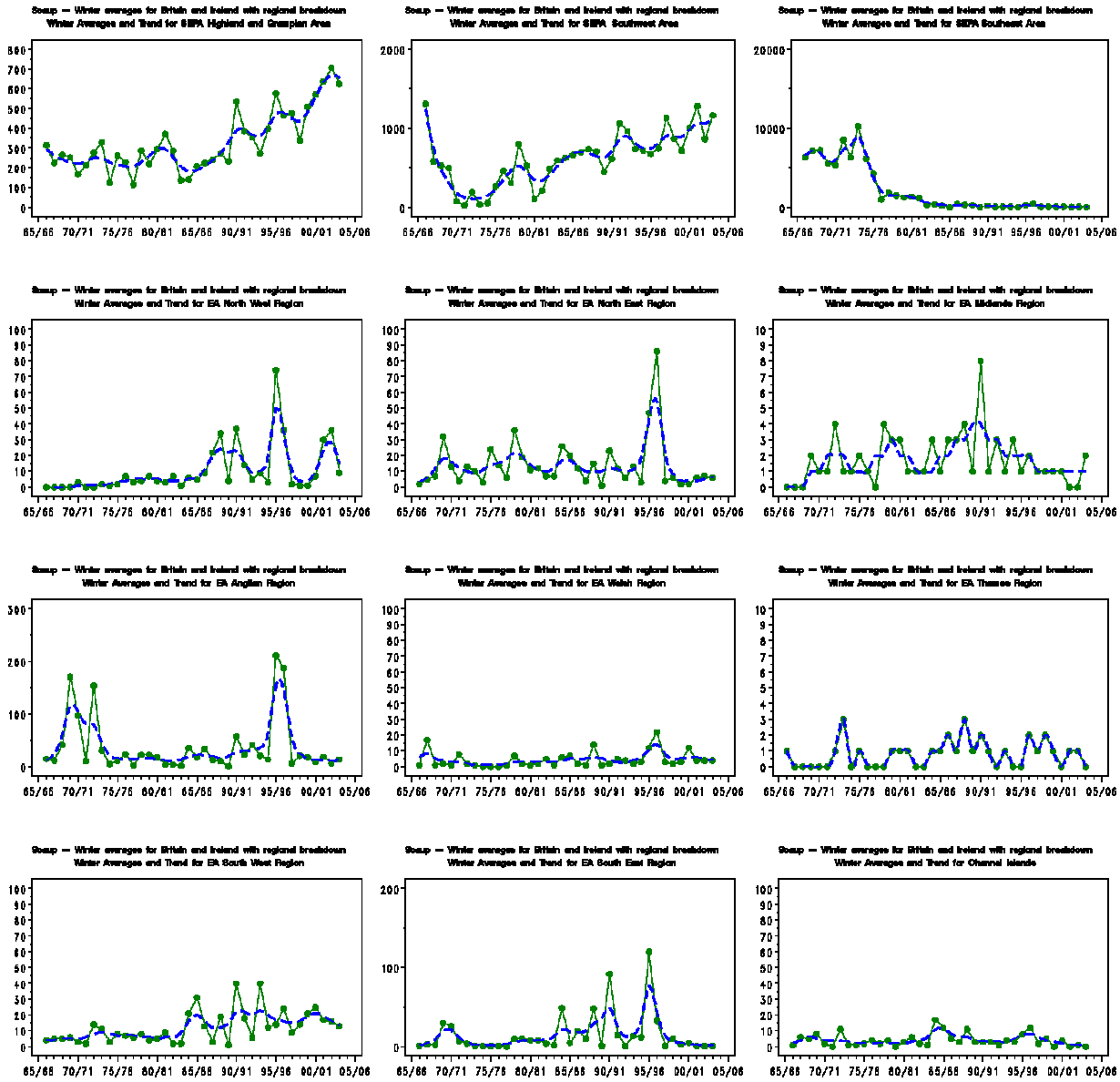

Figure 3.7.4 Smoothed trends and changes in the number of Scaup at Lough Neagh & Beg and in EA and SEPA regions in Great Britain.

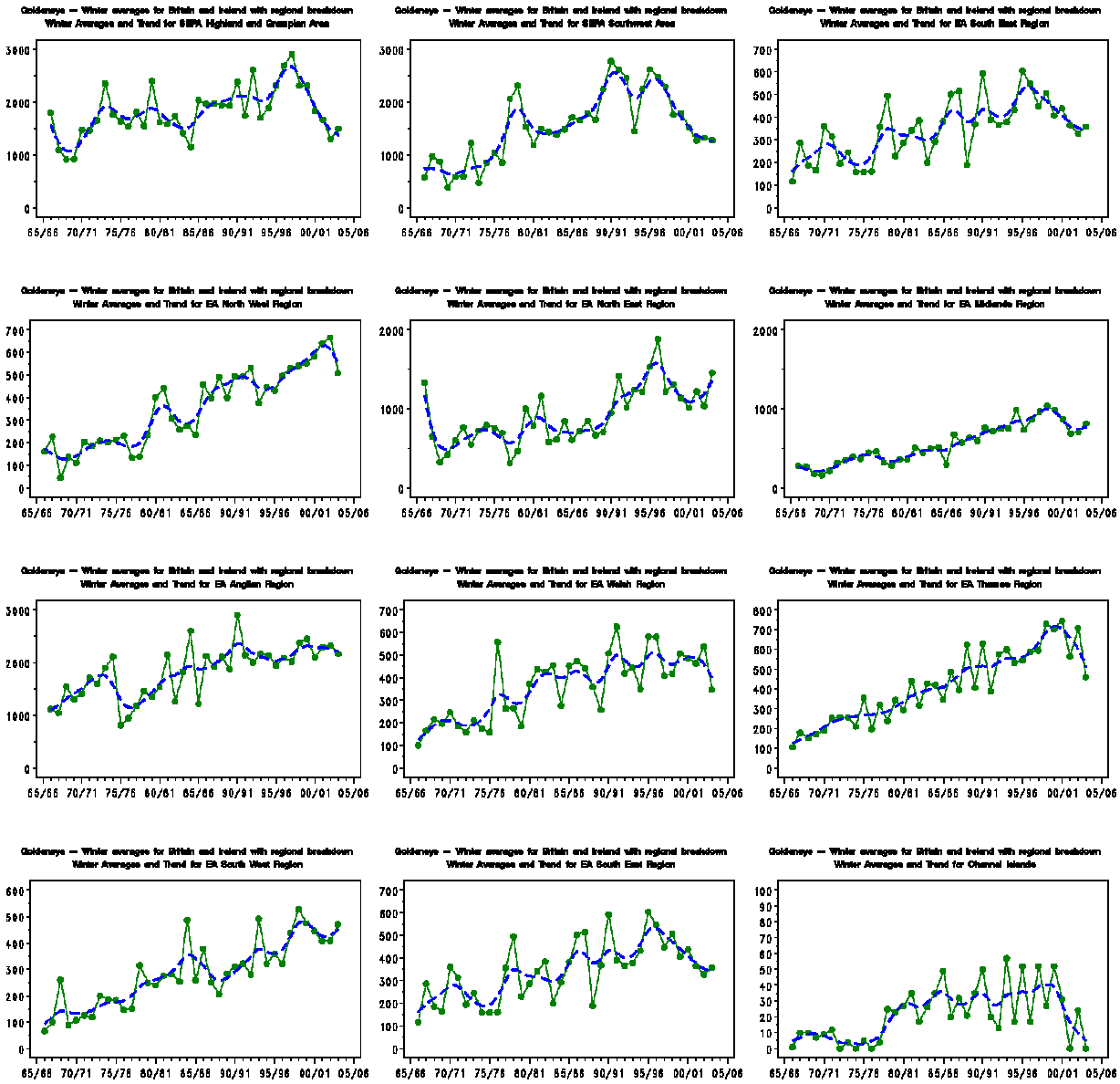

Figure 3.7.5 Smoothed trends and changes in the number of Goldeneye at Lough Neagh & Beg and in EA and SEPA regions in Great Britain.

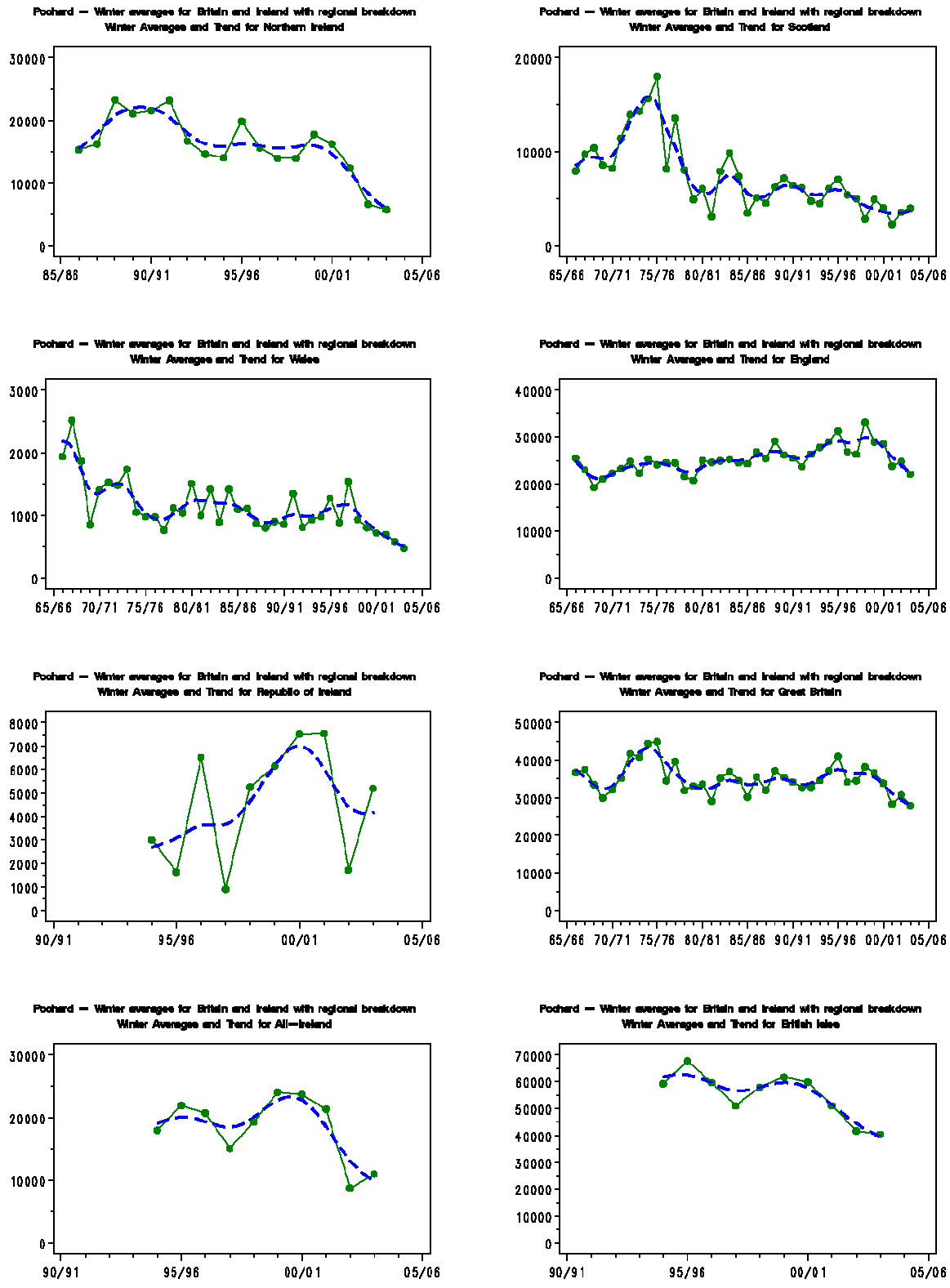

Figure 3.7.6 Smoothed trends and changes in the number of Pochard in Great Britain and Ireland and their constituent countries.

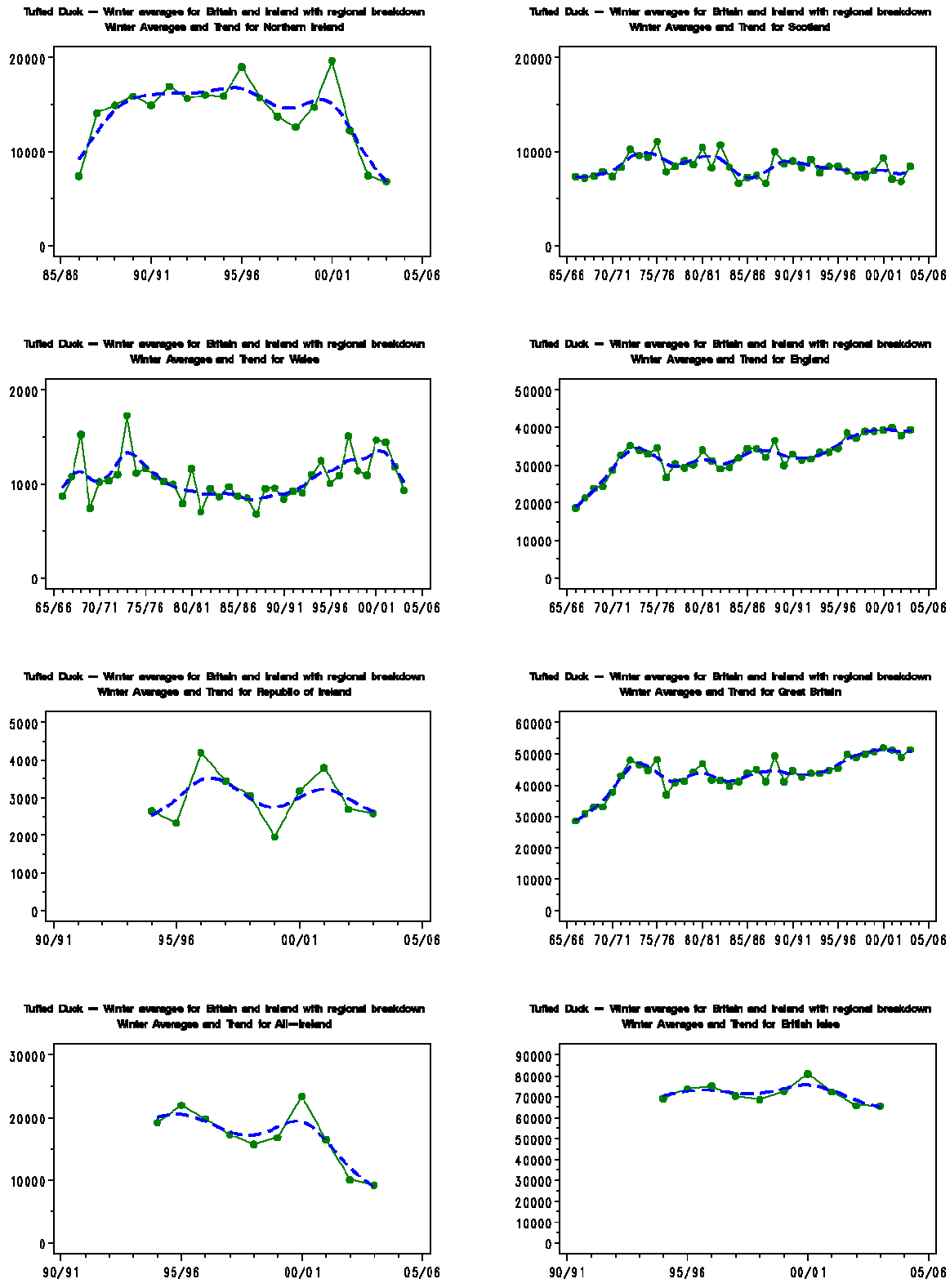

Figure 3.7.7 Smoothed trends and changes in the number of Tufted Duck in Great Britain and Ireland and their constituent countries.

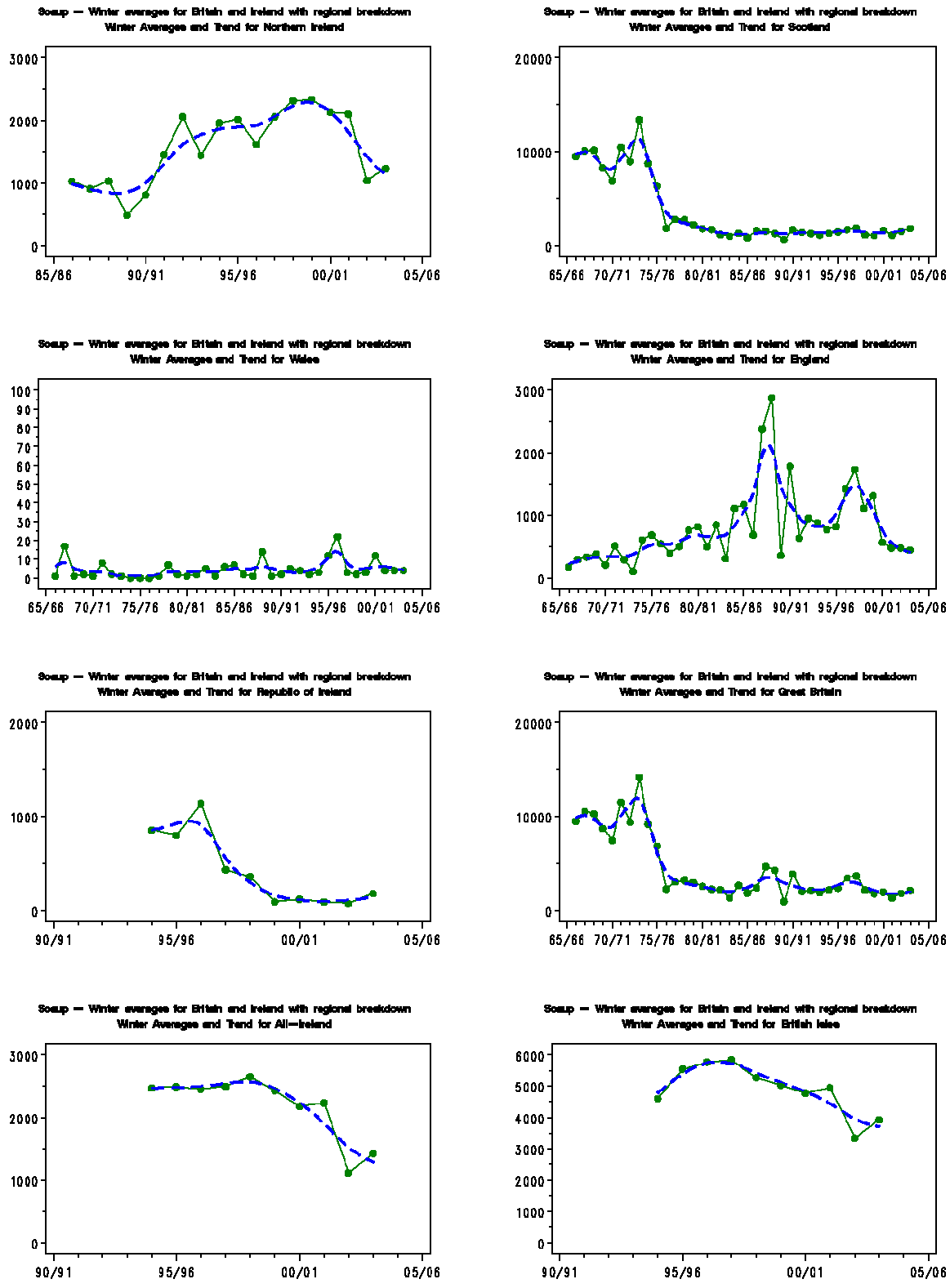

Figure 3.7.8 Smoothed trends and changes in the number of Scaup in Great Britain and Ireland and their constituent countries.

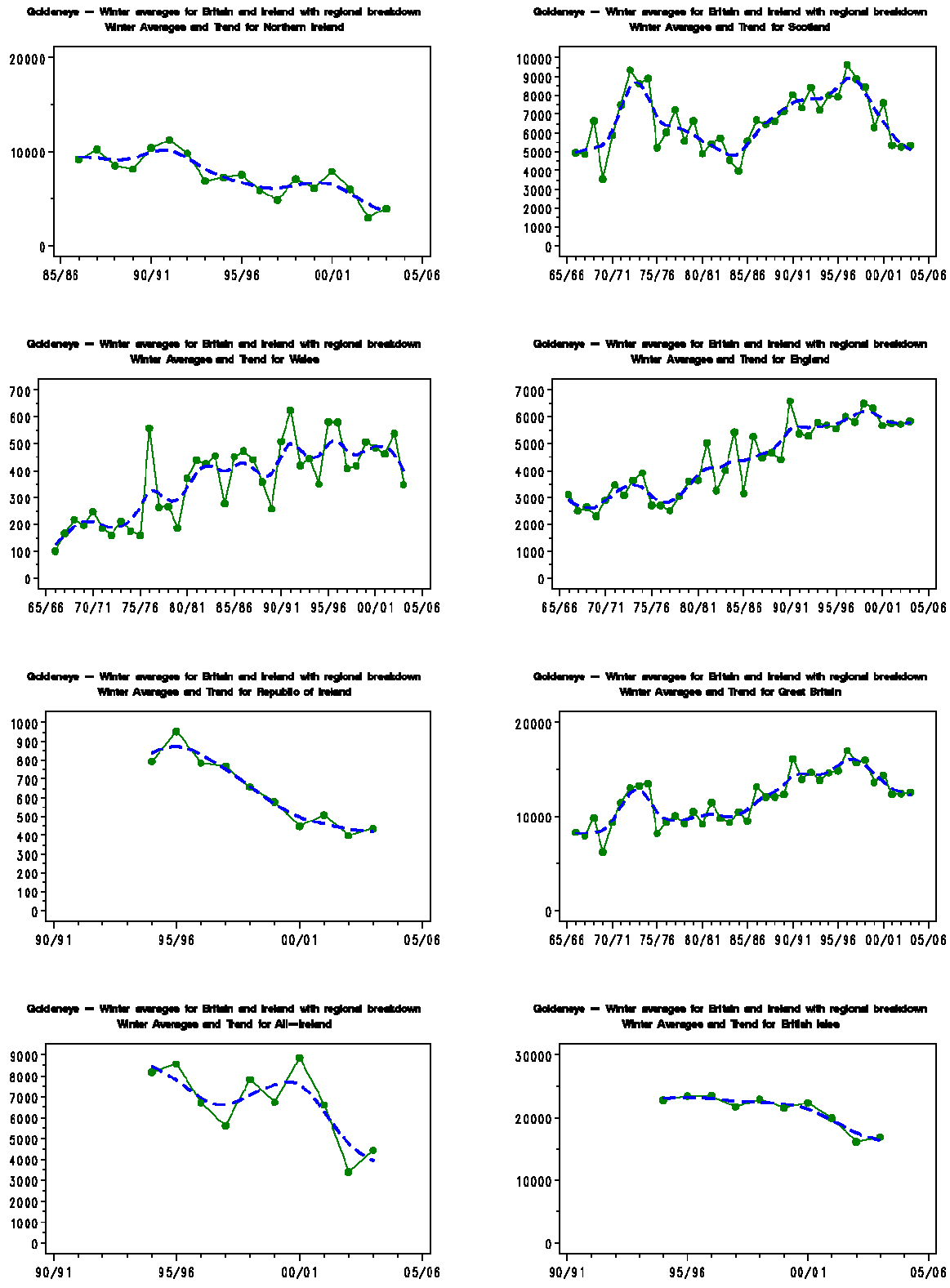

Figure 3.7.9 Smoothed trends and changes in the number of Goldeneye in Great Britain and Ireland and their constituent countries.

3.8 Comparison of Changes at Lough Neagh & Beg to Northern Ireland

Comparisons of changes in numbers of all of the four species at Lough Neagh & Beg to those in Northern Ireland as a whole are shown in Fig. 3.8.1. A very high proportion of the Northern Ireland total is hosted by Lough Neagh, reflecting the importance of this site.

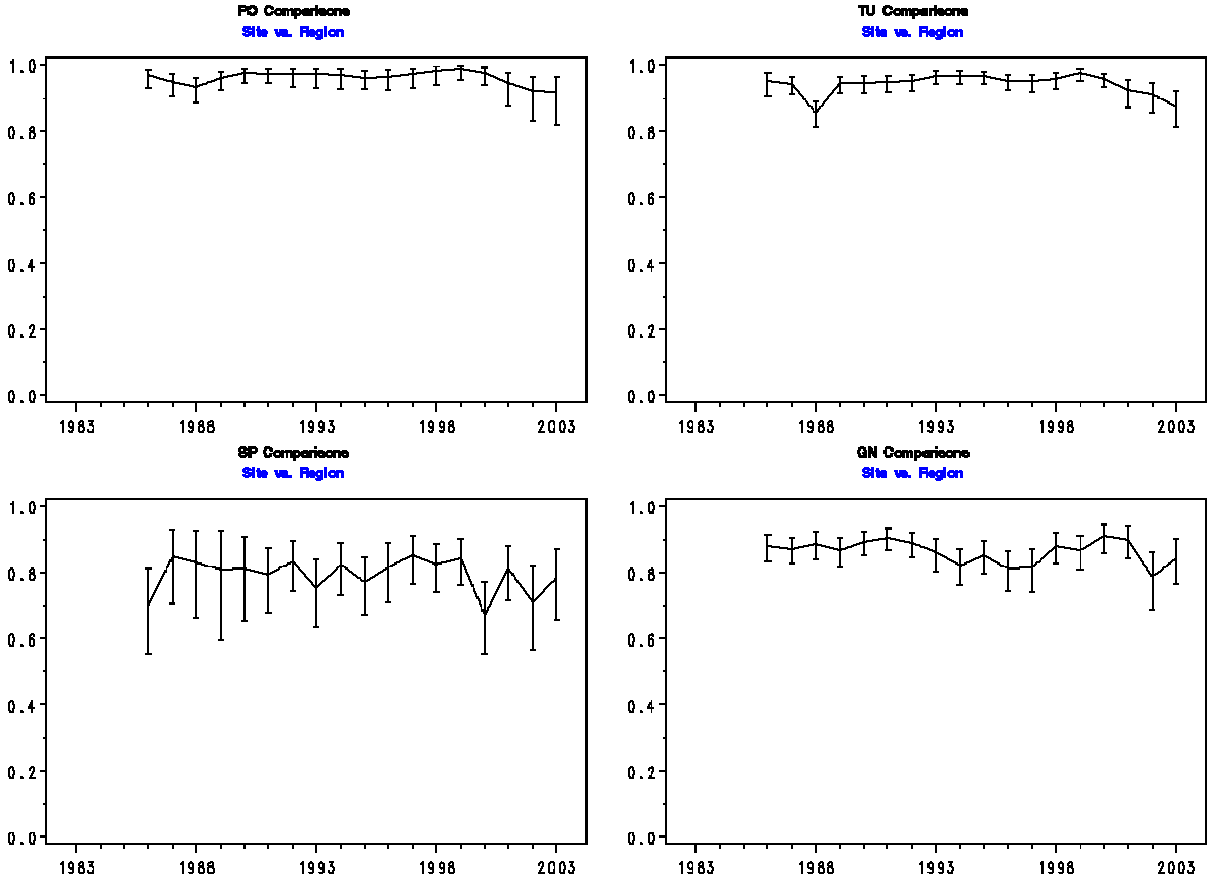

Figure 3.8.1 Comparison of changes in the number of Pochard (top-left: PO), Tufted Duck (top-right: TU), Scaup (bottom-left: SP) and Goldeneye (bottom-right: GN) to changes in numbers in Northern Ireland as a whole.

3.9 Trends in Numbers Elsewhere in Europe

Changes in the number of Pochard and Tufted Duck in five regions of Europe (Northwest Europe, the Baltic-Nordic region, Central Europe, East Mediterranean and West Mediterranean) are shown in Figs. 3.9.1 and 3.9.2. Changes in the number of Goldeneye in three regions of Europe (Northwest Europe, the Baltic-Nordic region and Central Europe) are shown in Fig. 3.9.3. Data to produce trends for Scaup and Goldeneye in Eastern and Western Mediterranean are not yet available. However, the changes in numbers in The Netherlands (from van Roomen *et al.* 2005) and along the Baltic coast of Germany (Wahl & Garthe, in lit.) are shown in Fig. 3.9.4.

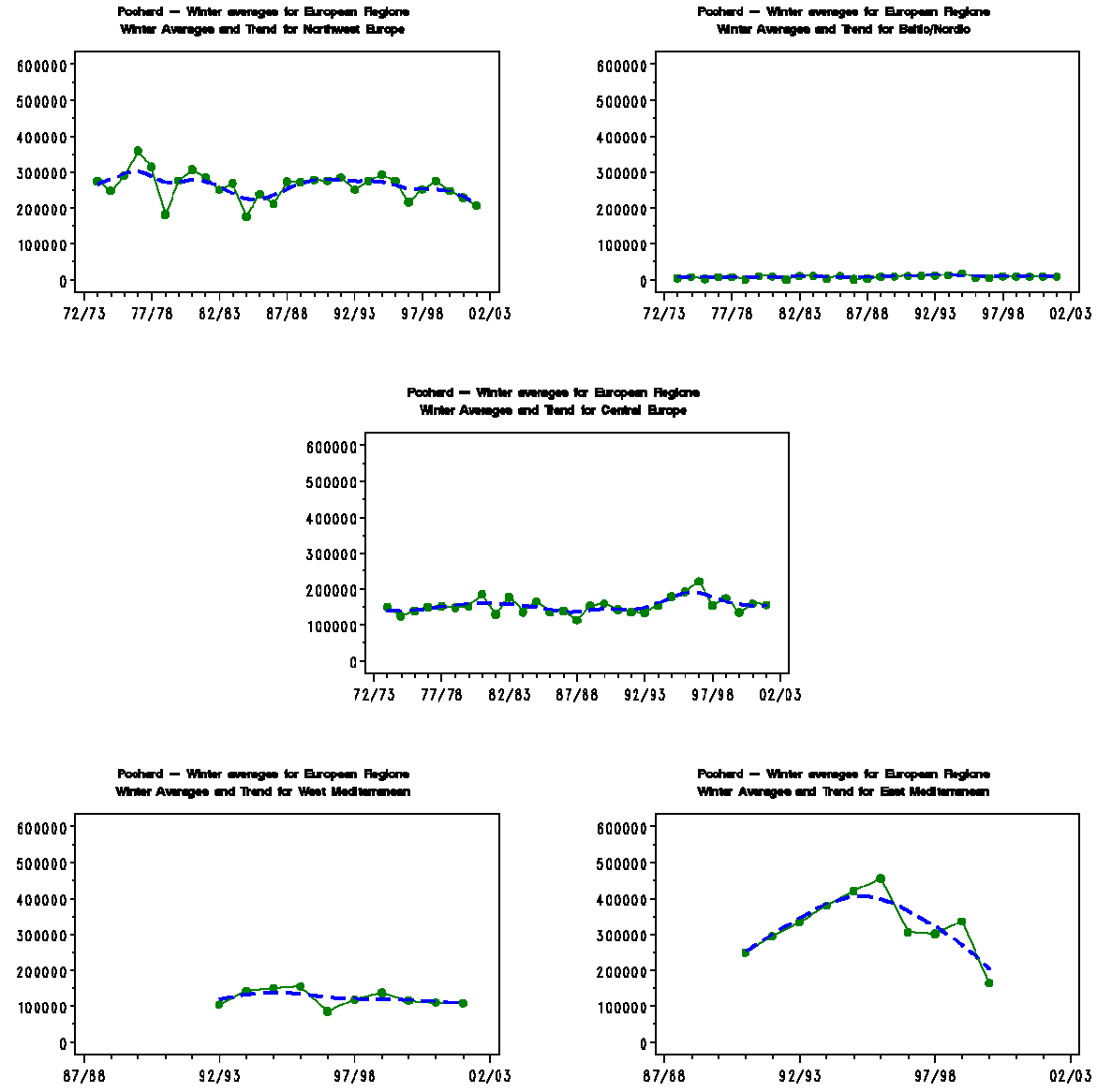

Figure 3.9.1 Changes in numbers and smoothed trends for Pochard in various regions in Europe.

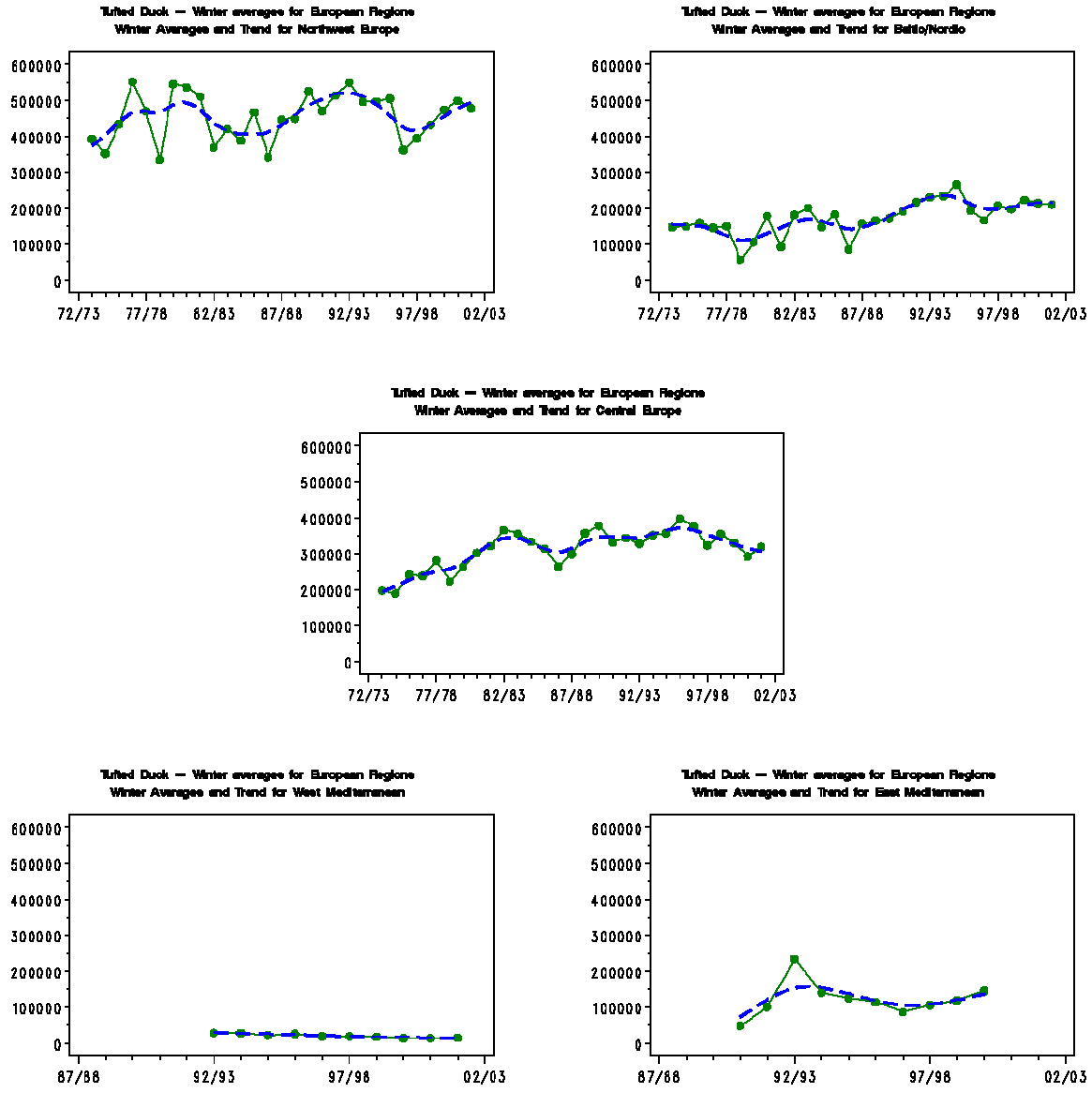

Figure 3.9.2 Changes in numbers and smoothed trends for Tufted Duck in various regions in Europe.

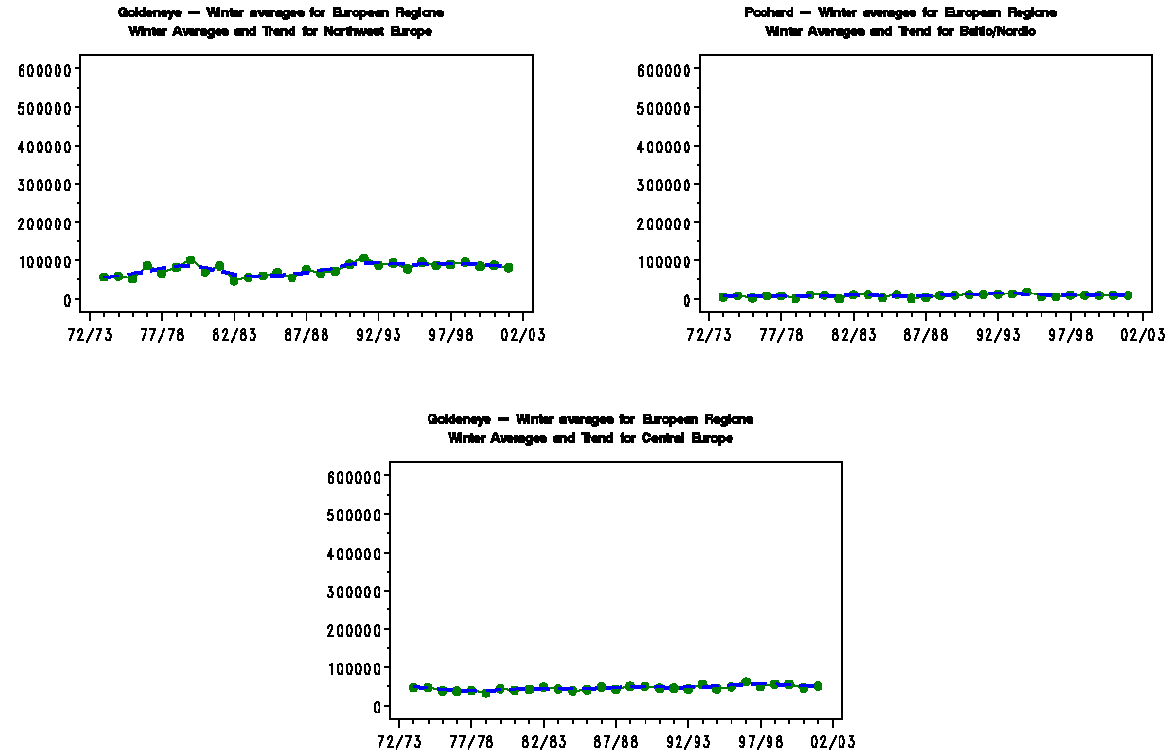

Figure 3.9.3 Changes in numbers and smoothed trends for Goldeneye in various regions in Europe.

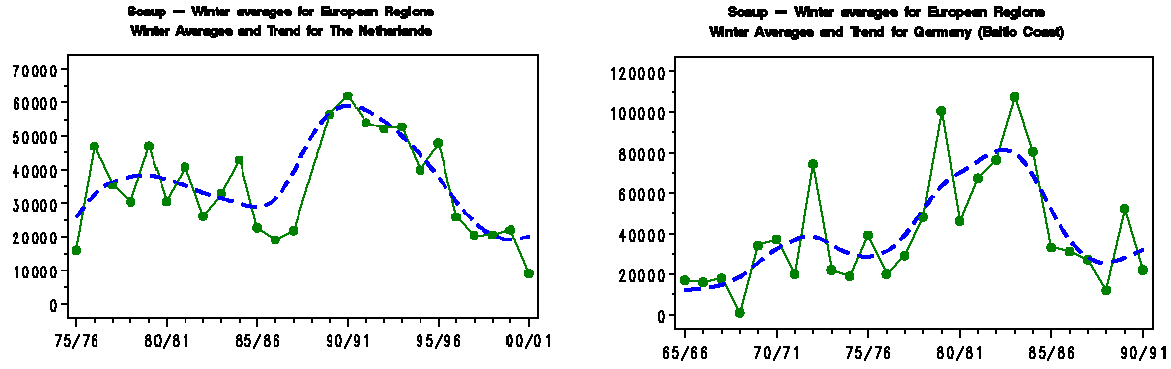

Figure 3.9.4 Changes in numbers and smoothed trends for Scaup in The Netherlands (from van Roomen *et al.* 2005) and the Baltic Coast of Germany (Wahl & Garthe, in lit).

4. DISCUSSION

4.1 Pochard

Prior to WeBS coverage, when the method of counting was somewhat less standardised than it is currently, Pochard underwent considerable short-term variation in numbers making it difficult to discern long-term changes, although numbers appear to have declined in the late 1960s. WeBS counts reveal a slight increase in numbers in the late 1980s from 15,000 to 22,000, but a marked recent decline to 5,000 in 2003/04.

The majority (and highest densities) of birds occur in sheltered bays, notably in the northwest, southwest and southeast corners of Lough Neagh. The biggest decline appears to have occurred in Washing Bay, situated in the southwest corner of the Lough, where numbers decreased from c. 9,000 in the winter of 1990/91 to fewer than 3,000 in 1993/94. Declines in the northeast and southeast parts of the Lough occurred later, suggesting a degree of re-distribution. The fact that numbers did not increase substantially on any other sectors of the Lough during the period in which declines occurred in Washing Bay, suggest that cause of the decline on Lough Neagh may have initially taken place in Washing Bay and then spread to other parts of the site. More recently Washing Bay has hosted an increasing proportion of the site total despite, relative stability in numbers overall. However it is worth noting that numbers in Washing Bay underwent an equally rapid increase in the late 1980s: from 2,100 to 9,000. As numbers on the site as a whole increased slightly during this period, but not nearly to the same degree as in this particular sector, it would seem that this bay temporarily hosted an uncharacteristically high proportion of the site total and redistributions between different parts of the site occur fairly regularly.

The diving ducks on Lough Neagh tend to concentrate their feeding activity from dusk to dawn (Evans 2000; Allen *et al.* 2004a, 2004b) using the sheltered bays to roost and loaf, particularly in areas of low disturbance. The rapid decline and preceding increase in numbers in Washing Bay, cannot therefore be attributable to changes in food availability, and it is arguably more likely that changes in disturbance regimes are responsible. Although human disturbance has a greater impact on dabbling ducks than diving ducks, diving ducks are sometimes accidentally caught in gill nets and are also quarry species for wildfowlers (Evans 2000; Allen *et al.* 2004a, 2004b)

Lough Neagh is the most important site for Pochard in Great Britain and Ireland (Collier *et al.* 2005; Crowe 2005). Indeed during most of the period of WeBS coverage, the counts for this one site were higher than the combined WeBS totals in any EA or SEPA region of Great Britain, exceeded totals for Scotland, Wales and the Republic of Ireland and were comparable to total numbers in England. The decline at Lough Neagh is an order of magnitude greater than any recent changes in numbers occurring on any other site in Great Britain and Ireland, although a decline of similar magnitude occurred in the Forth Estuary / Duddingston Loch in the late 1970s, where numbers crashed from c. 9,000 to fewer than 500 in space of five years due to improvements in water quality at sewage outflows (Salmon 1981; Campbell 1984).

There is little evidence to suggest that declines at Lough Neagh are balanced wholly by increases elsewhere in Great Britain and Ireland. The trend for most regions reveals stable numbers or general decreases rather than increases, with sustained declines occurring in Wales and Scotland and recent declines in England and the Republic of Ireland. However, there appears to have been fairly large increases at Lough Corrib (from about 8,000 to 13,000), suggesting at least some of the Pochard associated with Lough Neagh could have relocated. Relocation to the Ouse and Nene Washes, as suggested by Allen *et al.* (2004a, 2004b), is less likely however. Uncharacteristically large increases at these sites in the late 1990s (when water levels were high) have been largely negated by recent declines, with recent counts similar to those throughout much of the 1980s and early 1990s (Collier *et al.* 2005; Maclean *et al.* 2005).

The extent to which the birds have relocated to elsewhere in Europe is uncertain. The Netherlands has experienced relative stability in numbers since the early 1990s (van Roomen *et al.* 2005) and numbers in northwest Europe as a whole, where c. 250,000 currently over-winter, have declined slightly. Numbers in the Baltic/Nordic region are generally increasing, with c. 10,000 over-wintering currently. It is unlikely that this trend is due to a relocation from Lough Neagh as it is more probable that this is due to a general northeasterly redistribution of birds from The Netherlands and Germany in response to the significant increase in winter temperatures in Europe since the mid-1980s. Such changes have been observed in a number of other waterbird species (Maclean *et al.* in review). Moreover, the magnitude of the increase is insufficient to balance changes occurring at Lough Neagh.

The majority of birds over-wintering in other regions of Europe belong to a different breeding population, originating from Central and NE Europe rather than Russia and Northern Europe (Delany and Scott 2002). Whilst it is feasible that birds from Russia could use other sites in Europe in preference to a more western migration (Allen *et al.* 2004a, 2004b) and ringing recoveries suggest regular movements between the British Isles and continental Europe as far east as the Black Sea (Wernham *et al.* 2002), the trends elsewhere in Europe provide little direct evidence of such relocation, but in many instances observer coverage is too poor to assess this with certainty. Numbers at Lough Neagh are around 10% of those in counted in Central Europe and West Mediterranean and both those regions have hosted a relatively stable number of Pochard. The East Mediterranean hosts the most Pochard, where numbers increased from 220,000 to 450,000 between 1990/91 and 1995/96, prompting the suggestion by Allen *et al.* (2004a, 2004b) that diving ducks from Lough Neagh were relocated to this region. Since the mid-1990s, the upward trend has reversed and a substantial decline has occurred, with numbers now less than 150,000. It is unclear to what extent this change is driven by a genuine decline in numbers, particularly at key sites, or whether it is due to local movements and changes in counter coverage. Most of the important sites in this region report very large between year changes in numbers (Delany *et al.* 1999; Delany and Scott 2002) suggesting either local population movements are occurring or that there are varying degrees of observer coverage and effort at these key sites. However, given the distance, there is little reason to believe that Pochard from Lough Neagh are relocating to the East Mediterranean / Black Sea region.

4.2 Tufted Duck

Historic counts (prior to WeBS reporting) suggest that Tufted Duck showed dramatic declines on the site during the early 1980s following a period of stability through the 1960s and probably the 1970s. WeBS data reveals that Tufted Duck underwent a marked increase in the late 1980s, from 8,000 to 15,000, suggesting that the decline in the early 1980s was temporary. Since the early 1990s, but particularly in the late 1990s / early 2000s, there has been a marked decrease, from a peak of 16,000 birds to around 5,500 in 2003/04.

The distribution of Tufted Duck at Lough Neagh is similar to that of Pochard, with the highest densities occurring in sheltered bays. All four corners of Lough Neagh host high densities, but numbers are greatest in Washing Bay. Sector level data does not suggest that any one part of the site has been particularly affected. In most of the areas where large numbers occurred, trends are characterised by peaks and troughs with little evidence of any one sector being affected disproportionately. However, in areas hosting medium numbers of birds (e.g. the northeast and east parts of the Lough Antrim), clear declines are evident. This would perhaps suggest that the entire site has become unfavourable, but that core roosting / loafing areas are still used. However, the only strong evidence of a redistribution within the site is of a shift from the northwest to the southeast of the Lough, as a number of sectors in the northwest have undergone a decreases in the proportion of the site total hosted, concurrent with increases in the southeast. As with Pochard, it is difficult to attribute sector level changes in counts to sector-level changes in favourable feeding conditions as the majority of feeding occurs at night and in different areas used for diurnal roosting / loafing. However, the sector level changes in Tufted Duck numbers would suggest that the factors affecting the large increase and subsequent decrease in the number of Pochard in Washing Bay are peculiar to this latter species.

Lough Neagh remains the most important site for Tufted Duck in Great Britain and Ireland (Collier *et al.* 2005, Crowe 2005), with numbers for most of the duration of WeBS counting comparable to the combined WeBS totals for the whole of England and of Scotland and exceeding count totals in Wales, the Republic of Ireland and the rest of Northern Ireland. There is some evidence that Tufted Duck have at least partially re-distributed themselves to England as numbers have increased in central parts of England in the last 15 years. Rutland Water in particular has seen large increases: from c. 2,000 in the early 1990s to c. 7,000 in recent years (Collier *et al.* 2005). The evidence that such increases represent an influx of birds from Lough Neagh remains circumstantial however. Elsewhere in Great Britain numbers have not increased. There is evidence of a slight decline in Scotland and a sharp downturn in numbers in Wales in the last-two years, currently difficult to distinguish from periodic fluctuations.

There is some evidence that birds from Lough Neagh could be re-distributing towards continental Europe. Although in The Netherlands, the most important country for Tufted Duck in northwest Europe and the most likely country that birds would move to, numbers have remained relatively stable during the period of decline at Lough Neagh, numbers in northwest Europe as a whole have increased slightly and increases in Baltic-Nordic region of Europe have been greater still. About three-quarters of a million Tufted Ducks over-winter in the northwest and Baltic-Nordic regions of Europe, so in relative terms, the number over-wintering on Lough Neagh is small and could easily be absorbed with barely discernable changes to surrounding areas. For example, in The Netherlands, Germany and Denmark alone, 16 sites regularly host more than 10,000 Tufted Duck (Delany *et al.* 1999), a greater number than Lough Neagh now hosts.

Elsewhere in Europe, over-wintering birds belong to a different breeding population, as birds originate from East and Central Europe, the Black Sea and the Mediterranean rather than North and Northwest Europe. As with Pochard however, it is feasible that birds breeding in northern Europe could now opt for more easterly and/or continental over-wintering grounds as winter temperatures have become milder. The West Mediterranean hosts relatively few Tufted Ducks, but numbers have declined: from c. 30,000 in the early 1990s to c. 15,000 in the early 2000s. Both Central Europe and the East Mediterranean region host large numbers. In central Europe numbers have decreased since the early 1990s, from around 400,000 to a little more than 300,000 in more recent winters. In the East Mediterranean numbers peaked at around 250,000 in the early 1990s, but later declined to less than 100,000 by the late 1990s and then increased again, with numbers estimated to be around 125,000. Again the revealed trend could be due to genuine changes in numbers, particularly at key sites, but may also be due to local movements and changes in counter coverage. As with Pochard, most of the important sites in this region appear to exhibit very large between year changes in numbers (Delany *et al.* 1999; Gilissen *et al.* 2002) suggesting either local population movements or varying degrees of observer coverage. Given the low observer coverage in the region and the apparent large changes in numbers in relatively short periods of time, it is difficult to propose with any confidence that birds from Lough Neagh could be redistributing to this region. Any such changes would not be discernable from total numbers within the region.

4.3 Scaup

Historically (prior to the period of WeBS reporting), the number of Scaup on Lough Neagh showed no consistent trend, although numbers were quite variable with occasional large peaks occurring in some years. WeBS data reveal that Scaup underwent a marked increase in numbers between the mid-1980s and late 1990s, from 700 to 1,800. Since 1998 there has been a very sharp decrease from 1,800 to around 800 birds in 2003/04, but numbers have since recovered and the most recent counts are the highest ever recorded (Maclean *et al.* in press; Enlander in lit.). Unlike the preceding species, the greatest numbers and highest densities of Scaup occur in the northwest and western parts of the Lough and the majority of the decline is a result of a downturn in numbers from this part of the Lough. There is also evidence of a re-distribution within the site complex. In the late 1980s and early 1990s there was a shift from the west of the Lough into Toome Bay in the north. In the late 1990s and early 2000s, there has been a shift away from the west of Lough Neagh to the south east of the Lough. As with the

other species of diving duck it is difficult to attribute sector level changes to changes in feeding conditions as the majority of feeding occurs at night, not necessarily at the same location used during the daytime (Evans 2000; Allen *et al.* 2004a, 2004b).

In the late 1980s, the number of Scaup over-wintering on Lough Neagh and Beg was comparable to the combined WeBS total for the whole of England and of Scotland and exceeded numbers in any EA or SEPA region, Wales, the Republic of Ireland and the rest of Northern Ireland. The decline at Lough Neagh is greater than the change in number at any other site in Great Britain or Ireland, although there appears to have been a decline of only slightly lesser magnitude in the Solway Firth (although this is difficult to assess given incomplete coverage of this site in recent years). However, the decline is dwarfed by that which occurred in Forth Estuary in the 1970s as a result of improvements in wastewater treatment (Campbell 1984). Numbers at this site declined from a peak of over 25,000 in the late 1960s to as few as 14 in the winter of 2003/04. In a single year (between the winters of 1975/76 and 1976/77) numbers declined from 10,280 to 1,530.

There is little evidence that this species has re-distributed itself within Great Britain and Ireland during the period of decline. The general trend in Great Britain and Ireland excluding Lough Neagh is also downward, with significant declines (aside from at the Solway) occurring at other important sites such as the Tralee Bay complex, Castlemaine Harbour and Carlingford Lough. However, numbers in Belfast Lough have increased from c. 100 in the early 1990s to almost 700 in recent years, an increase likely to be due at least in part to an influx from Lough Neagh.

The extent to which Scaup may re-distributed to other sites in Europe during the period of decline is hard to discern as the numbers occurring on Lough Neagh are relatively small compared to other sites in Europe. The most important site in Europe is the IJsselmeer in The Netherlands, which host around 85% of The Netherlands over-wintering population and one third of the European population (Noordhuis *et al.* 1994; van Roomen *et al.* 2005). Numbers in The Netherlands have declined markedly in the 1990s and 2000s, from a peak of around 180,000 in the early 1990s to fewer than 90,000 individuals in recent winters, with mean numbers declining from c. 60,000 to c. 8,000. The majority of this decline is due to a decrease in numbers on the IJsselmeer, although the trend for the site is somewhat more variable as large numbers occasionally traverse the causeway into the Wadden Sea, presumably during periods of cold weather (van Roomen *et al.* 2005). Trends in the number of Scaup in European regions have not been produced by Wetlands International. Along the Schleswig-Holstein coast of Germany, there is also evidence of recent declines, which to a certain extent parallel those occurring in Holland (but with some evidence of a recent increase in numbers). However, as many Scaup also occur in adjacent Denmark and move freely between the two countries, it is difficult to interpret trends. Overall there appears to be large inter-annual variation in numbers, with c. 40,000 recorded in 1997, c. 15,000 in 1998 and c. 60,000 in 1999 (Gilissen *et al.* 2002). The extent to which these variations are due to differing observer coverage of these sites is unclear. As it would appear that numbers have declined however, it is unlikely that birds from Lough Neagh have re-distributed to Europe.

Given the apparent declines elsewhere in Europe that occurred concurrently with declines at Lough Neagh and Beg and given that numbers have now recovered, it seems likely that the decline in Scaup on Lough Neagh was due to a wholesale decline in the global or regional populations which has since recovered, potentially un-related to site factors on wintering grounds. However, given the concentrations of the wintering population on a small number of key sites, it is hard to assess the importance of unfavourable site conditions. For example, Scaup in the IJsselmeer feed almost exclusively on Zebra Mussels (*Dreissena polymorpha*), numbers of which are affected nutrient concentrations, heavy-metal pollution and oxygen-concentrations (de Vaate 1991). The chemical status of the IJsselmeer has altered significantly in recent years, with a general trend towards improved water quality (de Vaate 1991).

Scaup over-wintering in the Caspian and Black Seas originate from breeding populations in Siberia rather than Northern Europe, although western Siberian birds may periodically over-winter in

northwest Europe. Currently, information regarding changes in the over-wintering numbers in the Caspian and Black Sea are insufficient to reveal anything meaningful regarding birds from Lough Neagh potentially opting to over-winter at these eastern locations during some winters.

4.4 Goldeneye

From the 1960s onwards, but prior to WeBS reporting, Goldeneye numbers at Lough Neagh varied little. Since the mid-1980s (and hence the entire period of WeBS coverage), there has been a steady decline from around 9,000 to 3,800 individuals in 2003/04. Goldeneye are more uniformly distributed throughout the site than the other species, but still occur in highest densities in sheltered bays, such as the four corners of the Lough. The mean density maps show little evidence of a sharp decline from any particular area, but particularly between 1989-93 and 1994-98, birds appear to have retreated into core areas. Peak densities reveal a more substantial decline, particularly from the northwest of the Lough. No one sector hosts a high proportion of the site's Goldeneye and in most sectors regularly hosting over 200 birds there is evidence of a consistent decline in numbers since the early 1990s, although at a few of the western sectors the decline occurred later, suggesting a slight shift towards western sectors. Numbers in the south, the area that hosts the most Goldeneye, although exhibiting a general decline, have fluctuated to a greater degree than other sites. Although Goldeneye undertake a lot of their feeding at night, they feed diurnally more than the other diving duck species (Evans 2000). This species thus provides the greatest clue as to how feeding conditions may have altered. The fact that they are widely distributed throughout the lake, with declines from everywhere rather than one particular sector would suggest that whole site is affected. The significance of the westward shift is hard to assess, but would perhaps suggest that it is the easterly portions of the Lough that were affected first.

Despite large declines, the number of Goldeneye over-wintering on Lough Neagh and Beg is comparable to the combined WeBS total for the whole of England and of Scotland and exceeds numbers in Wales, the Republic of Ireland, the rest of Northern Ireland and any EA or SEPA region. The decline at Lough Neagh is considerably greater than changes occurring on any other site in Great Britain or Ireland. However, declines c. 5,500 to c. 1,000 in the late 1970s and declines from 1,700 to less than 1,000 in the late 1990s / early 2000s occurred on the Forth Estuary. The early decline was primarily due to improvements in water quality (Campbell 1984). The causes of the later decline are largely unknown, but could be related to further water quality improvements or part of a wider trend. There is evidence of a widespread decline at numerous sites in Ireland and Scotland, with corresponding increases in England. There is little to suggest that birds from Lough Neagh have redistributed to elsewhere in Great Britain or Ireland however. Numbers have increased on inland water bodies in England, possibly due to the creation of new habitat such as flooded gravel pits. However the magnitude of such increases are not sufficient to counteract the declines at Lough Neagh and may equally be due to a re-distribution from Scotland. Moreover, particularly in EA Midlands and Thames regions there is evidence of marked recent declines.

About 7% of the NW European and Baltic-Nordic population of Goldeneye currently occurs on Lough Neagh. Other important areas in this part of Europe include the Schleswig-Holstein coast and adjacent Denmark and the Rhine delta region of The Netherlands. It is hard to assess whether birds have relocated from Lough Neagh to elsewhere in Europe as some parts of Europe receive low observer coverage. The Netherlands trend has remained stable since the early 1980s (van Roomen *et al.* 2005) and in northwest Europe as a whole, numbers have declined from c. 110,000 to c. 80,000 in recent winters. It is possible that they have relocated to the Baltic/Nordic region. Numbers in the Baltic/ Nordic have increased substantially, from c. 60,000 in the early 1990s to 120,000 in recent winters. However, it is perhaps more likely that the increase in numbers in the Baltic / Nordic region is due to birds relocating there from closer parts of northwest Europe. Numbers in central Europe have fluctuated, but show some evidence of a decrease in the 1990s, suggesting that bird have not relocated to there. Only very small numbers over-winter in the west Mediterranean, except at the Camargue in France. Up to date trends have not been produced by Wetlands International, but the trend between

1990 and 1996, suggests a gradual decline, thus suggesting that birds have not relocated from Lough Neagh to this region

Goldeneye over-wintering at Lough Neagh are likely to originate from Fenno-Scandia (Wernham *et al.* 2002). Those over-wintering in the East Mediterranean / Black Sea area originate from two breeding populations. Some also originate from Scandinavia, so it possible that birds could relocate from Lough Neagh to this region. However numbers are bolstered by birds originating from Siberia (Delany and Scott 2002). Significant numbers over-winter in Yugoslavia (up to 30,000) and Romania (up to 9,000). Even moderately adequate coverage of the sites with key concentrations of these species is sporadic. Consequently, Wetlands International has not produced up to date trends, but numbers between 1995 and 1998 have fluctuated markedly (Gilissen *et al.* 2002; Delany *et al.* 1999). Given the comparatively low coverage, it is difficult to determine the possibility that birds have relocated from Lough Neagh to this region.

5. CONCLUSIONS

With respect to Pochard, Tufted Duck and Goldeneye, the balance of evidence would suggest that the causes of decline at Lough Neagh and Lough Beg are primarily site related, rather than the result of large-scale processes such as climate change, particularly as the declines of these three species have occurred more-or-less concurrently. No declines of the same magnitude are evident at any other site in Great Britain and Ireland and other species of waterfowl with different resource requirements have not been affected in the same way. However, further work, particularly an assessment of how diving ducks respond to changes in their food supply, would need to be undertaken before site-related issues could be pin-pointed as the sole causal factors. One possible means of doing this would be develop models that allow survival to be calculated from behavioural-based models (see, for example, Stillman *et al.* 2000) and then compare how well such models predict observed changes in numbers. These models would need to be calibrated using direct observations of diving ducks, knowledge of the energetics of these species and historic actual or predicted chironomid data (see Kaiser 2005, Kaiser *et al.* 2006 for an example of a similar approach with Common Scoter *Melanitta nigra*).

The reasons for the decline in Scaup numbers between 1999/2000 and 2003/04 are less certain, but this decline appears to have since been largely negated. Similar declines may have occurred on the Solway Firth and have occurred in the IJsselmeer in The Netherlands and along the Schleswig-Holstein coast of Germany, perhaps suggesting that there has been a general downturn in breeding success affecting the European population as a whole or that substantial shifts in the distribution of over-wintering birds have occurred. However it is also possible that these declines are due to site related factors. Although decreases in numbers following uncharacteristically high numbers in the winters of 1995/96 and 1996/97 are evident in a number of regions in England, in no area of Great Britain have numbers decreased for such a sustained period of time. However the decline in the Republic of Ireland parallels that at Lough Neagh, again suggesting large-scale factors. It is noteworthy that the majority of birds in England originate from breeding populations in Russia, whereas the majority in Northern Ireland originate from Iceland (Wernham *et al.* 2002). Perhaps the reasons for the decline and subsequent recovery relate primarily to the Icelandic population.

The most obvious site related cause is that suggested by Allen *et al.* (2004a, 2004b), who proposed that there has been a decline in food availability caused by increased nutrient status. Despite phosphate-stripping at tertiary sewage plants, nutrient levels in the Lough have increased due to agricultural run-off. All four species of duck feed predominantly on chironomid larva at Lough Neagh (Allen *et al.* 2004a, 2004b). Although chironomids generally benefit from eutrophic conditions, hyper-trophic conditions can lead to low-levels of dissolved oxygen in sediments and increased pH. Species of chironomid differ in their sensitivity to high pH and low oxygen concentrations, with more tolerant species tending to be larger and more abundant in deeper water and muddier sediments. Whilst expert opinion (Carter, per Enlander in lit) is that changes in the trophic status of Lough Neagh would need to go beyond those presently recorded to result in a significant decline in chironomid biomass and species composition, other studies suggest that chironomids can be indirectly affected by the trophic status of water-bodies, through alterations to substrate conditions, macrophyte cover and fish populations (Langdon *et al.* 2006).

Three of the diving duck species, Pochard, Tufted Duck and Goldeneye, tend to feed on similar sized larva, whereas Scaup feed on the larger chironomids more tolerant of high nutrient levels. The decline in Scaup was more recent than that of other species, having only occurred since the winter of 1998/99 and predominantly since 2001/02, suggesting that either the factor causing the decline of this species differed from that which caused the decline of the other species or that only recently has the Lough deteriorated to such a degree that the prey of Scaup have been affected.

There is some evidence that the birds have been able to respond to poorer conditions at Lough Neagh by relocating elsewhere. Increases, concurrent with the declines at Lough Neagh, have occurred at a number of sites important for diving duck in Great Britain and Ireland. For example, Pochard appear to have increased at Lake Corrib, Tufted Duck at Rutland Water, Scaup at Belfast Lough and

Goldeneye at a number if sites in central England. By and large, however, the magnitude of the increases at these sites does not counter-balance the decreases at Lough Neagh and could in any case be attributable to other causes. With the exception of Tufted Duck, which has undergone increases in Northwest Europe and particularly the Baltic / Nordic region of Europe, evidence that diving ducks have relocated to elsewhere in Europe is lacking as most regions have experienced stable or declining numbers or host such large numbers that any relocation would be difficult to distinguish from background fluctuations.

Suggestions that the increase in winter temperatures in Europe since the mid-1980s have rendered sites further east more favourable and have thus facilitated relocation (Allen *et al.* 2004a, 2004b) cannot be confirmed at this stage as observer coverage of Eastern European sites remains sporadic. In any case, the proposed benefit to diving ducks in terms of shortened migration journeys would, by and large, not accrue to Tufted Duck and Scaup, as for these two species, a high proportion of birds over-wintering at Lough Neagh and Beg originate from Iceland (Wernham *et al.* 2002; Kershaw and Crowe 2005). Birds could respond to poorer conditions at Lough Neagh in a number of ways. On the one hand, birds, aided by the spate of recent mild winters, could be relocating further east. Alternatively, they could relocate to sites already occupied by diving ducks, where they would suffer from increased competition or cause the displacement of birds previously occupying those sites. Another alternative is that they could remain site faithful, arrive on their breeding grounds in a poorer condition and consequently suffer poorer breeding success. Lastly, they may be unable to contend with the unfavourable conditions and consequently suffer increased mortality rates. In all likelihood, some combination of these responses is occurring and an assessment of their relative importance awaits further work.

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