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An analysis of associated trends in Sparrowhawk abundance and potential prey species in woodland and farmland habitats.

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1. Extensive count data from the BTO's Common Birds Census (CBC) were used to test for correlations between temporal trends in the abundance of Sparrowhawks and the abundance of a range of potential avian prey species during the period 1964 to 1993.

2. Newton & Haas (1984) showed that Sparrowhawks declined least and recovered first in western Britain and declined most and recovered latest in eastern Britain. Temporal trends in the abundance of Sparrowhawks were therefore compared with trends in the abundance of potential avian prey species in each of the 4 regions of Britain defined by Newton & Haas (1984). For Sparrowhawks the proportion of CBC plots considered to contain a breeding pair was used as an annual index of abundance. Temporal trends in the abundance of potential prey species was measured as the mean density of breeding territories from a sample of CBC plots.

3. The significance of time trends in the abundance of both Sparrowhawks and potential prey was assessed using linear regression. Tests of association between these time trends were carried out using simple correlation, and also by correlating residuals from the linear regressions (thus controlling for temporal trends).

4. Regional trends in the Sparrowhawk CBC data were similar to those described by Newton & Haas (1984) with later and more pronounced increases in abundance in eastern Britain. There was no significant trend in the abundance of Sparrowhawks in western Britain.

5. Species such as Wood Pigeon, Great Tit, Blue Tit, Coal Tit, Long-tailed Tit, Wren and Chaffinch have increased in eastern Britain during the period of recovery of the Sparrowhawk population, and are therefore very unlikely to have been limited by Sparrowhawks during the period of study.

6. In eastern Britain, there were significant negative correlations between long-term changes in the abundance of Sparrowhawks and 15 out of 31 potential prey species considered. For 8 species, residuals from the long-term trends in abundance were correlated with residuals from the long-term trends in Sparrowhawk abundance. For five of these eight species (Turtle Dove, Song Thrush, Blackbird, Tree Sparrow and Linnet) there was also evidence of long-term declines in abundance in eastern Britain, suggesting a possible effect of Sparrowhawks on the prey species.

7. Although Turtle Doves, Song Thrushes, Blackbirds and Tree Sparrows declined in western Britain as well as in the east, declines in the west tended to be smaller in magnitude (and in some cases not significant) compared to those in the east. Linnets have declined in eastern Britain but not in the west. For each of these five species it is possible that increased predation by Sparrowhawks has had a limiting effect on the size of the breeding population of the prey species. However, with the possible exception of Linnet, it is likely that factors other than Sparrowhawk predation have had a stronger limiting influence.

2. INTRODUCTION

Fluctuations in the abundance of the Sparrowhawk *Accipiter nisus* in Britain, have been well documented following a serious decline in numbers in the late 1950s (Prestt 1965, Newton 1974, Newton 1979, Sharrock 1976, Marchant 1980, Newton & Haas 1984). The scarcity of the species at this time was largely attributed to the agricultural use of organochlorine pesticides and their subsequent accumulation in the food chain (Ratcliffe 1970, Newton & Bogan 1974, Cooke *et al.* 1982). Following successive restrictions on the use of these compounds in 1962, 1965 and 1975, Sparrowhawk population levels have recovered to pre-1940s status in many regions of Britain (Newton & Hass 1984), to the point where interest has been shown in the possible deleterious effects that the Sparrowhawks may have on prey populations.

In Britain, Sparrowhawks prey almost entirely on birds. Males hunt birds up to the size of thrushes (Turidae), whilst the larger females may hunt prey up to the size of Wood Pigeons *Columba palumbus*. In general, Sparrowhawks have a cosmopolitan diet which is numerically dominated by resident passerine species but with strong local selectivity in its choice of prey. For example, in southern Scotland, 72 prey species were identified in the diet of Sparrowhawks, but of these, six species predominated (Chaffinch *Fringilla coelebs*, Song Thrush *Turdus philomelos*, Blackbird *T. merula*, Starling *Sturnus vulgaris*, Robin *Erithacus rubecula* and Meadow Pipit *Anthus pratensis*, plus Redwing *Turdus iliacus* and Fieldfare *T. pilaris* in the winter (Newton 1986)). Diet differs according to prey availability and therefore around farmland woods the House Sparrow *Passer domesticus*, Mistle Thrush *Turdus viscivorus* and tit species are important additions, whilst on sheepwalk, the Lapwing *Vanellus vanellus* forms a significant proportion of the diet. In Europe as a whole, the House Sparrow, Chaffinch, Song Thrush and Yellowhammer *Emberiza citrinella* occurred most consistently in the diet (Newton 1986). Newton (1986) discusses several species which are taken in greater proportion to their abundance: Robin, Tree Pipit *Anthus trivialis*, Great Tit *Parus major*, House Sparrow, Tree Sparrow *Passer montanus* and Turtle Dove *Streptopelia turtur* being examples. In contrast, Spotted Flycatcher *Muscicapa striata*, Wren *Troglodytes troglodytes*, Chaffinch and Dunnock *Prunella modularis* generally suffer lower rates of predation than might be expected from their abundance. Newton (1986) gives the Bullfinch *Pyrrhula pyrrhula* special mention since it was known to have become more abundant during the period when the Sparrowhawk was much rarer. However, there is no evidence that the Bullfinch is especially susceptible to Sparrowhawk predation.

The catholic diet of the Sparrowhawk might serve to minimise any potential effect on the population of a single prey species, and as far as we know there are no studies which have demonstrated any long-term limiting effect on the size of the breeding population of any prey species. In one study in southern England, Great tits *Parus major* and Blue Tits *P. caeruleus* were subjected to very intensive predation pressure by Sparrowhawks in the near vicinity of the Sparrowhawks nest, so much so that the prey populations were depleted by up to 30% (Geer 1978). However this removal of prey species had no significant impact on the breeding populations of the prey species in the subsequent seasons largely because the majority of victims were juveniles.

If Sparrowhawk predation has had a limiting effect on a prey population then we might expect (i) a negative association between temporal changes in abundance of the predator and the prey and (ii) the timing of the changes to coincide in time (Newton & Haas 1984, Newton & Wyllie 1992). One way of examining whether such relationships exist is to

analyse Common Birds Census (CBC) data. These data have been collected on a long-term systematic basis since 1962, and in this study we used CBC data to test for associations between changes in Sparrowhawk abundance and a range of potential prey species. The selection of these species was not exhaustive but represented declining species, which from previous studies, were deemed to be vulnerable to Sparrowhawk predation and several other species that are considered less susceptible for the sake of comparison.

3. METHODS

Territory densities of all prey species were obtained from the British Trust for Ornithology's Common Bird Census (CBC) database. The period under examination was 1964 to 1993 inclusive except for the House Sparrow which was not thought to have been surveyed accurately before 1976 and therefore the earlier years were excluded (Marchant *et al.* 1990). The CBC is a territory mapping method in which a series of visits is made to a defined plot of land and contacts with birds (registrations) are recorded on a large-scale map. At the end of a summer, territories are estimated from clusters of registrations for each species and provide relative (not absolute) annual estimates of territory densities for each plot. Counters are discouraged from surveying long, thin plots since their predominant edge effect can inflate the estimate of territory density. Plots which are poorly counted, irregularly counted or are less than 40 ha in area (10 ha for woodland plots) are excluded from the analysis. CBC plots are classified as either farmland or woodland, where woodland plots comprise all kinds of semi-natural, broad-leaved and mixed woodland but excludes parkland, scrubby heathland and even-aged plantations of conifers. Farmland plots comprise not more than 10% woodland within the survey area and can be any type of arable, horticultural or grazing land.

Newton & Haas (1984) describe the recovery of Sparrowhawks in relation to four zones or regions in Britain which broadly reflect an east to west cline in the magnitude of the organochlorine effect in the 1950s. In the west (zone 1) Sparrowhawk numbers were reduced by less than 50% of the pre 1940s level before recovering to that level, whilst in the east (zone 4) the Sparrowhawk became virtually extinct in some areas (see Fig. 1 for full definition of zonation). Theoretically, if Sparrowhawk predation acts as an important limiting factor on prey species, then a negative relationship might be expected between the abundance of the predator and the prey, particularly in those regions where the Sparrowhawk's recovery has been greatest. Resident birds might be expected to suffer a higher level of predation than migrant prey species simply because they are exposed to the predator all year round. Here we used the same system of zonation as Newton & Haas (1984) to investigate the recovery of the Sparrowhawk in relation to the population trends of 32 potential prey species (Fig. 1). These prey species were chosen as representatives of woodland, farmland, resident and migrant birds and are: Lapwing, Wood Pigeon, Turtle Dove, Skylark *Alauda arvensis*, Swallow *Hirundo rustica*, Jay *Garralus glandarius*, Great Tit, Blue Tit, Coal Tit *Parus ater*, Long-tailed Tit *Aegithalos caudatus*, Wren, Robin, Blackbird, Song Thrush, Mistle Thrush, Whitethroat *Sylvia communis*, Willow Warbler *Phylloscopus trochilus*, Chiffchaff *P. collibyta*, Goldcrest *Regulus regulus*, Spotted Flycatcher, Dunnock, Meadow Pipit, Tree Pipit, Starling, House Sparrow, Tree Sparrow, Greenfinch *Carduelis chloris*, Goldfinch *C. carduelis*, Linnet *C. cannabina*, Bullfinch, Chaffinch and Yellowhammer.

Population trends shown by the CBC are often presented as an index relative to a value of 100 set for an arbitrarily selected datum year (Marchant *et al.* 1990). Index values are calculated as cumulative percentage changes across years and are therefore subject to autocorrelation (Greenwood 1989). To minimise this problem, population trends for this study were calculated directly from the estimates of mean territory density from annual samples of CBC plots (Gooch, Baillie & Birkhead 1991). Linear regression was then used to assess temporal trends and analysis of covariance was used to compare trends across regions. Average annual rates of change in density were calculated from regression coefficients.

A Sparrowhawk is considered to have attempted to breed on a CBC plot if birds are seen on three or more visits by the observer during the course of a summer. Most CBC plots are recorded as containing either one or no Sparrowhawk territories and plots with two or more territories constitute only 2% of records. Estimates of territory density based on CBC records may therefore be misleading since the Sparrowhawk territories largely conform to presence/absence data. A better way of presenting changes in Sparrowhawk breeding abundance is to calculate changes in the proportion of CBC plots considered to hold breeding Sparrowhawks (Marchant 1980). To increase the sample of CBC plots which contribute to these analyses, farmland and woodland habitats were combined to give overall annual estimates of proportion of plots occupied by Sparrowhawks.

In order to test the hypothesis that changes in the abundance of potential prey species were caused by changes in the abundance of Sparrowhawks we present simple correlations between annual potential prey densities and the proportion of CBC plots containing Sparrowhawks. We also cross-correlate residuals from linear regressions so as to take account of any underlying temporal trends in the data. Data were either $\log_{10}$ or $\arcsin(\sqrt{})$ transformed as appropriate. These analyses are presented for zones 3 and 4 where changes in Sparrowhawk abundance have been most pronounced.

4. RESULTS

4.1 Sparrowhawk population trends

The proportion of CBC plots containing Sparrowhawks increased in three of the four zones within Britain, the greatest increase occurring in zone 3 (Table 1) in both farmland and woodland habitats (Figs 2a & 2b). In central Britain (zones 2 and 3) the proportion of CBC plots containing Sparrowhawks began to increase during the mid- to late-1970s, whilst in eastern Britain (zone 4) the increase was not apparent until the mid-1980s (Fig 2c). In the west (zone 1), the proportion of CBC plots supporting Sparrowhawk territories remained fairly constant on farmland but declined in woodland over the 29 year study period (Figs. 2a & 2b). On farmland, population trends of Sparrowhawks did not differ between the four regions, although trends did differ in woodland and for both habitats combined. In general, the trend towards a greater increase in the proportion of CBC plots supporting Sparrowhawks in the east of the UK than the west, and the timing of the increase in zone 3 and 4 are consistent with previous studies (Newton & Haas 1984, Newton & Wyllie 1992). The following accounts describe associations between the territory density estimates of 32 potential prey species and the presence of Sparrowhawks territories on CBC plots.

4.2 Prey species accounts

4.2.1 **Lapwing** (Fig 2d)

There has been a significant decline in the density of Lapwings in eastern Britain since the 1960s, particularly in zone 4 (Table 2). Trends in abundance are not correlated with Sparrowhawk presence in these regions, and there was no significant association of residual variation (Table 4).

4.2.2 **Wood Pigeon** (Figs 2e & 3a)

There has been an increase in territory density on both farmland and woodland throughout the UK (Table 2 & 3). Trends in abundance are positively correlated with Sparrowhawk abundance in these regions, but there was no association of residual variation (Table 4 & 5).

4.2.3 **Turtle Dove** (Figs 2f & 3b)

There has been a significant decline in territory density mainly in eastern Britain, and particularly during the 1980s in zones 3 and 4. There was a negative correlation between trends in Sparrowhawk abundance and trends in Turtle Dove abundance in zones 3 and 4 on farmland, and in zone 3 in woodland (where the changes in Sparrowhawk abundance was greatest). There was also a significant residual correlation for trends on farmland in zone 4 (Table 4).

4.2.4 **Skylark** (Fig 2g)

There have been significant declines in Skylark density in eastern Britain (zones 3 and 4). The greatest declines began during the mid-1970s and although negatively correlated with the presence of Sparrowhawks in these regions there were no significant correlations between residual changes in abundance (Table 4).

4.2.5 **Swallow** (Fig 2h)

There have been significant increases in breeding densities in the west of Britain (zones 1 and 2). There were no significant correlations with Sparrowhawk abundance in any zone, and residual changes in abundance were not correlated.

4.2.6 **Jay** (Fig 3c)

There has been a decline in territory density in zone 2, and an increase in zone 3 and no change elsewhere (Table 3). There was no significant negative correlation with Sparrowhawk presence in either eastern zones and residual changes in abundance were not correlated.

4.2.7 **Great Tit** (Figs 2i & 3d)

There have been significant increases in the density of breeding Great Tits throughout Britain on farmland, but only in zone 3 in woodland (Table 2 & 3). There were no significant negative correlations with Sparrowhawk abundance in any region, and residual changes in abundance were not correlated (Table 4 & 5).

4.2.8 **Blue Tit** (Figs 2j & 3e)

There have been significant trends in breeding densities throughout Britain on farmland and in 3 out of 4 zones in woodland. There were no significant negative correlations between temporal changes in the abundance of Blue Tits and Sparrowhawks in either eastern zone, and residual changes in abundance were not correlated (Table 4 & 5).

4.2.9 **Coal Tit** (Figs 2e)

There have been significant trends in Coal Tit density in eastern Britain (zones 3 and 4). There was no significant negative correlation between changes in Coal Tit density and changes in Sparrowhawk abundance, and residual changes in abundance were not correlated (Table 5).

4.2.10 **Long-tailed Tit** (Fig 3g)

There has been a significant increase in territory density in the eastern Britain (zone 3 and 4). Although there was no correlation between changes in breeding density and changes in Sparrowhawk abundance in zone 3, approximately 14% of residual variation in changes in Long-tailed Tit breeding density was explained by changes in the abundance of Sparrowhawks (Table 5).

4.2.11 **Wren** (Figs 2k & 3h)

There have been significant increases in Wren breeding densities in the east of Britain, and no significant negative correlation with Sparrowhawk abundance in either eastern zone. Despite there being no negative correlation with changes in Sparrowhawk abundance in zone 3, approximately 37% and 29% of residual variation in Wren breeding density could be explained by residual changes in the abundance of Sparrowhawks on farmland and woodland respectively (Table 4 & 5).

4.2.12 **Robin** (Figs 2l & 3i)

There have been no significant trends in the Robin breeding densities on farmland in any zone within Britain (Table 2). However, there was a significant negative correlation between changes in the abundance of Sparrowhawks on farmland, and about 34% of residual variation in Robin breeding density could be explained by changes in the abundance of Sparrowhawks (Table 4). There were no similar relationships either for farmland in zone 4, or for woodland in zone 3 or 4.

4.2.13 **Blackbird** (Figs 2m & 3j)

There has been a general decline in breeding densities of Blackbirds in all regions on farmland and in zones 1 and 3 in woodland. On both farmland and in woodland changes in Blackbird density were negatively correlated with changes in the abundance of Sparrowhawks in zone 3. Residual changes in Blackbird density were only correlated with residual changes in Sparrowhawk abundance on farmland in zone 3 (Table 4).

4.2.14 **Song Thrush** (Figs 2n & 3k)

With the exception of woodland in western Britain, there has been a general decline in the density of breeding Song Thrushes in all regions and habitats of Britain since the early 1970s. This decline has been particularly severe in eastern Britain and has been strongly and negatively correlated with changes in the abundance of Sparrowhawks in zone 3 and to a lesser extent in zone 4. Residual changes in the abundance of Sparrowhawks was correlated with residual changes in the density of Song Thrushes on both farmland and woodland in zone 3 (but not in zone 4) (Tables 4 & 5).

4.2.15 **Mistle Thrush** (Fig 3l)

There have been small but significant declines in the density of breeding Mistle Thrushes in zones 2 and 4, but there was no negative correlation with temporal changes in Sparrowhawk abundance or with residual changes in abundance (Table 5).

4.2.16 **Whitethroat** (Fig 2o)

There has been a general decline in Whitethroat densities in all regions of Britain since the mid-1960s, followed by an increase during the early 1990s. Although there is a negative correlation between changes in the abundance of Sparrowhawks and Whitethroats in zone 3, Whitethroats increased quite strongly during the early 1990s when Sparrowhawk abundance has been greatest. Residual changes in abundance were not correlated (Table 4).

4.2.17 **Willow Warbler** (Fig 3m)

There has been a significant decline in territory density in zones 1 and 3 only (Table 3) and in zone 3 this is strongly and negatively correlated with the abundance of Sparrowhawk territories (Table 5). However there was no significant association of residual variation between the two species (Table 5).

4.2.18 **Chiffchaff** (Fig 3n)

There has been a small but significant decrease in territory density in zone 2 but an increase in territory density in zone 4. In zone 4 both Chiffchaffs and Sparrowhawks have increase in abundance (Tables 3 & 5).

4.2.19 **Goldcrest** (Fig 3o)

There has been a small significant increase in the east of Britain, but no change elsewhere and no significant negative association with the presence of Sparrowhawk territories (Table 3 & 5).

4.2.20 **Spotted Flycatcher** (Fig 3p)

There has been a significant decline in territory density in zone 1 and 3. Densities were greatest during the 1960s and 1980s. In zone 3 territory density was negatively correlated with the abundance of Sparrowhawks but there was no significant association of residual variation (Table 5).

4.2.21 **Dunnock** (Figs 2p & 3q)

There has been a significant decline in territory density on farmland in the east of Britain since the mid 1970s. Although negatively correlated with the presence of Sparrowhawk territories in zone 3 (Table 2 & 3) there was no significant association of residual variation between the two species (Table 4 & 5).

4.2.22 **Meadow Pipit** (Fig 2q)

There has been a small significant increase the number of Meadow Pipits in the west of Britain but no change elsewhere and no significant relationship with Sparrowhawk numbers in zone 3 or 4 (Table 4).

4.2.23 **Tree Pipit** (Fig 3q)

There have been significant declines in the abundance of Tree pipits in the east of Britain (zones 3 & 4), but they were only negatively correlated with the abundance of Sparrowhawks in zone 3. There was no association of residual variation between the two species (Table 5).

4.2.24 **Starling** (Fig 3s)

There have been steep declines in the abundance of Starlings throughout Britain since the mid 1960s and during the 1980s and 1990s (Table 3). Territory density was negatively correlated

with the presence of Sparrowhawk territories in zone 3 but there was no significant association of residual variation (Table 5). The species is poorly surveyed by CBC methods.

4.2.25 House Sparrow (Fig 2r)

This species also is poorly surveyed by CBC methods since it is a colonial nester, often in urban areas, and may not be socially monogamous. The trend for combined zones and habitats agrees with the national trend which peaks in 1979. But when split by zone the data suggest a possible increase in abundance in zone 3 (and to a lesser extent in zone 4), and as such there was no negative association with the occurrence of Sparrowhawks. Neither was there any association of residual variation between the two species (Table 4).

4.2.26 Tree Sparrow (Figs 3l)

There has been a general decline throughout Britain, particularly in the east (zones 3 & 4) since the mid 1970s (Table 3). Territory density was negatively correlated with the presence of Sparrowhawk territories in zone 3 but not in zone 4. In zone 3 the presence of Sparrowhawks was able to explain approximately 19% of the residual variation in Tree Sparrow territory density (Table 5).

4.2.27 Greenfinch (Figs 2s & 3u)

There was no significant decline in territory density on either farmland or in woodland, except on farmland in zone 3 (Table 2 & 3) since the mid 1970s. On farmland in zone 3 there was a significant negative correlation with the presence of Sparrowhawk territories but no significant association of residual variation between the two species (Table 4).

4.2.28 Goldfinch (Fig 2t)

Small significant declines in territory density have taken place in the east of Britain (zones 3 & 4) since the mid 1970s, but the Goldfinch was only negatively correlated with Sparrowhawk numbers in zone 3. There was no significant association of residual variation between the two species (Table 4).

4.2.29 Linnet (Fig 2u)

A significant decline in territory density in zones 3 and 4 and negatively correlated with the presence of Sparrowhawk territories in these areas (Tables 2 & 4). In zone 3, Sparrowhawks explained approximately 33% of residual variation in Linnet territory density but there was no such association in zone 4 (Table 4 & 5).

4.2.30 Bullfinch (Fig 3v)

There was no significant change in territory density in any zone within Britain, and no correlation with the presence of Sparrowhawk territories (Table 5).

4.2.31 **Chaffinch** (Figs 2v & 3w)

There has been a significant increase in territory density throughout Britain except in woodland in the west (zone 1). No negative association with the presence of Sparrowhawk territories and no association of residual variation between the two species (Table 4 & 5).

4.2.32 **Yellowhammer** (Fig 2w)

There has been a significant decline in territory density in the west (zone 1) but elsewhere numbers have remained stable (Table 2). There was no significant association with the presence of Sparrowhawks and no significant association of residual variation between the two species (Table 4).

4.3 Prey species summary

4.3.1 Associations

In general, there were few consistent effects across habitats or zones suggesting that the relationships between predator and prey were not robust or that the data have low statistical power. At low abundance, estimates of territory density for some species may not be accurately calculated from CBC style analysis, and this may explain the poor representation of Turtle Doves in zone 1. Figure 4 shows the number of CBC plots used to calculate annual estimates of territory density (for prey species) or the percentage of plots supporting Sparrowhawk territories in each zone on farmland and in woodland respectively. CBC plots tend to be concentrated towards the south-east of England which is reflected in the high average number of contributing CBC plots located in zone 3 and hence the likelihood of greater statistical power in tests conducted on data from this region. In woodland, zones 3 and 4 were comparable in terms of sample size. On farmland, there was greater disparity between these two zones but the annual sample size in zone 4 rarely fell below ten. Outside of zone 1, most annual calculations were also based on annual sample sizes of 10 or more plots, although in the early 1960s there were few contributing woodland sites.

Of the 32 prey species studied, 15 were negatively correlated with the abundance of Sparrowhawks in either woodland or on farmland. There were eight species for which a significant proportion of the residual variation was explained by the presence of Sparrowhawk territories (Turtle Dove, Long-tailed Tit, Wren, Robin, Song Thrush, Blackbird, Tree Sparrow and Linnet) three of which showed no decrease in territory density over the period of study (Long-tailed Tit, Wren and Robin). The Turtle Dove, Wren, Robin and Linnet showed the strongest negative residual association with the Sparrowhawk abundance (that is, at $p < 0.01$), but only Linnet showed a decline in territory density over the study period. There were several species that were considered to be vulnerable to Sparrowhawk predation which showed no association of residual variation between predator and prey. These species include Lapwing, Skylark, Tree Pipit, Meadow Pipit and Yellowhammer (Newton 1986). There was also no association between Sparrowhawk and Bullfinch in any habitat or zone.

On farmland, the temporal trend of Turtle Dove, Skylark, Song Thrush and Linnet were negatively correlated in both zones 3 and 4 (Table 4). In woodland, no species were negatively correlated with Sparrowhawk abundance in both eastern zones although

Sparrowhawks increased much later in zone 4 and the temporal trend was weaker than in zone 3 (Fig 2c). On farmland, Turtle Dove was the only species which was negatively correlated with Sparrowhawk abundance in both zones 3 and 4 (Table 4). In addition, Song Thrush, Blackbird and Dunnock have each declined in zone 1 where there has been no coincidental rise in Sparrowhawk numbers. The greatest increases in Sparrowhawks was in woodland yet the strongest association with prey species were from farmland habitats.

4.3.2 Timing of associations

In zone 3, the most rapid phase of increase for the Sparrowhawk was immediately after 1976 (Marchant *et al.* 1990; Fig 2c). Prey populations that were affected by this increase should have begun to decline at the same time or possibly a year or two later. Of the five declining species above which where negatively associated with Sparrowhawk abundance in zone 3, three had begun to decline on or before 1975 (Turtle Dove 1974/75, Song Thrush pre 1974, Blackbird early 1970s) and a fourth, the Tree Sparrow started to decline between 1975 and 1977 (Fig 3l; cf. Marchant *et al.* 1990). The Linnet began to decline around 1976 in zone 3 and possibly later (Fig. 2u), but in zone 4 the Linnet began to decline in the late 1970s, much earlier than the steepest increase in Sparrowhawk numbers in this zone (early 1980s). In zone 4 the Song Thrush declined started in the late 1960s in woodland and in the early 1970s on farmland. Both these events occur earlier than the steepest increase in Sparrowhawk abundance in that zone.

4.3.3 Migrants

In zone 3 there was no increased tendency for resident species be negatively associated with Sparrowhawk numbers than migrant species (45%; n = 24 and 62.5%; n = 8, residents and migrants respectively: $\chi^2 = 0.38$, df = 1, ns (although not all assumptions are met for this test)).

5. DISCUSSION

There was considerable regional variation in the temporal changes that occurred in Sparrowhawk numbers, ranging from no overall change in zone 1, to a greater than 300% increase in the east on farmland (zone 3). In general these changes were consistent with previous studies (Newton and Haas 1984). Newton (1986) discussed several species which tended to predominate in the diet of Sparrowhawks. Five of those species (Turtle Dove, Song Thrush, Blackbird, Robin and Tree Sparrow) were identified here as being negatively correlated with Sparrowhawks after the removal of the time trend from the relationship in either zone 3 or zone 4. There was no such association for several other declining and vulnerable species including: Lapwing, Starling, Skylark or Tree Pipit which are also currently in decline.

These tests of association can only indicated possible relationships between the abundance of Sparrowhawks and the abundance of prey species. However, in almost every species there were inconsistencies, either in the timing of the relationships or in differences between zones or habitats. For example, a strong negative association was found between the abundance of Song Thrushes and Sparrowhawk on farmland in zone 3, with 17% of residual variation explained in the relationship. But the Song Thrush is also in steep decline in other parts of Britain, including the west where Sparrowhawk numbers have not increased and cannot be used as an explanation of the Song Thrushes decline there, although the Song Thrushes decline has been slower in the west than in the east, and it is possible that Sparrowhawks have helped contribute to the decline of Song Thrushes in eastern regions. Similar zonal relationships are true of the Blackbird, Dunnock, Starling and Spotted Flycatcher although for the latter three species there was no association of residual variation in zone 3 or zone 4 either.

The Song Thrush has been in declining in Britain since the early to mid 1970s (Henderson *et al.* 1995), even though the steepest phase of recovery for Sparrowhawks began later than this, around 1975 (Newton and Haas 1984, Newton and Wyllie 1992). Between the Sparrowhawk and Linnet there was some coincidence in the timing of the relationship in zone 3, where Linnets began to decline after 1975. But the same relationship was not true of zone 4. The Tree Sparrow also began to decline around 1976 in zone 3 and in zone 4. In zone 4, however, the Sparrowhawk's recovery was later than this (Newton and Haas 1984; Fig 2c). The Yellowhammer is recognised as a common prey species (Newton 1986) but has declined only in the zone 1 where Sparrowhawks have not increased in abundance and thus no relationship was found between the two species. The Bullfinch has been highlighted as a species having possibly benefitted from the decline of the Sparrowhawk in the 1960s. There was no suggestion of any causal relationship between Sparrowhawk numbers and Bullfinch numbers, although the timing of their most recent decline (since 1976) is coincidental with the Sparrowhawks increase (Marchant *et al.* 1990).

Interestingly, significant proportions of residual variation for three species which did not decline over the study period (Wren, Long-tailed tit and Robin) were explained by the increase in Sparrowhawks and may imply populations which are partly limited by Sparrowhawk numbers even though the prey population itself is not currently in decline. There was no such relationship for the Woodpigeon, however, which despite being a very important component of the diet of female Sparrowhawks and their broods, at least in terms of biomass (Newton 1986) has increased dramatically throughout the UK.

Given the frequency of univariate tests conducted here it may be prudent to consider only those associations which are significant at the $p = 0.01$ level. This reduces the list of potentially effected and declining species to just Turtle Dove and Linnet though neither species showed any consistency in the effect between zones or in the case of the Turtle Dove, between zones or habitats. For the Linnet 33% of residual variation was explained by Sparrowhawks and it is therefore possible that some localised depletion of this species has occurred in the south-east where most CBC plots are located. There is very little evidence, from CBC data, that Sparrowhawks have had a significant limiting effect on any prey population within Britain.

Other possible causes of population declines also need to be considered for the five main species which are possible effected by Sparrowhawk numbers (see Marchant *et al.* 1990). For Turtle Dove other potentially important factors include the effects of prolonged drought and habitat loss in the African winter quarters as well as hunting pressure in Mediterranean Europe. For Song Thrush factors such as changes in land use, the use of molluscicides and the loss of habitat mosaics may have affected British population been important (Henderson *et al.* 1990). In the cases of Linnet and Tree Sparrow, loss of winter feeding habitat and perhaps also loss of breeding habitat may have reduced breeding populations.

Further insights into the potential impact of Sparrowhawk predation on the populations of avian prey species could be acquired by comparing regional trends in the densities of potential prey species on CBC plots with complete annual counts of Sparrowhawk nests which are available for some regions of Britain, particularly eastern England (Dr I Newton, pers comm). These nest count data could also be used to validate trends in the abundance of Sparrowhawks derived from the CBC data. Further analyses of the CBC data might also involve the investigation of changes in the abundance of potential prey species at the level of the CBC plot. This would involve some sort of unbalanced Generalised Linear Modelling approach in which prey species density was the dependent variable, and with year (covariate) and the presence/absence of Sparrowhawks on the plot as independent variables. This sort of approach might have more power to detect any impact of Sparrowhawks on the breeding populations of potential prey species than the regional approach employed here.

ACKNOWLEDGEMENTS

The authors would like to thank Susan Waghorn and Dawn Balmer for assistance with the manuscript and figures. We are also grateful to the Royal Society for the Protection of Birds who funded this analysis and to the hundreds of dedicated CBC counters who have collected the data on which this report is based.

REFERENCES

Cooke, B.K, Bell A.A. & Haas, M.B. (1982) *Predatory birds, pesticides and pollution.* ITE, Cambridge.

Geer, T.A. (1978) Effects of nesting Sparrowhawks on nesting tits. Condor 80: 419-422.

Gooch, S., Baillie, S.R. & Birkhead, T.R. (1991) Magpie *Pica pica* and songbird populations. Retrospective investigation of trends in population density and breeding success. *J. Appl. Ecol.* 28, 1068-1086.

Greenwood, J.J.D. (1989) Bird population densities. *Nature* 338, 627-628.

Marchant, J.H. (1980) Recent trends in Sparrowhawk numbers in Britain. Bird Study 27, 152-154.

Marchant, J.H., Hudson, R., Carter, S.P. & Whittington, P. (1990) *Population trends in British Breeding birds.* British Trust for Ornithology, Tring.

Newton, I. (1974) Changes attributed to pesticides in the nesting success of the Sparrowhawk in Britain. *J. Appl. Ecol.* 11, 95-101.

Newton, I. (1979) *Population Ecology of Raptors.* Berkhamstead.

Newton, I. (1986) *The Sparrowhawk.* Poyser, Staffordshire.

Newton, I. & Bogan, J. (1974) Organochlorine residues, eggshell thinning and hatching success in British Sparrowhawks. *Nature* 249: 582-583.

Newton, I & Haas M.B. (1984) The return of the Sparrowhawk. *Brit. Birds* 77, 47-70.

Newton, I & Wyllie, I. (1992) Recovery of the sparrowhawk population in relation to declining pesticide contamination. *J. Appl. Ecol.* 29, 476-484.

Prestt, I. (1965) An enquiry into the recent breeding status of some of the smaller birds of prey and crows in Britain. *Bird Study* 12, 196-221.

Ratcliffe, D.A. (1970) Changes attributable to pesticides in egg breakage frequency and eggshell thickness in some British Birds *J. Appl. Ecol.*, 17, 76-107.

Sharrock, J.T.R. (1976) *The Atlas of British Breeding Birds in Britain and Ireland.* Berkhamstead.

Table 1. A summary of linear regression trends, describing here the percentage change in the proportion of CBC plots supporting Sparrowhawk territories between 1964 and 1993 on four zones (zone 1 = west, zone 4 = east) on farmland and in woodland.

	Farmland		Woodland		Combined	
Zone	Trend (P)	Percentage increase	Trend (P)	Percentage increase	Trend (P)	Percentage increase
1.	ns		- *	-54.7	ns	
2.	ns		ns		+ **	87.0
3.	+ ***	156.6	+ ***	217.5	+ ***	333.5
4.	ns		+ *	107.7	+ *	127.6

NB. * $P<0.05$, ** $P<0.01$ *** $P< 0.001$, ns = non significant.

Table 2. Changes in territory density of selected farmland birds between 1964 and 1993 in four zones of the UK calculated from linear regressions. For each species the direction and statistical significance of the trend is given where appropriate, as well as the percentage change in territory density over the 29 year period.

	Trend				Percentage change			
	Zone				Zone			
Species	1	2	3	4	1	2	3	4
Lapwing	ns	ns	ns	- ***				-96.4
Wood Pigeon	+ ***	+ ***	+ ***	+ ***				
Turtle Dove	- **	ns	- *	- ***	-83.1		-82.1	-45.7
Skylark	ns	ns	- ***	- **			-48.2	-47.0
Swallow	+ *	+ *	ns	ns				
Great Tit	+ *	+ ***	+ ***	+ **				
Blue Tit	+ **	+ ***	+ **	+ *				
Wren	+ *	+ **	+ *	+ **				
Robin	ns	ns	ns	ns				
Song Thrush	- **	- ***	- ***	- ***	-57.7	-71.2	-89.4	-70.2
Blackbird	- *	- **	- ***	- ***	-28.6	-43.2	-31.7	-29.9
Whitethroat	- **	- *	- **	ns	-77.9	-69.9	-64.9	
Dunnock	- *	ns	- ***	- ***	-27.7		-58.8	-37.3
Meadow Pipit	+ ***	ns	ns	ns				
House Sparrow	ns	ns	+ ***	+ *				
Greenfinch	ns	+ *	- ***	ns			-60.9	
Goldfinch	+ **	+ **	- *	- *			-41.1	-49.4
Linnet	ns	ns	- ***	- *			-24.5	-64.2
Chaffinch	+ **	+ ***	+ ***	+ ***				
Yellowhammer	- ***	ns	ns	ns	-48.9			

NB. * $P<0.05$, ** $P<0.01$ *** $P< 0.001$, ns = non significant.

Table 3. Changes in territory density of selected woodland birds between 1964 and 1993 in four zones of the UK calculated from linear regressions. For each species the direction and statistical significance of the trend is given where appropriate, as well as the percentage change in territory density over the 29 year period.

	Trend				Percentage change			
	Zone				Zone			
Species	1	2	3	4	1	2	3	4
Wood Pigeon	+ ***	+ ***	+ ***	+ ***				
Turtle Dove	ns	ns	- ***	ns			-93.5	
Jay	ns	- ***	+ **	ns		-16.1		
Great tit	ns	ns	+ ***	ns				
Blue Tit	+ **	ns	+ ***	+ **				
Coal Tit	+ *	ns	+ **	+ **				
Long-tailed Tit	ns	ns	+ **	+ ***				
Wren	ns	ns	+ ***	+ ***				
Robin	ns	- **	ns	ns		-24.0		
Blackbird	- *	ns	- **	ns	-12.5		24.0	
Song Thrush	ns	- **	- ***	- ***		-21.7	-59.0	-47.4
Mistle Thrush	ns	- *	ns	- *		-46.8		-28.8
Willow Warbler	- *	ns	- ***	ns	-30.0		-68.0	
Chiffchaff	ns	- *	ns	+ **		-25.7		
Goldcrest	ns	ns	ns	+ *				
Spotted Flycatcher	- **	ns	- ***	ns	-73.4		-90.9	
Dunnock	- *	ns	- ***	- ***	-58.1		-60.6	-40.3
Tree Pipit	ns	ns	- ***	- ***			-93.4	-82.3
Starling	- ***	- ***	- ***	ns	-96.8	-61.3	-95.6	
Tree Sparrow	- **	ns	- ***	- ***	-96.2		-97.0	-86.5
Greenfinch	ns	ns	ns	ns				
Bullfinch	ns	ns	ns	ns				
Chaffinch	- *	+ *	+ ***	+ **	-17.8			

NB. * $P<0.05$, ** $P<0.01$ *** $P< 0.001$, ns = non significant.

Table 4. Pearson correlation coefficients of the relationship between the proportion of CBC plots on which Sparrowhawk territories were assigned and territory density for selected farmland prey species in two zones within the UK between 1964 and 1993 (1976-1993 for House Sparrow). The residual analyses test for a relationship between predator and prey within the variance remaining after removal of the time trend.

	Zone 3		Zone 4	
Species	Time trend included	Residual	Time trend included	Residual
Lapwing	ns	ns	ns	
Wood Pigeon	0.76***	ns	ns	ns
Turtle Dove	- 0.45*	ns	-0.56**	-0.37*
Skylark	-0.71***	ns	-0.44*	ns
Swallow	ns	ns	ns	ns
Great Tit	0.66***	ns	0.47*	ns
Blue Tit	0.44*	ns	ns	ns
Wren	ns	-0.61*	ns	ns
Robin	-0.49**	-0.58**	ns	ns
Song Thrush	-0.88***	-0.41*	-0.44*	ns
Blackbird	-0.88***	-0.39*	ns	ns
Whitethroat	-0.45*	ns	ns	ns
Dunnock	-0.81***	ns	ns	ns
Meadow Pipit	ns	ns	ns	ns
House Sparrow	0.72***	ns	ns	ns
Greenfinch	-0.85***	ns	ns	ns
Goldfinch	-0.56**	ns	ns	ns
Linnet	-0.90***	-0.57**	-0.37*	ns
Chaffinch	0.62***	ns	0.48**	ns
Yellowhammer	ns	ns	ns	ns

NB. * $P<0.05$, ** $P<0.01$ *** $P< 0.001$, ns = non significant.

Table 5. Pearson correlation coefficients of the relationship between the proportion of CBC plots on which Sparrowhawk territories were assigned and territory density for selected woodland prey species in two zones within the UK between 1964 and 1993 (1976-1993 for House Sparrow). The residual analyses test for a relationship between predator and prey within the variance remaining after removal of the time trend.

	Zone 3		Zone 4	
Species	Time trend included	Residual	Time trend included	Residual
Wood Pigeon	0.70***	ns	0.39*	ns
Turtle Dove	-0.77***	ns	ns	ns
Jay	0.47 *	ns	ns	ns
Great Tit	0.62***	ns	0.38*	ns
Blue Tit	0.54 **	ns	0.44*	ns
Coal Tit	0.43 *	ns	ns	ns
Long-tailed Tit	ns	-0.37*	0.46*	ns
Wren	ns	-0.54**	0.49*	ns
Robin	ns	ns	ns	ns
Song Thrush	-0.81***	-0.37*	ns	ns
Blackbird	-0.57 **	ns	ns	ns
Mistle Thrush	ns	ns	ns	ns
Willow warbler	-0.69***	ns	ns	ns
Chiffchaff	ns	ns	0.45*	ns
Goldcrest	ns	ns	ns	ns
Spotted Flycatcher	-0.43 *	ns	ns	ns
Dunnock	-0.77***	ns	ns	ns
Tree Pipit	-0.77***	ns	ns	ns
Starling	-0.67***	ns	ns	ns
Tree Sparrow	-0.75***	-0.44*	ns	ns
Greenfinch	ns	ns	ns	ns
Bullfinch	ns	ns	ns	ns
Chaffinch	0.74***	ns	ns	ns

NB. * $P<0.05$, ** $P<0.01$ *** $P< 0.001$, ns = non significant.

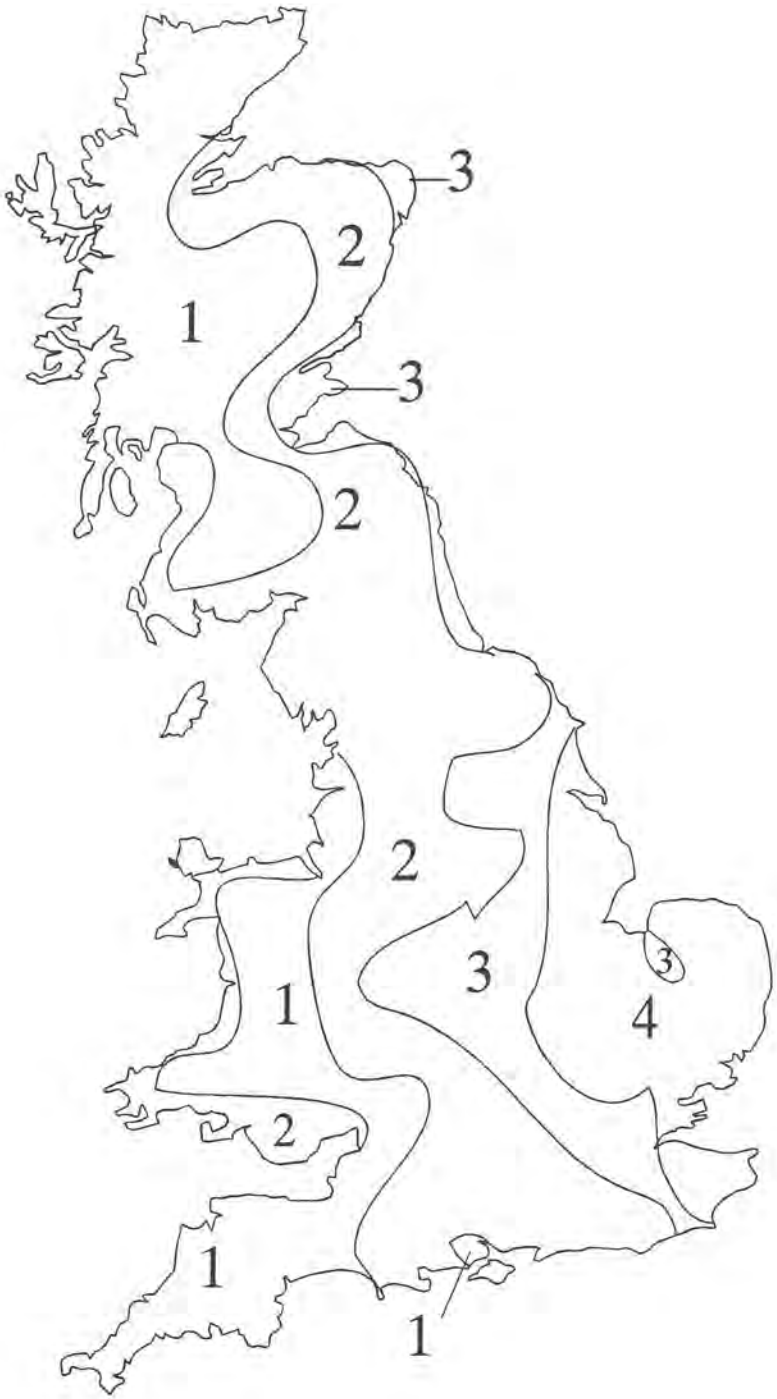

Fig 1. Four zones shown here are adapted from Newton and Haas (1984) and categorize the changes that have occurred in the abundance of Sparrowhawks since 1962. In zone 1, Sparrowhawks declined by <50% of their 1940s level and made a full recovery. In zone 2, the decline was greater than in zone 1 but the recovery was less than 50% by 1970. In zone 3, the decline was more marked than in zone 2 but the recovery was no more than 50% by 1980. In zone 4, the Sparrowhawk population was almost extinct around 1960 and there was little or no recovery by 1980.

Fig 2. Temporal changes in the proportion of farmland CBC plots with Sparrowhawk territories assigned to them (a, b and c) or in the territory density of 20 farmland prey species between 1964 and 1993 (d to w). The slope of the trend is described by a linear equation and the closeness of the CBC data to this slope is given by the r^2 values in each zone. Statistical differences between the slopes of the four zones for each species are given in the legend (analysis of covariance: ANCOVA).

SPARROWHAWK:FARMLAND

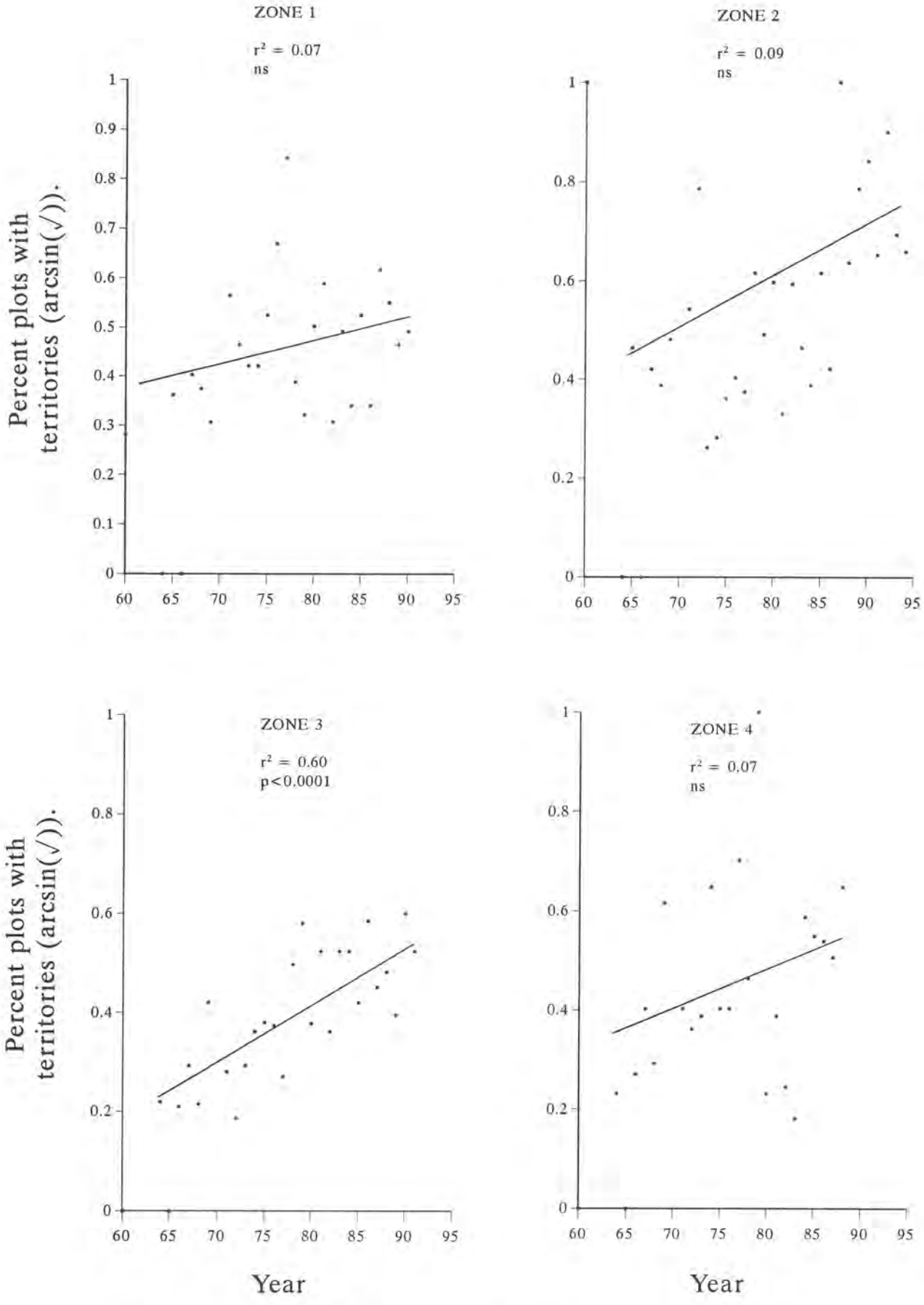

Fig 2.a ANCOVA, $F_{3,29}$=0.58, ns

SPARROWHAWK:WOODLAND

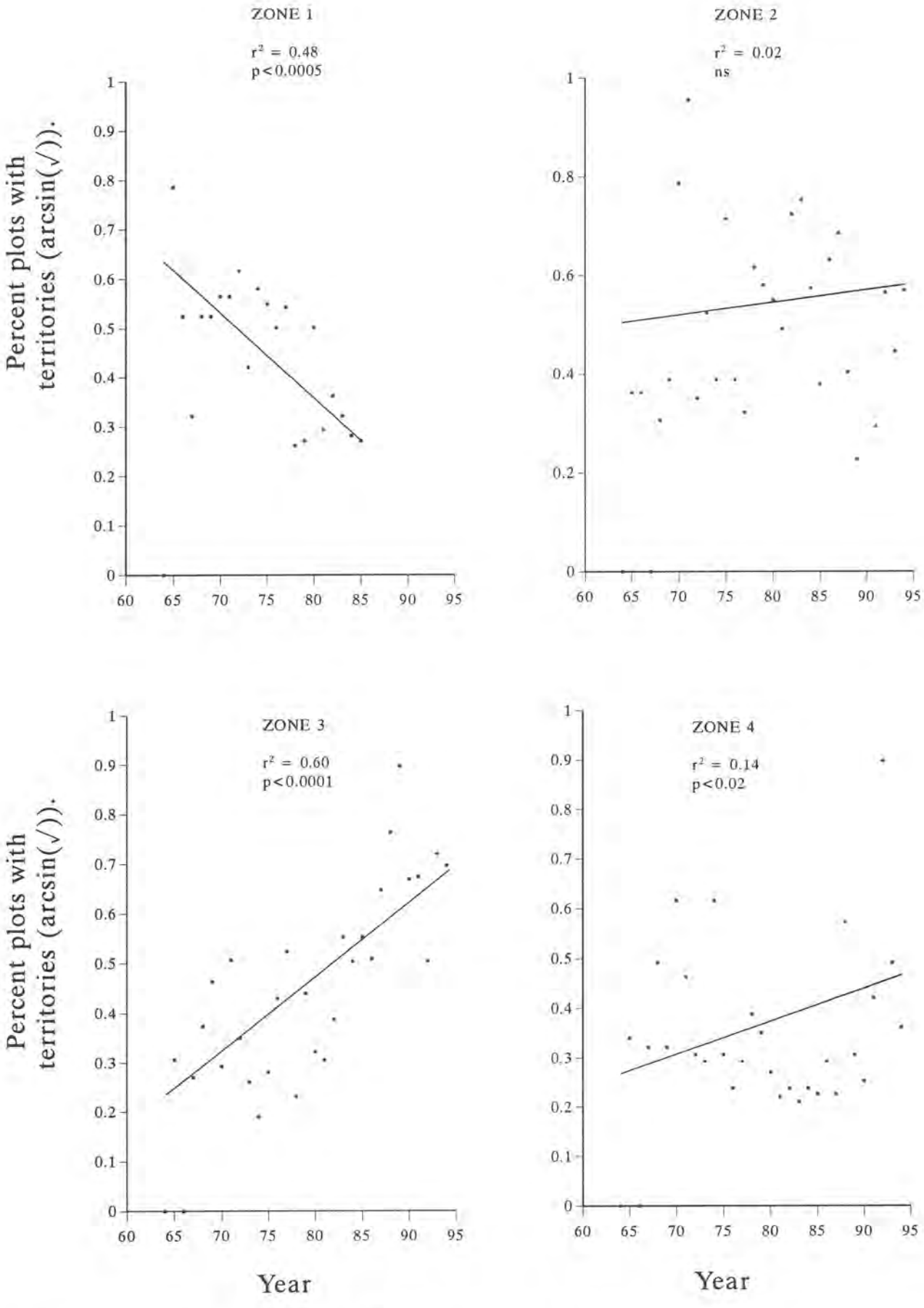

Fig 2.b ANCOVA, $F_{3,29}=30.2$, $P<0.0001$.

LAPWING:FARMLAND

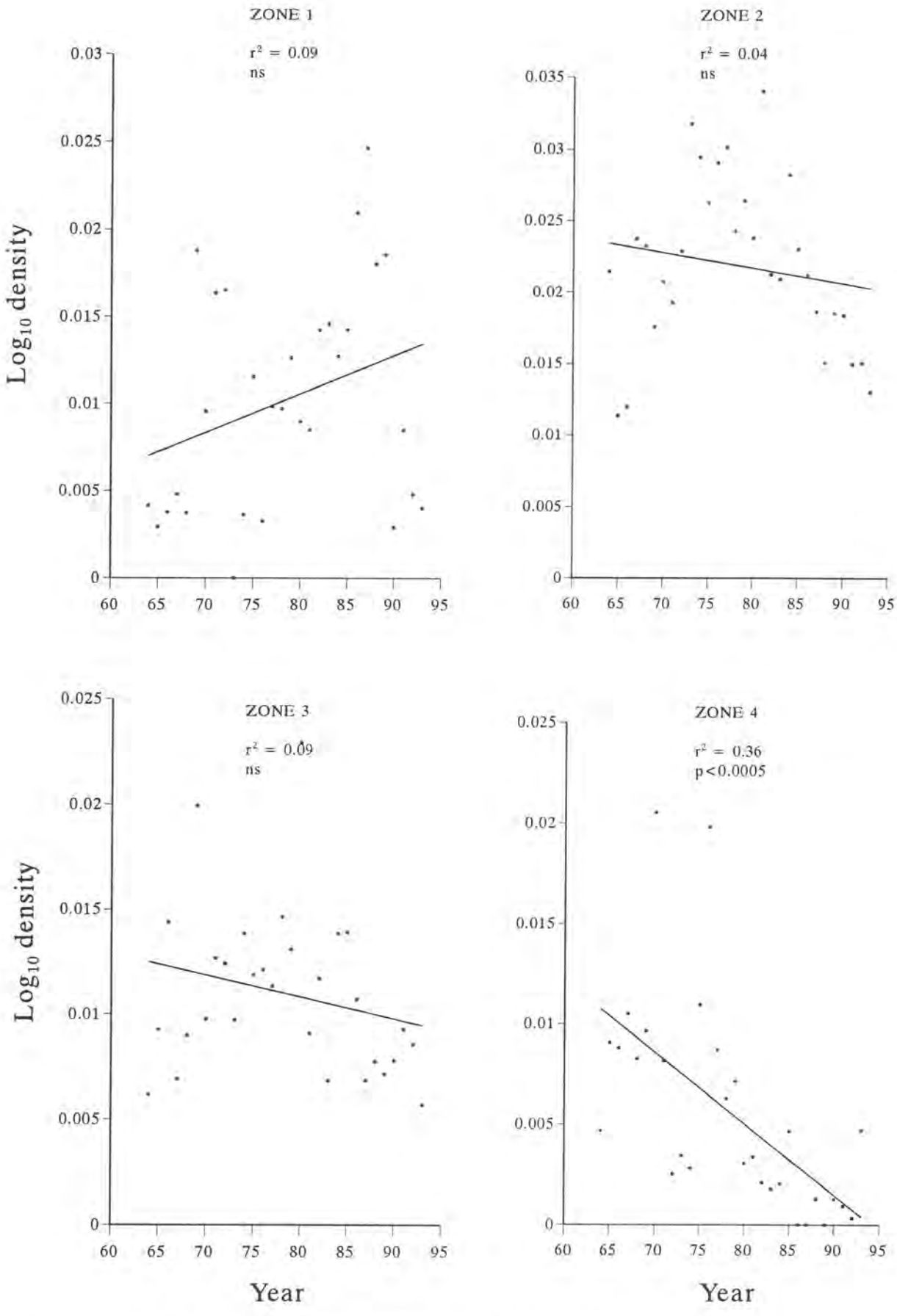

Fig 2.d ANCOVA, $F_{3,29}=4.34$ $P<0.006$.

WOODPIGEON:FARMLAND

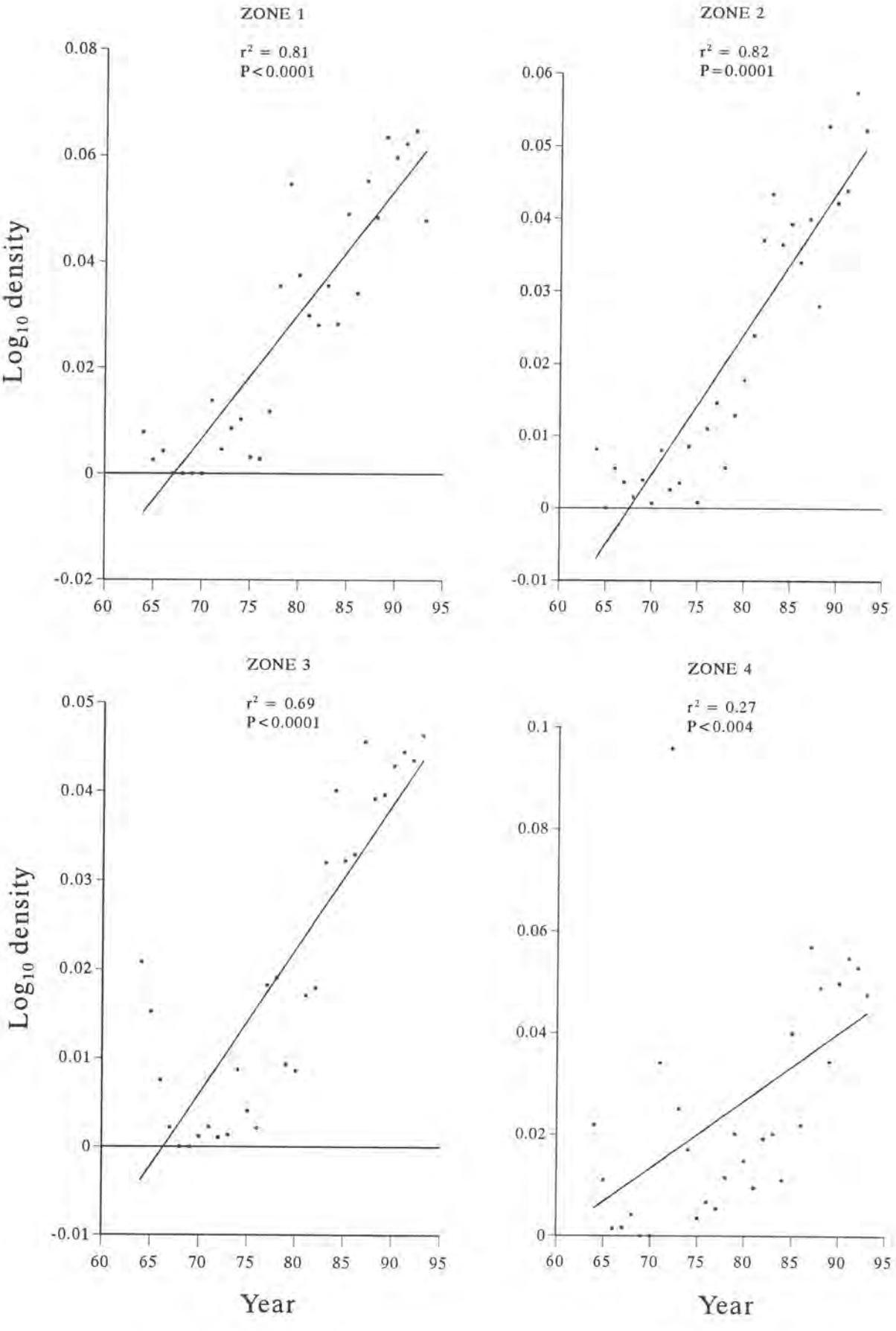

Fig 2.e ANCOVA, $F_{3,29}=2.91$ $P<0.04$.

TURTLE DOVE:FARMLAND

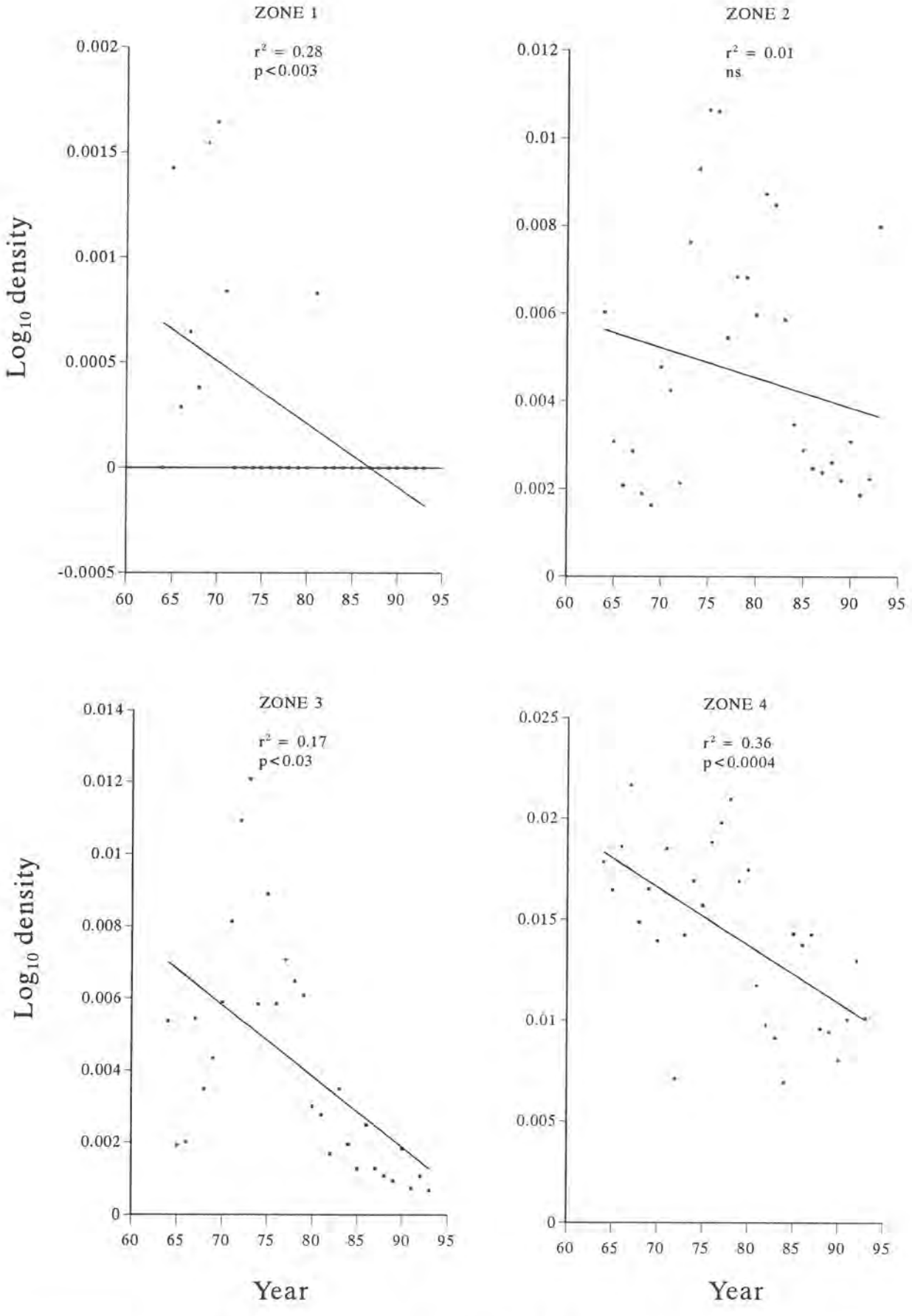

Fig 2.f ANCOVA, $F_{3,29}=6.50$ $P<0.005$.

SKYLARK:FARMLAND

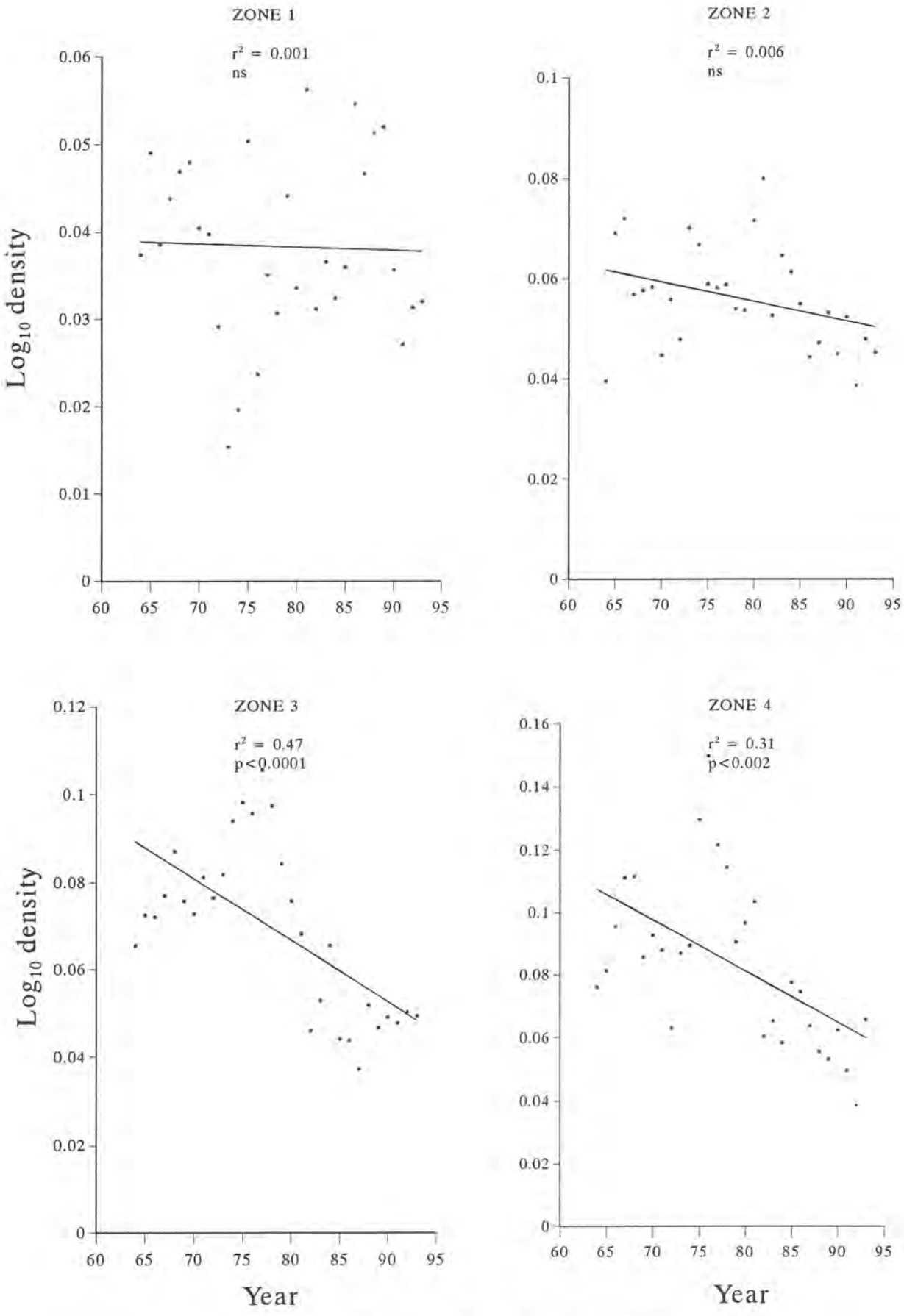

Fig 2.g ANCOVA, $F_{3,29}=7.94$ $P<0.0005$.

SWALLOW:FARMLAND

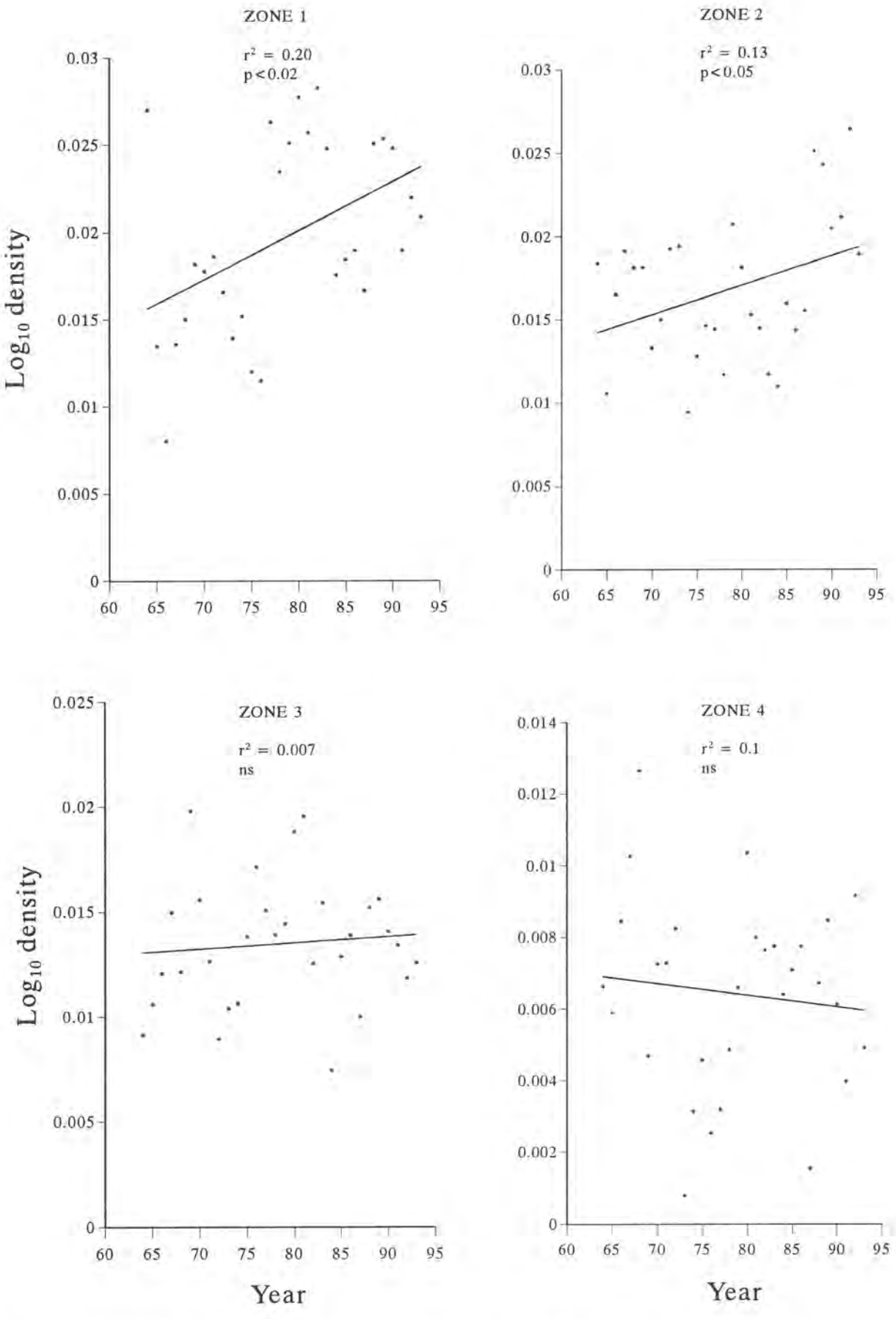

Fig 2.h ANCOVA, $F_{3,29}=3.34$ $P<0.03$.

GREAT TIT:FARMLAND

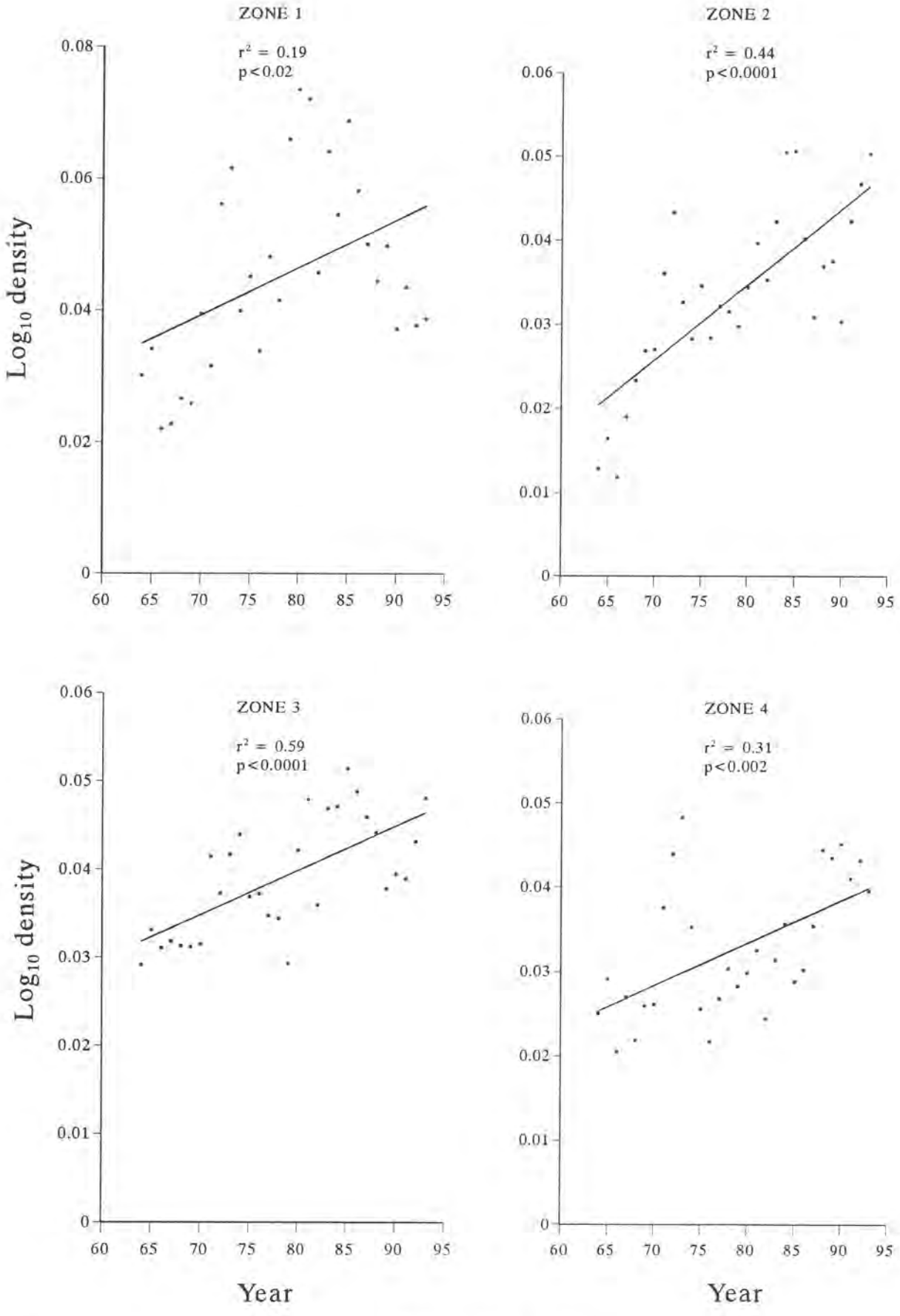

Fig 2.i ANCOVA, $F_{3,29}=0.6$, ns.

BLUE TIT:FARMLAND

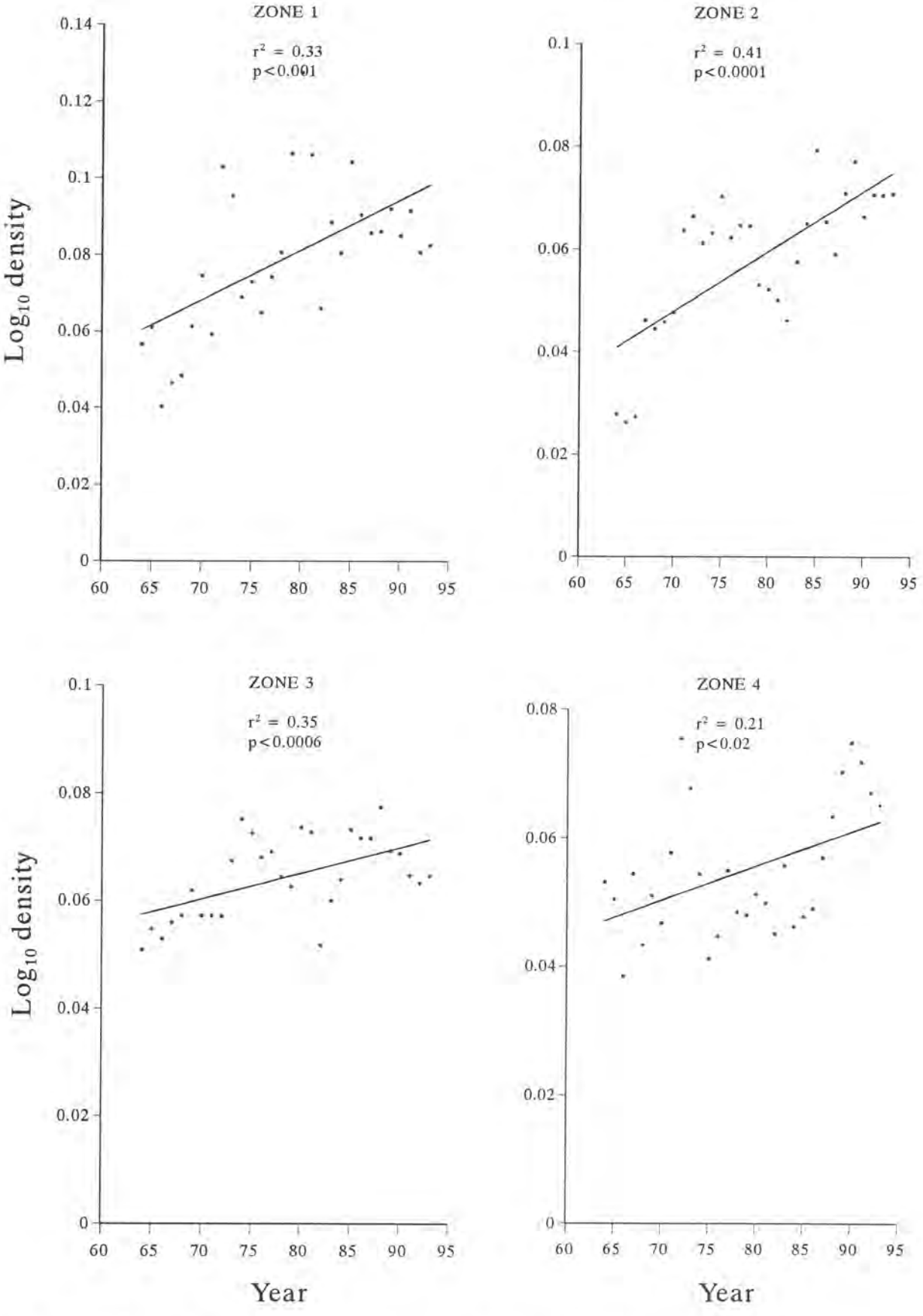

Fig 2.j ANCOVA, $F_{3,29}$=2.41, ns.

WREN:FARMLAND

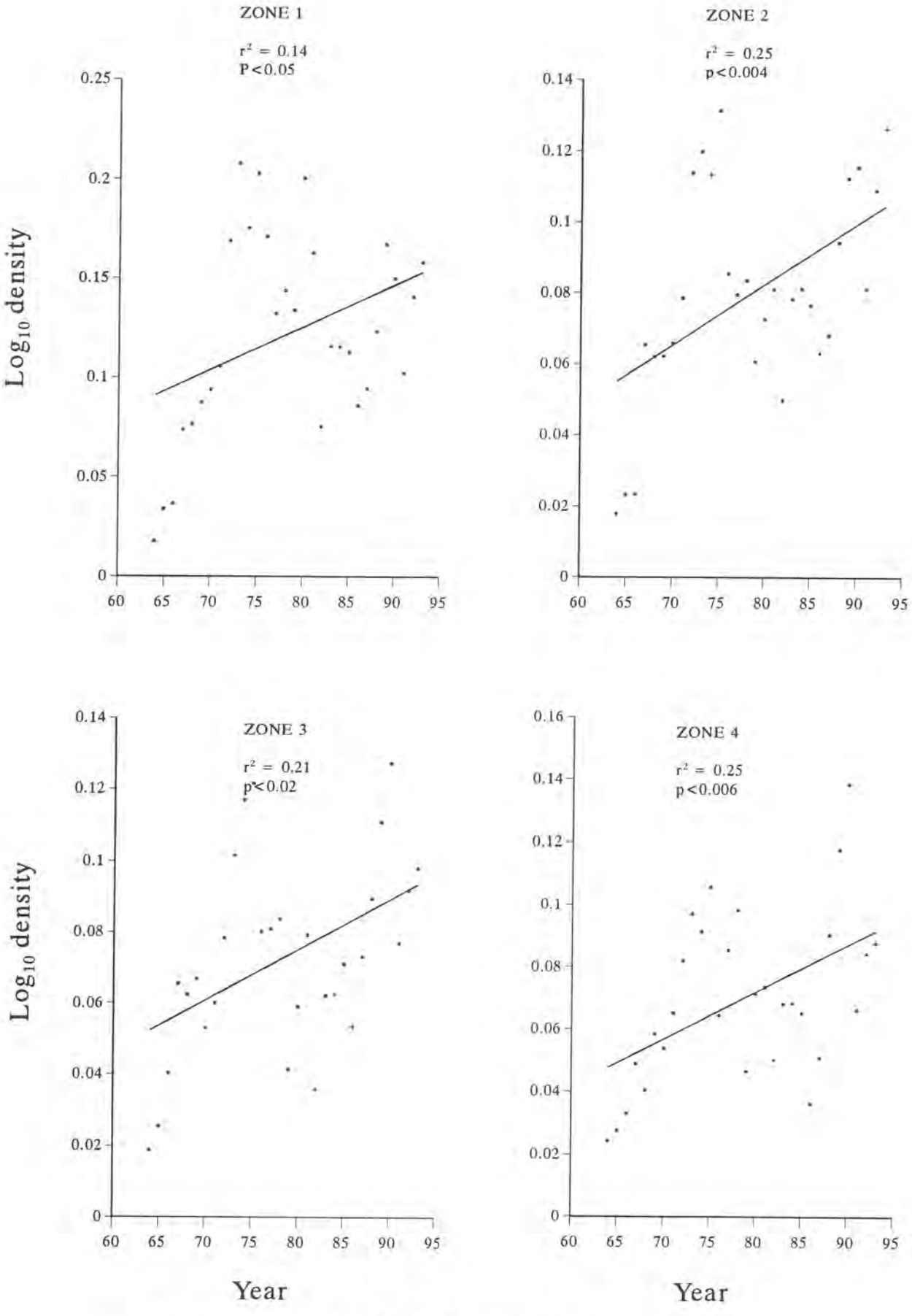

Fig 2.k ANCOVA, $F_{3,29}=0.22$, ns

ROBIN:FARMLAND

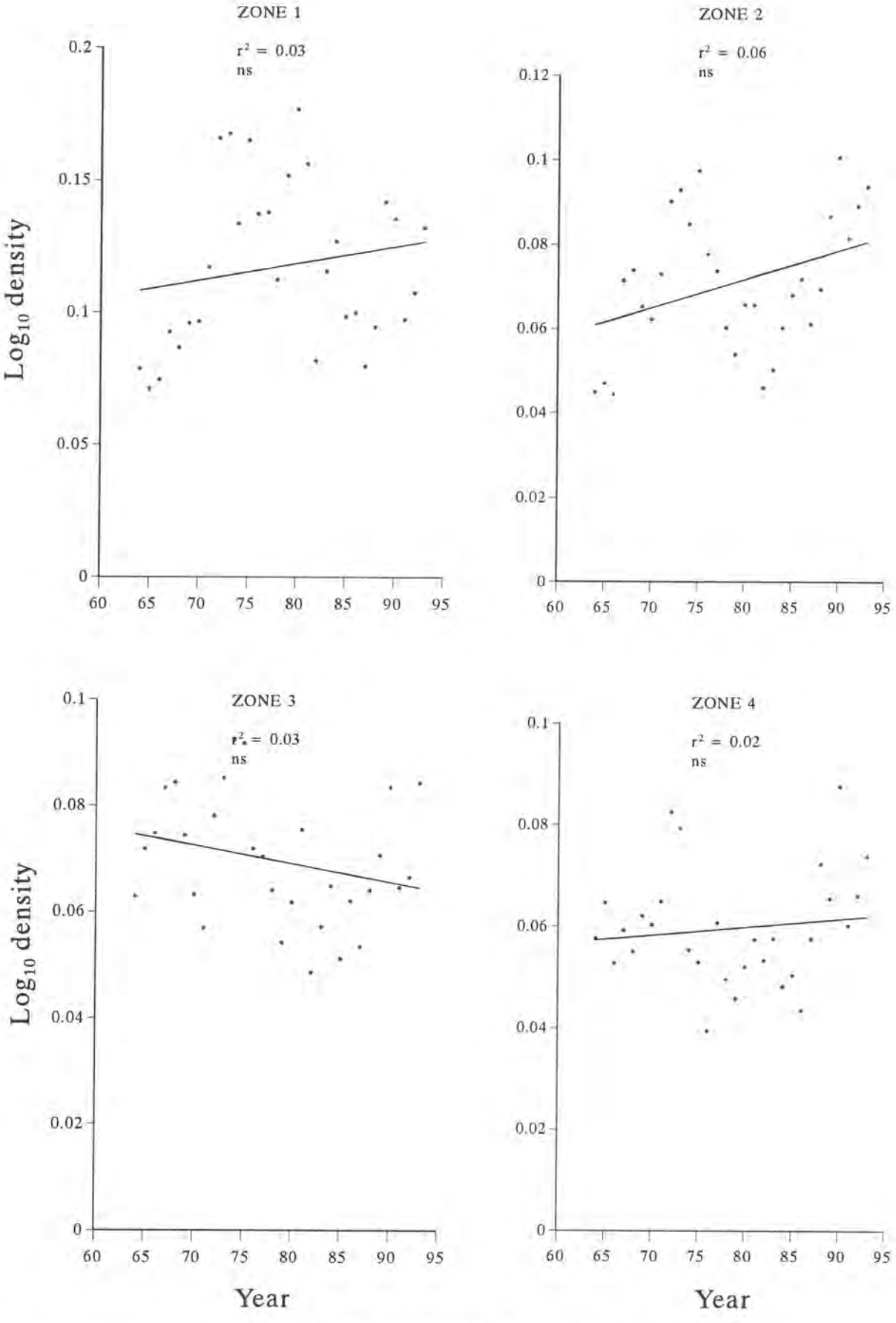

Fig 2.1 ANCOVA, $F_{3,29}$=0.9, ns

BLACKBIRD:FARMLAND

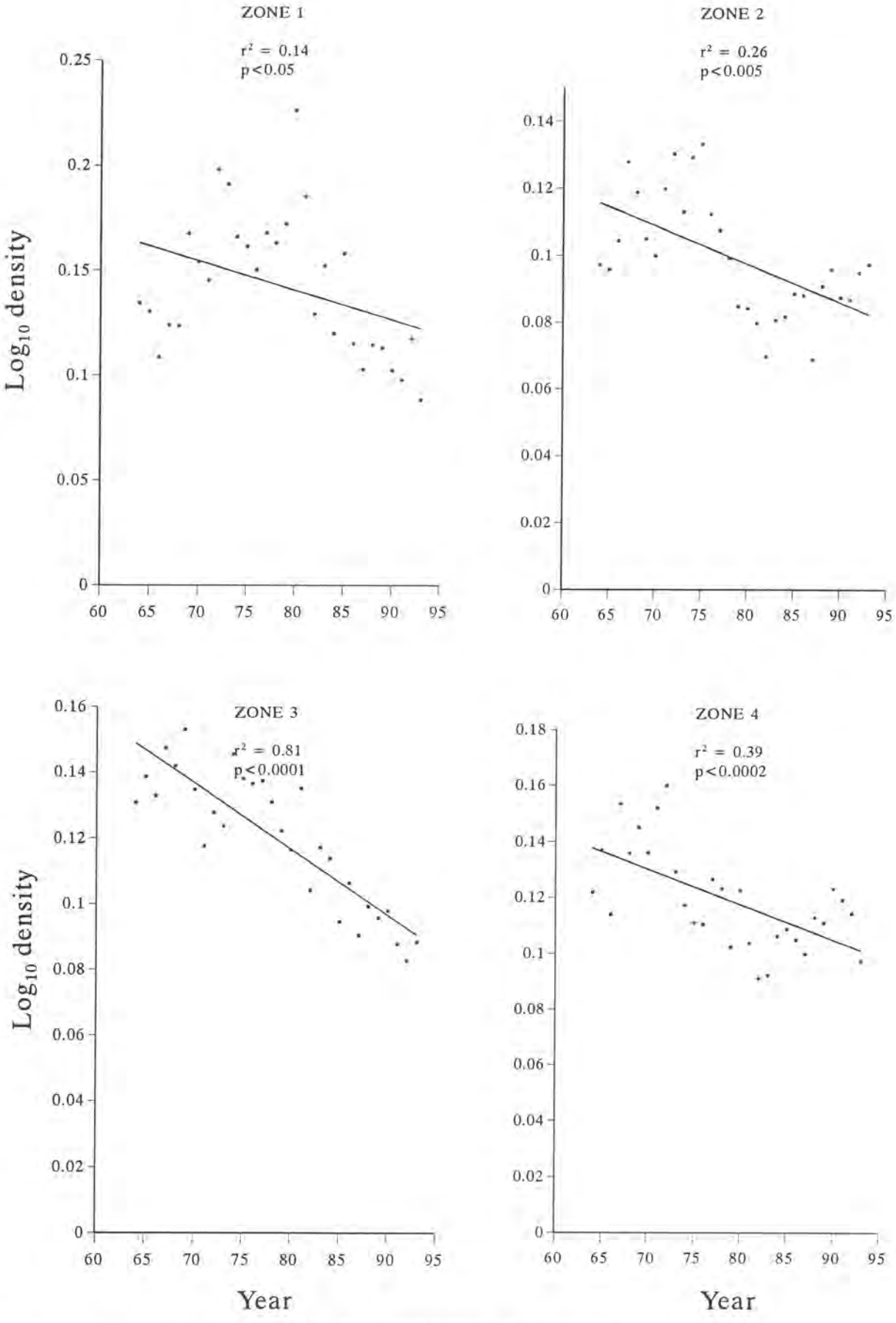

Fig 2.m ANCOVA, $F_{3,29}=2.04$, ns.

SONG THRUSH:FARMLAND

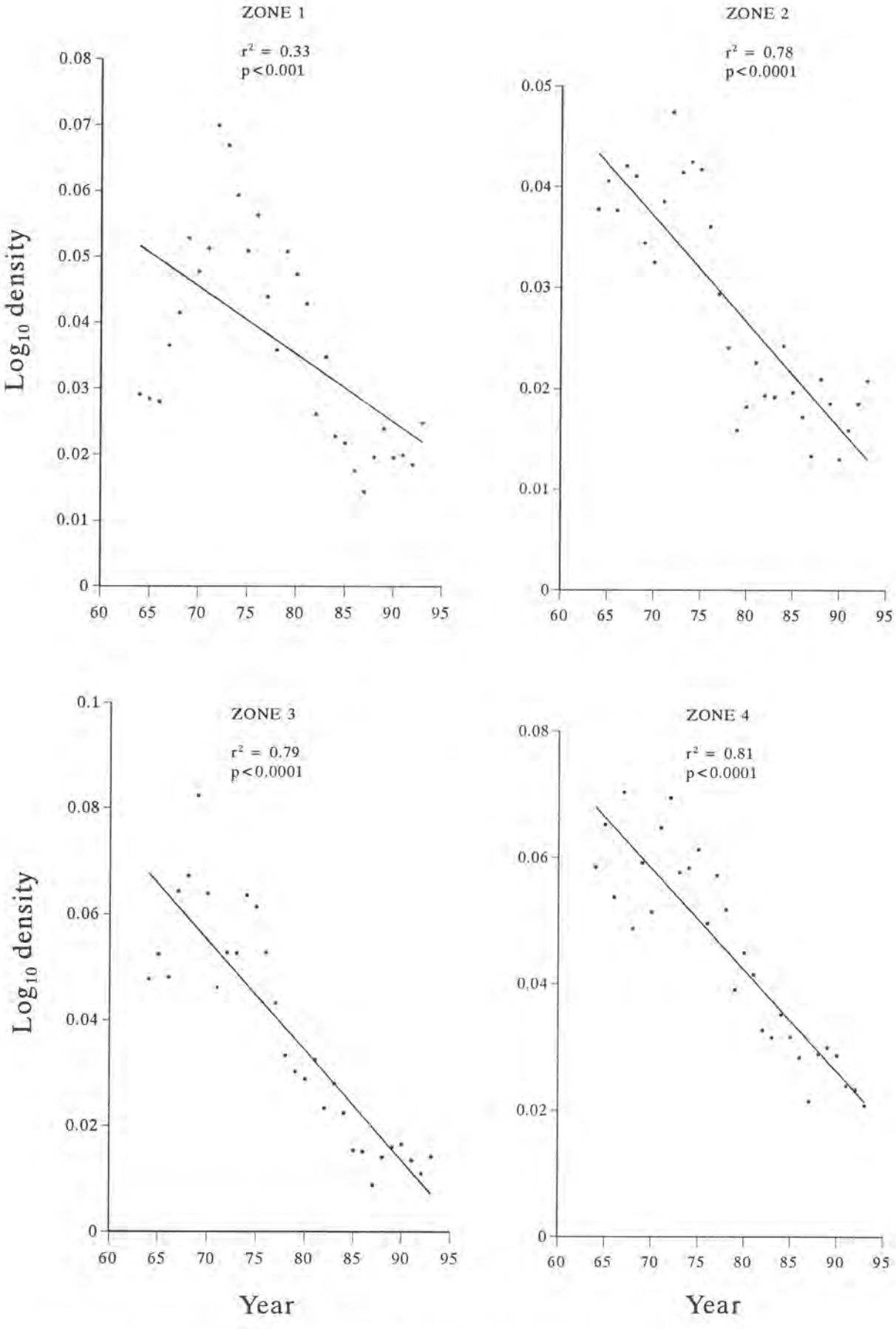

Fig 2.n ANCOVA, $F_{3,29}=7.23$ $P<0.0004$.

WHITETHROAT:FARMLAND

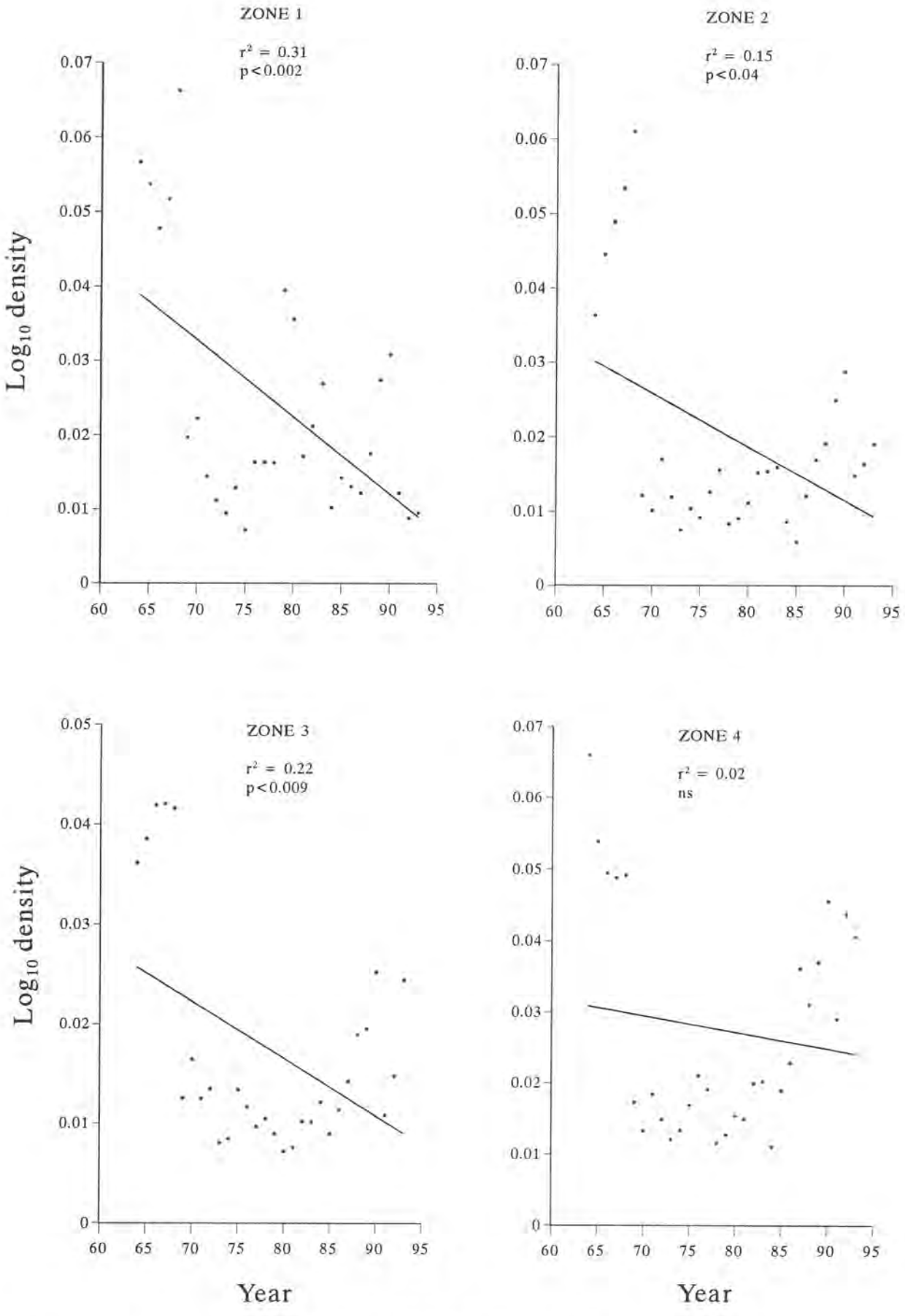

Fig 2.o ANCOVA, $F_{3,29}=1.49$, ns.

DUNNOCK:FARMLAND

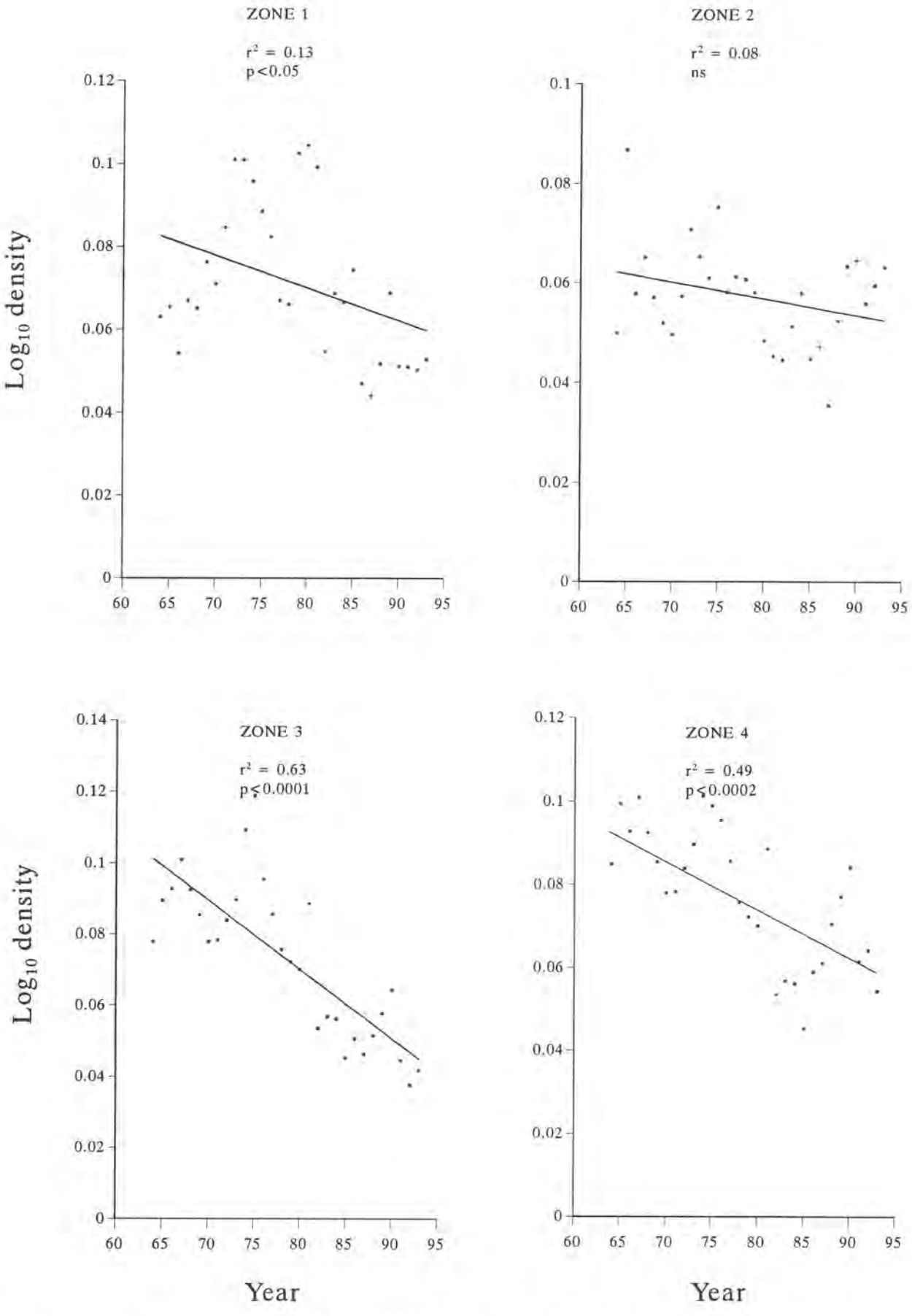

Fig 2.p ANCOVA, $F_{3,29}=5.99$, $P<0.001$

MEADOW PIPIT:FARMLAND

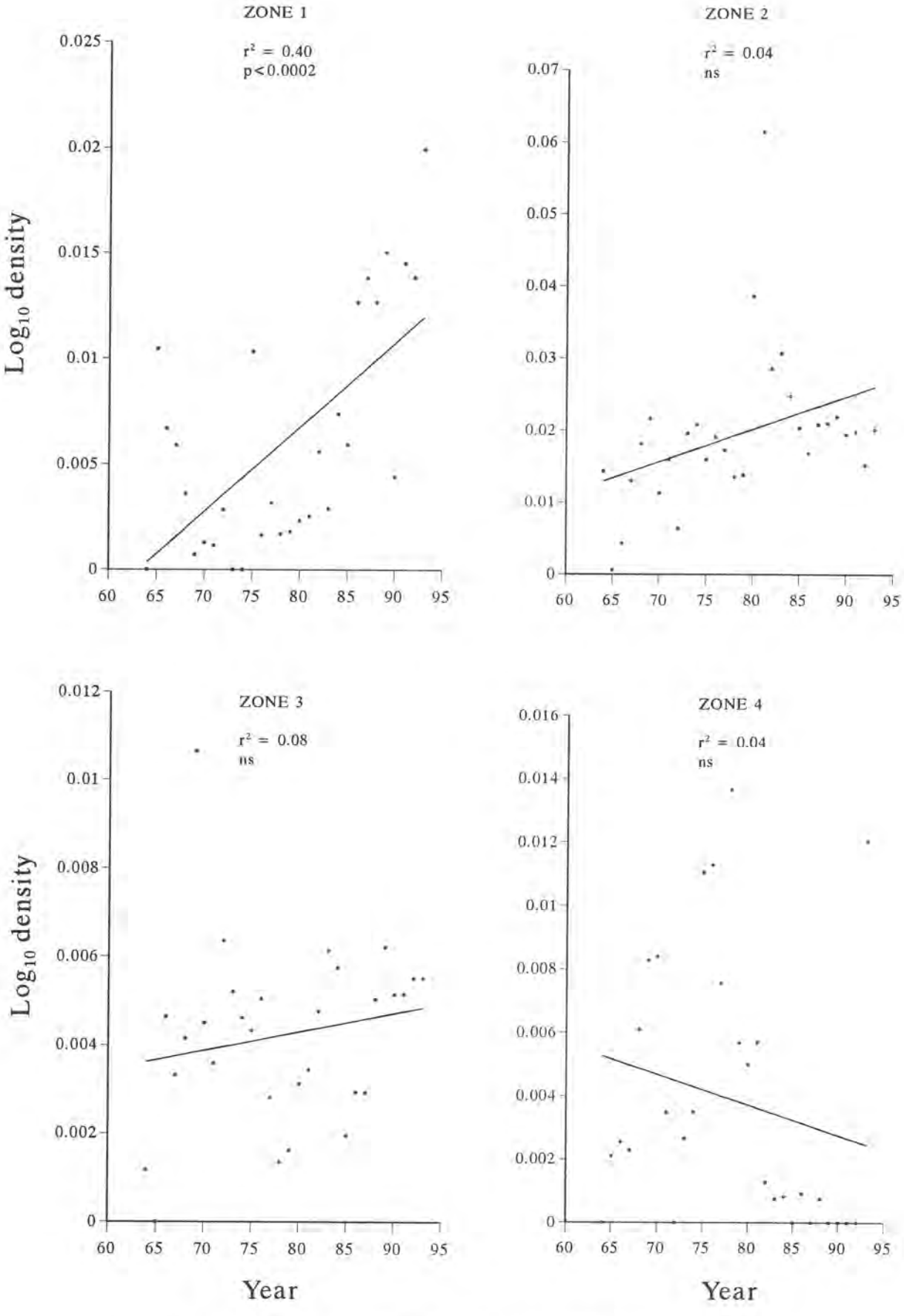

Fig 2.q ANCOVA, $F_{3,29}=2.77$, $P<0.05$

HOUSE SPARROW:FARMLAND

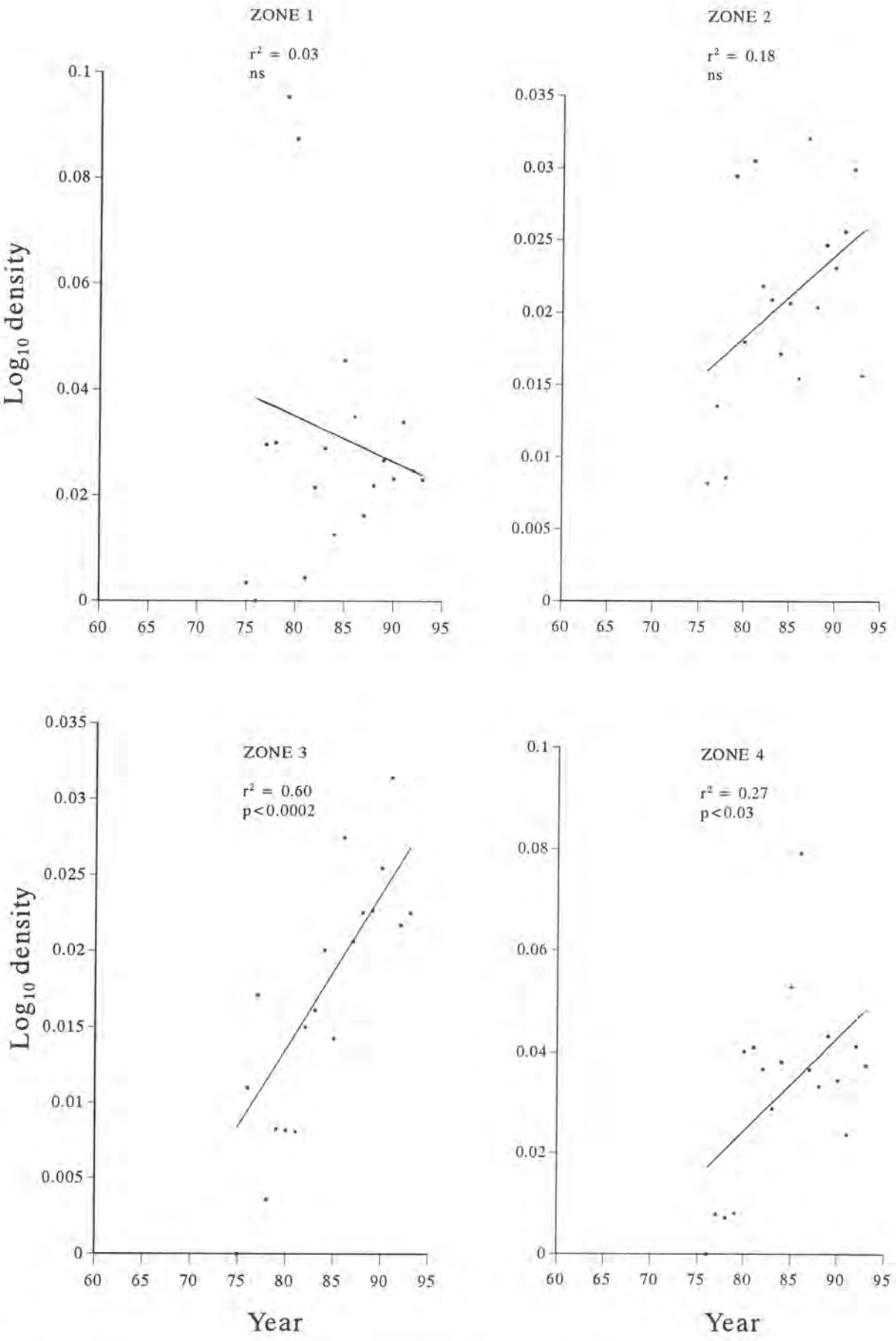

Fig 2.r ANCOVA, $F_{3,29}=2.61$, $P=0.05$

GREENFINCH:FARMLAND

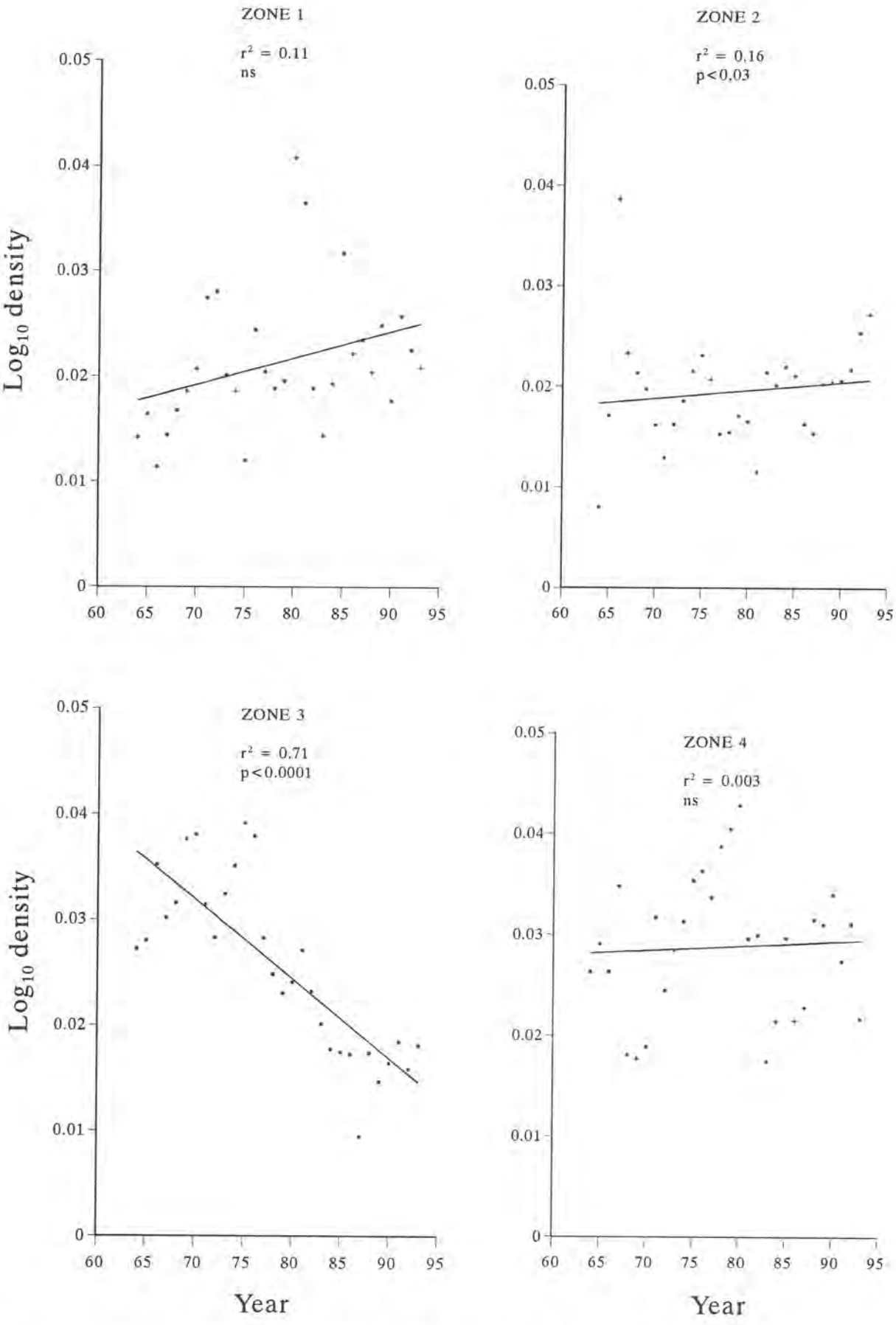

Fig 2.s ANCOVA, $F_{3,29}=18.24$ $P<0.0001$.

GOLDFINCH: FARMLAND

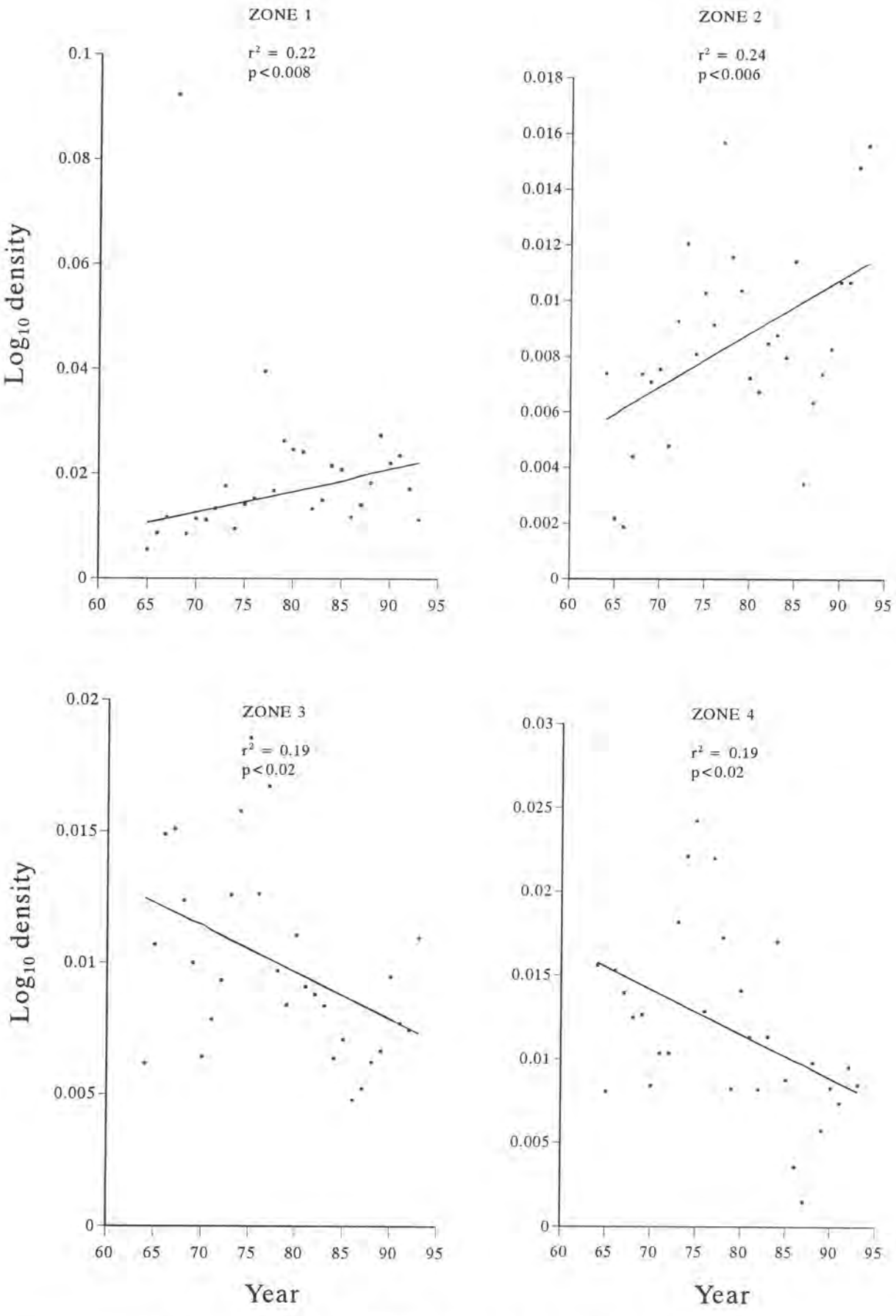

Fig 2.t ANCOVA, $F_{3,29}=9.96$, $P<0.0001$

LINNET:FARMLAND

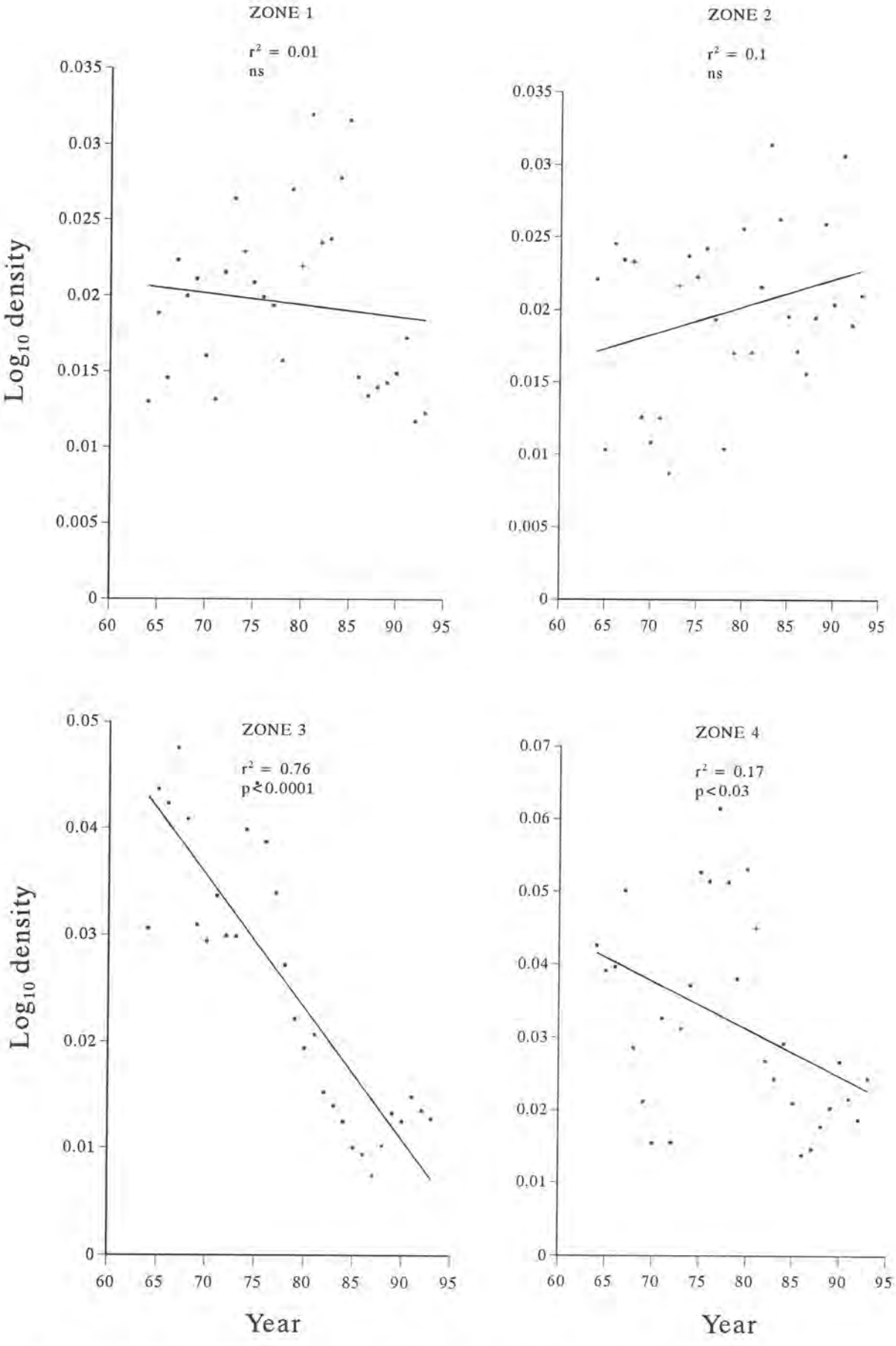

Fig 2.U ANCOVA, $F_{3,29}=14.1$ $P<0.0002$.

CHAFFINCH:FARMLAND

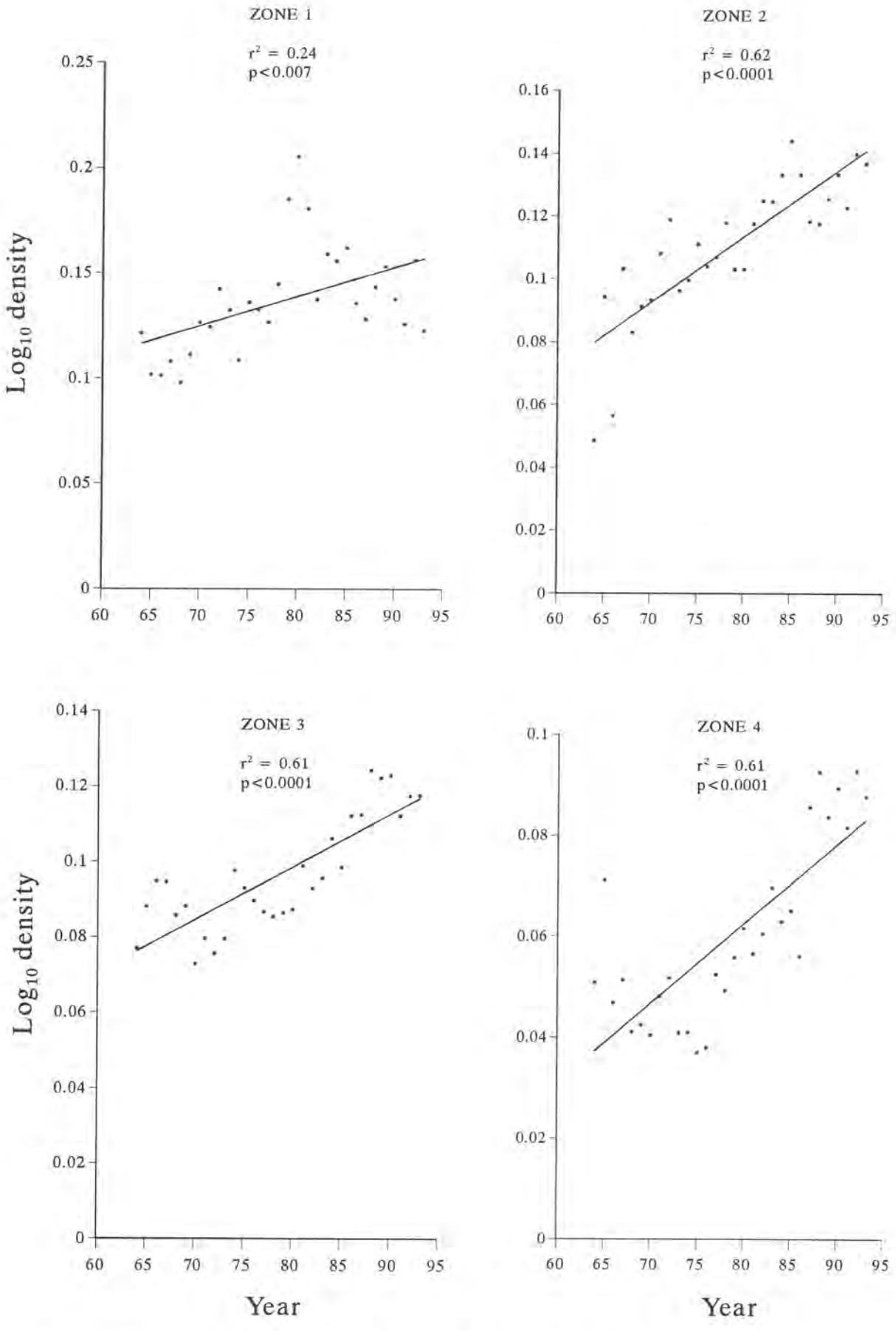

Fig 2.v ANCOVA, $F_{3,29}=0.92$, ns.

YELLOWHAMMER:FARMLAND

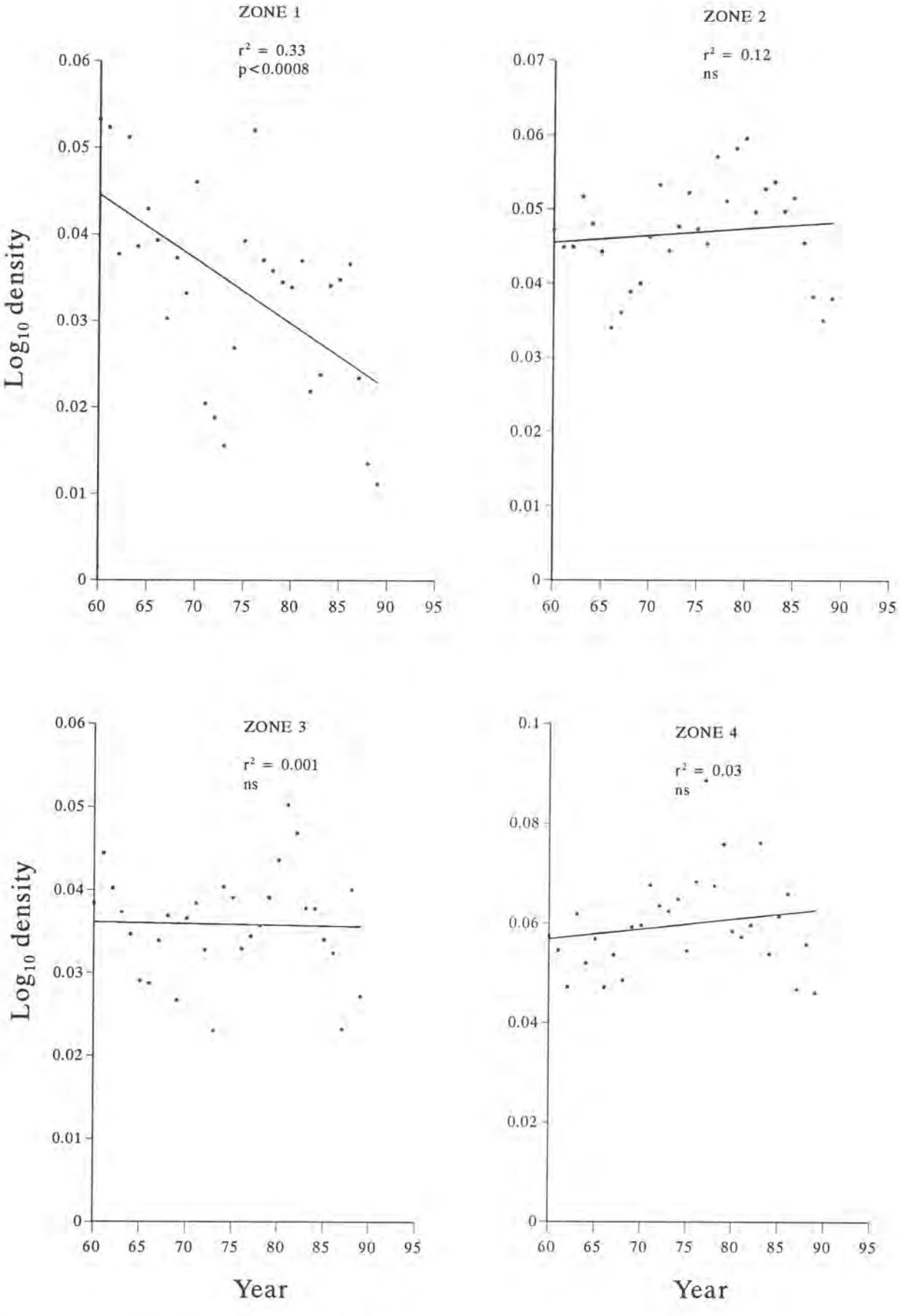

Fig 2.w ANCOVA, $F_{3,29}=7.03$ $P<0.0003$.

Fig 3. Temporal changes in territory density of 23 woodland prey species between 1964 and 1993 (a to w). The slope of the trend is described by a linear equation and the closeness of the CBC data to this slope is given by the r^2 values in each zone. Statistical differences between the slopes of the four zones for each species are given in the legend (analysis of covariance: ANCOVA).

WOODPIGEON:WOODLAND

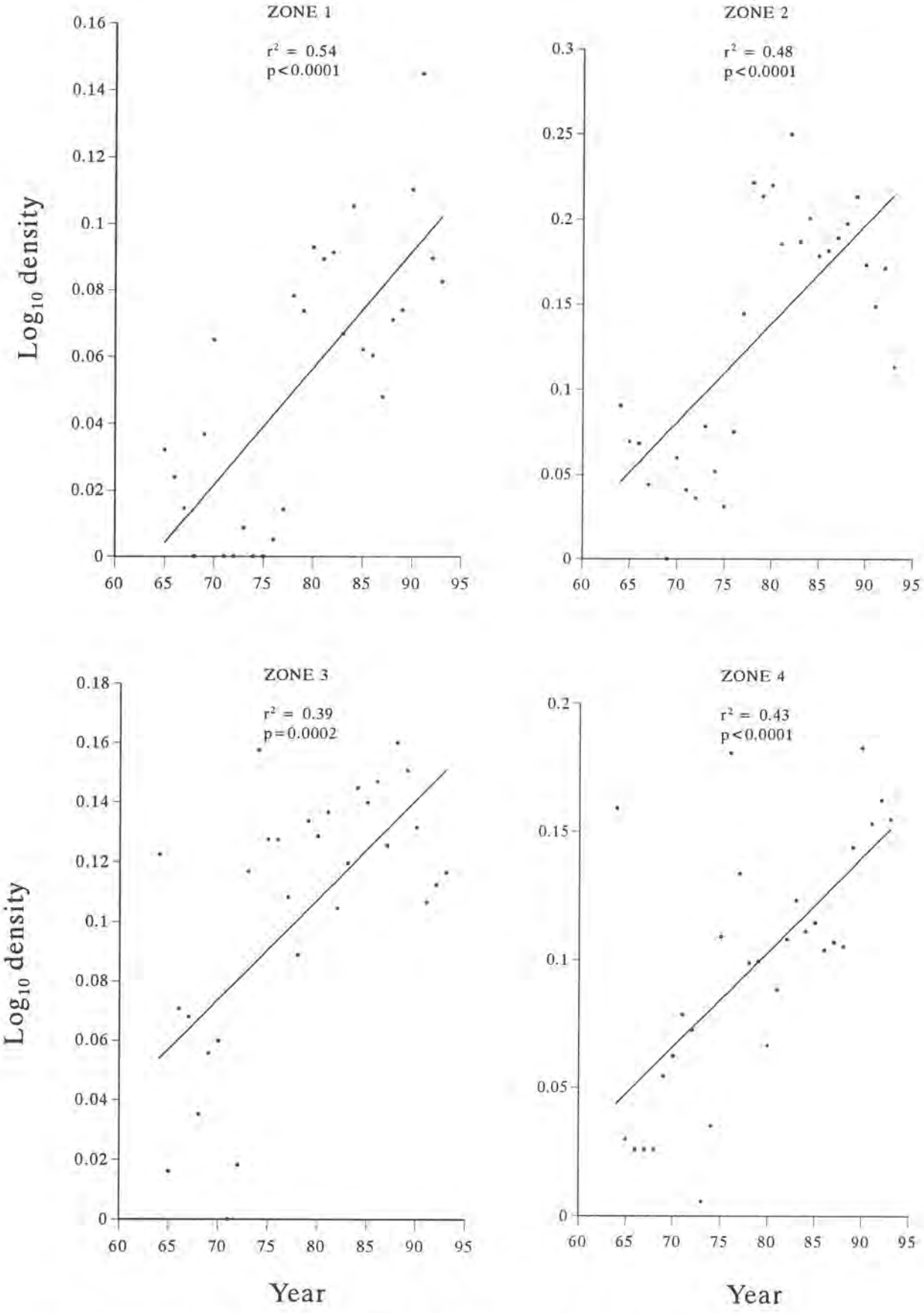

Fig 3.a ANCOVA, $F_{3,29}=1.78$, ns

TURTLE DOVE:WOODLAND

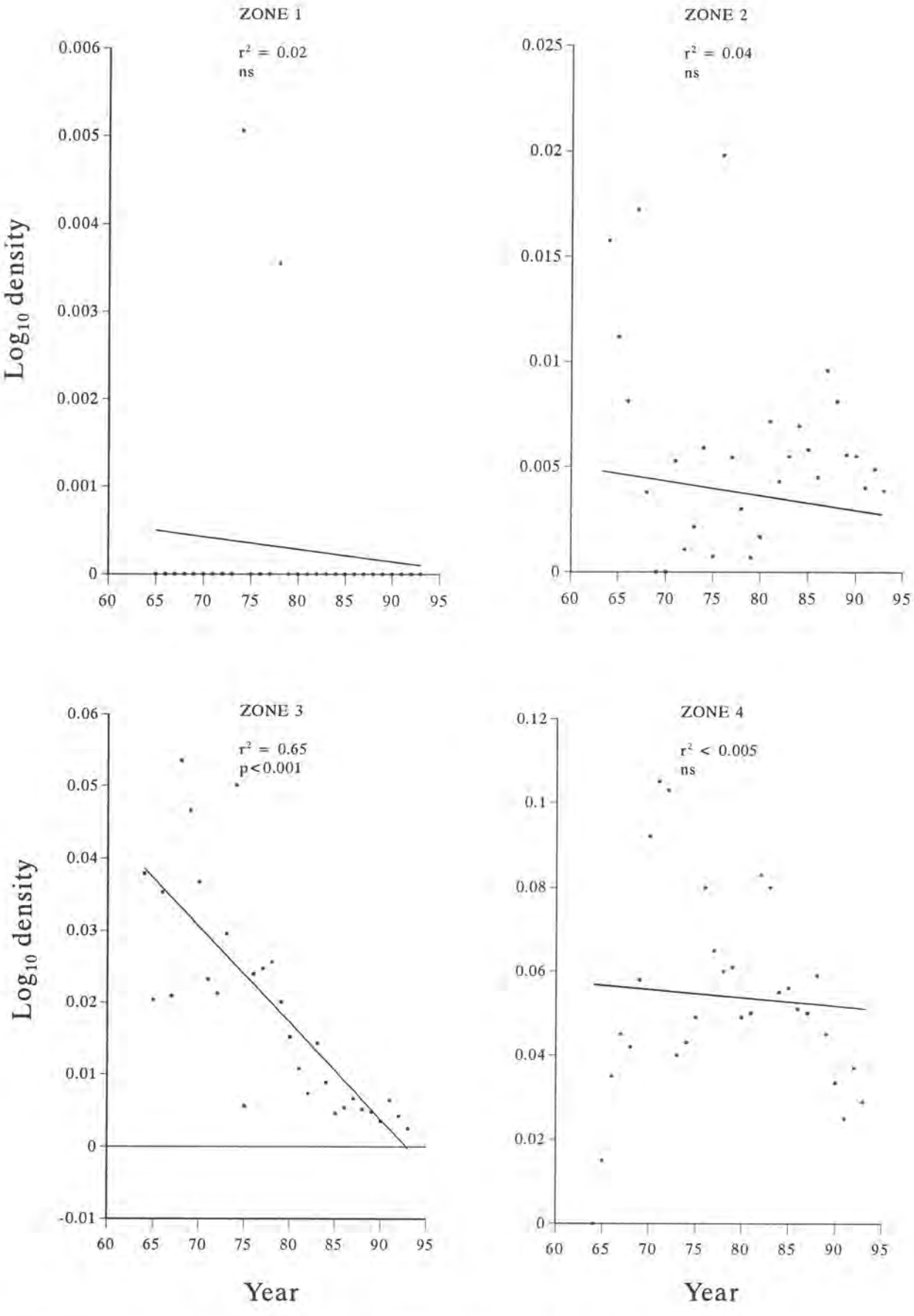

Fig 3.b ANCOVA, $F_{3,29}=6.54$, $P<0.0004$

JAY:WOODLAND

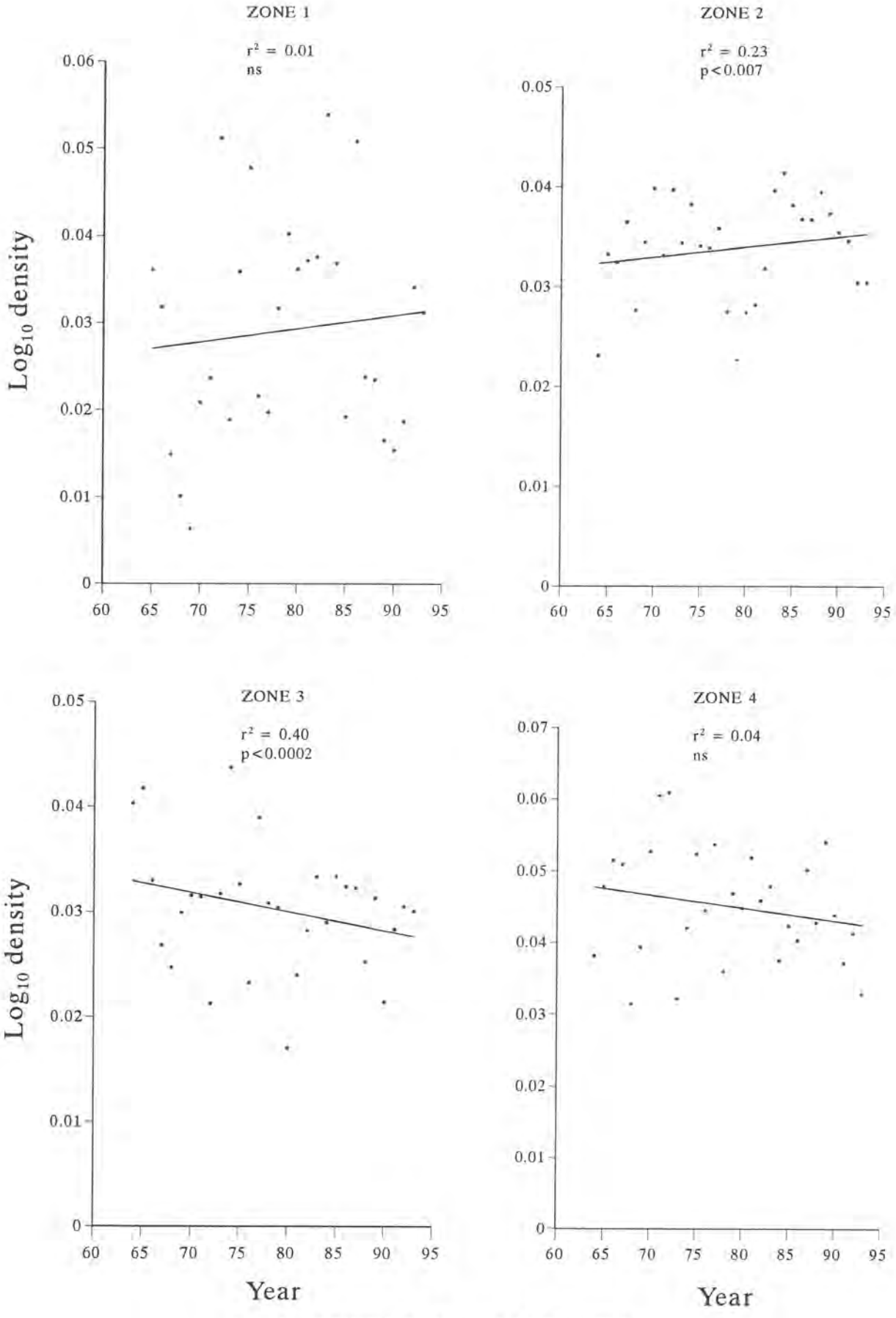

Fig 3.c ANCOVA, $F_{3,29}=4.52$ $P<0.005$.

GREAT TIT:WOODLAND

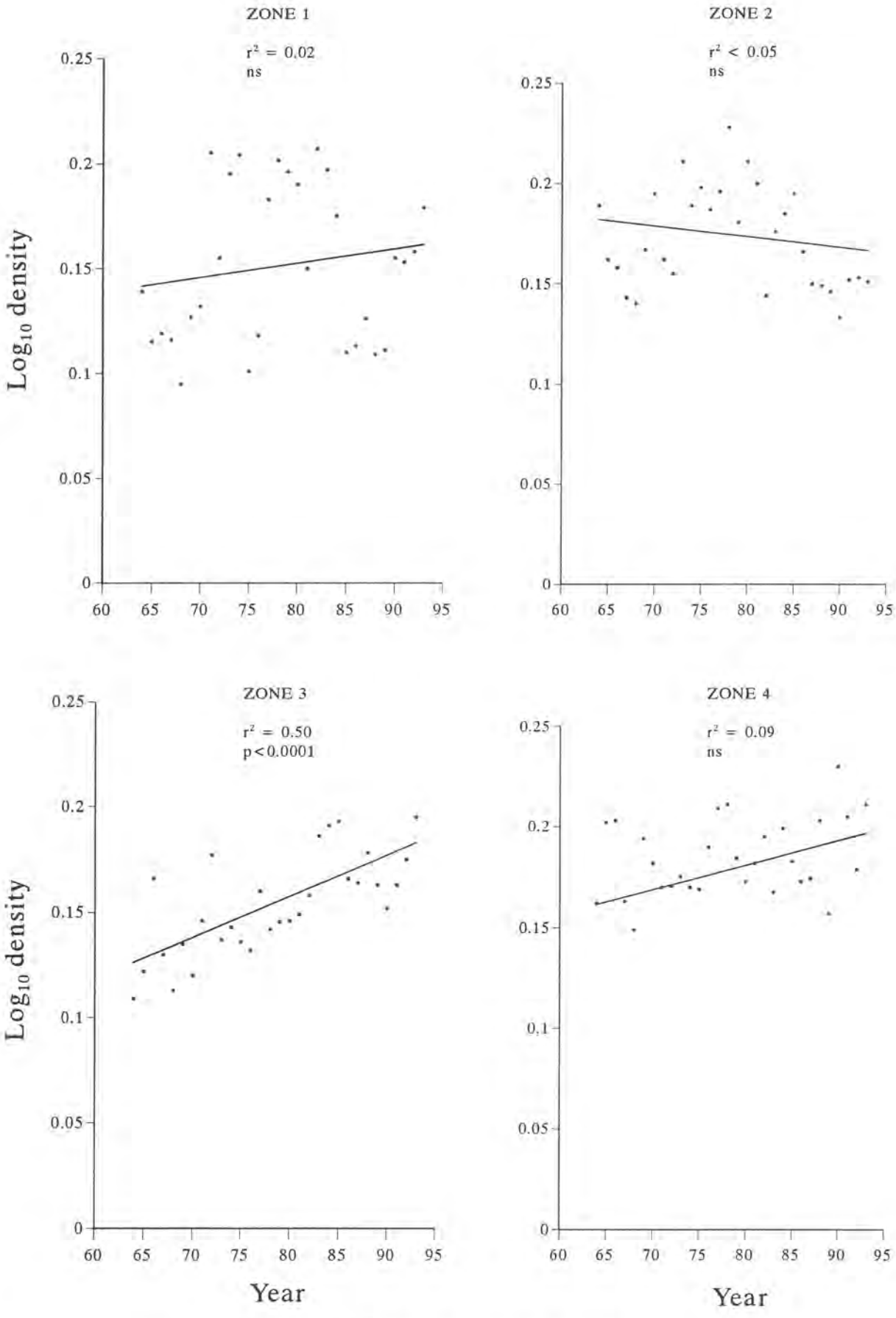

Fig 3.d ANCOVA, $F_{3,29}=3.49$ $P<0.02$.

BLUE TIT:WOODLAND

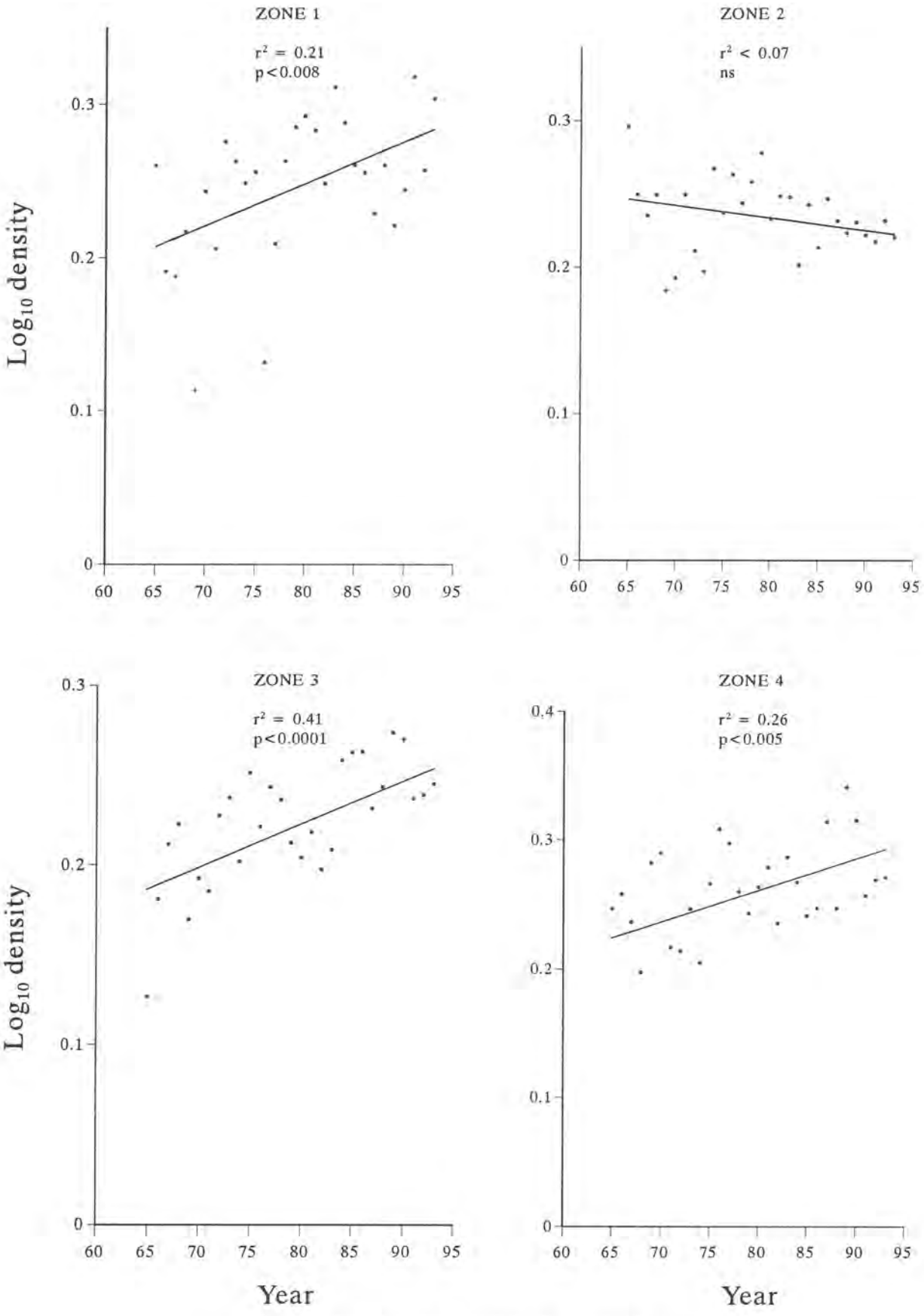

Fig 3.e ANCOVA, $F_{3,29}=5.58$, $P<0.002$

COAL TIT:WOODLAND

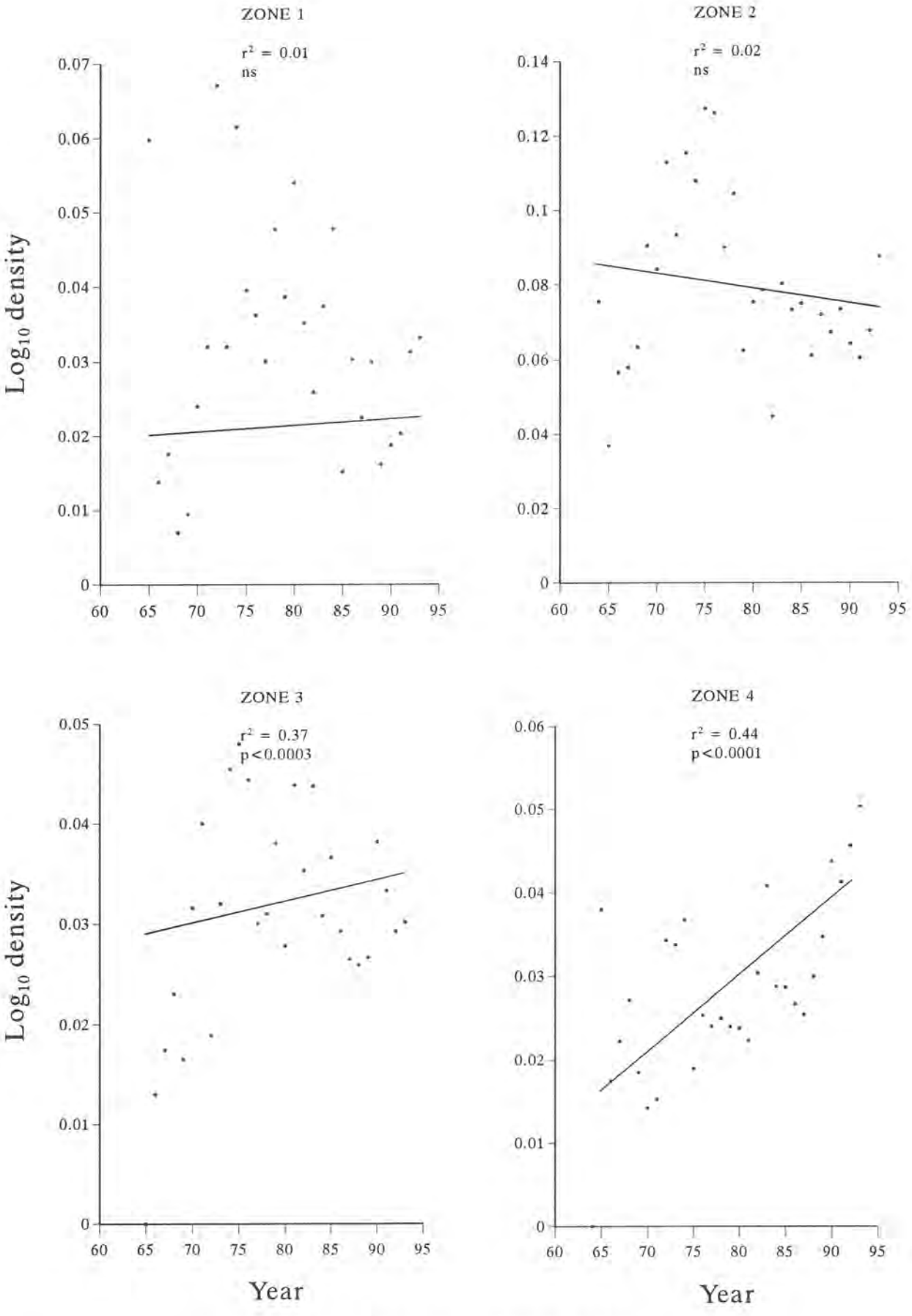

Fig 3.f ANCOVA, $F_{3,29}$=5.95 P<0.008.

LONG-TAILED TIT:WOODLAND

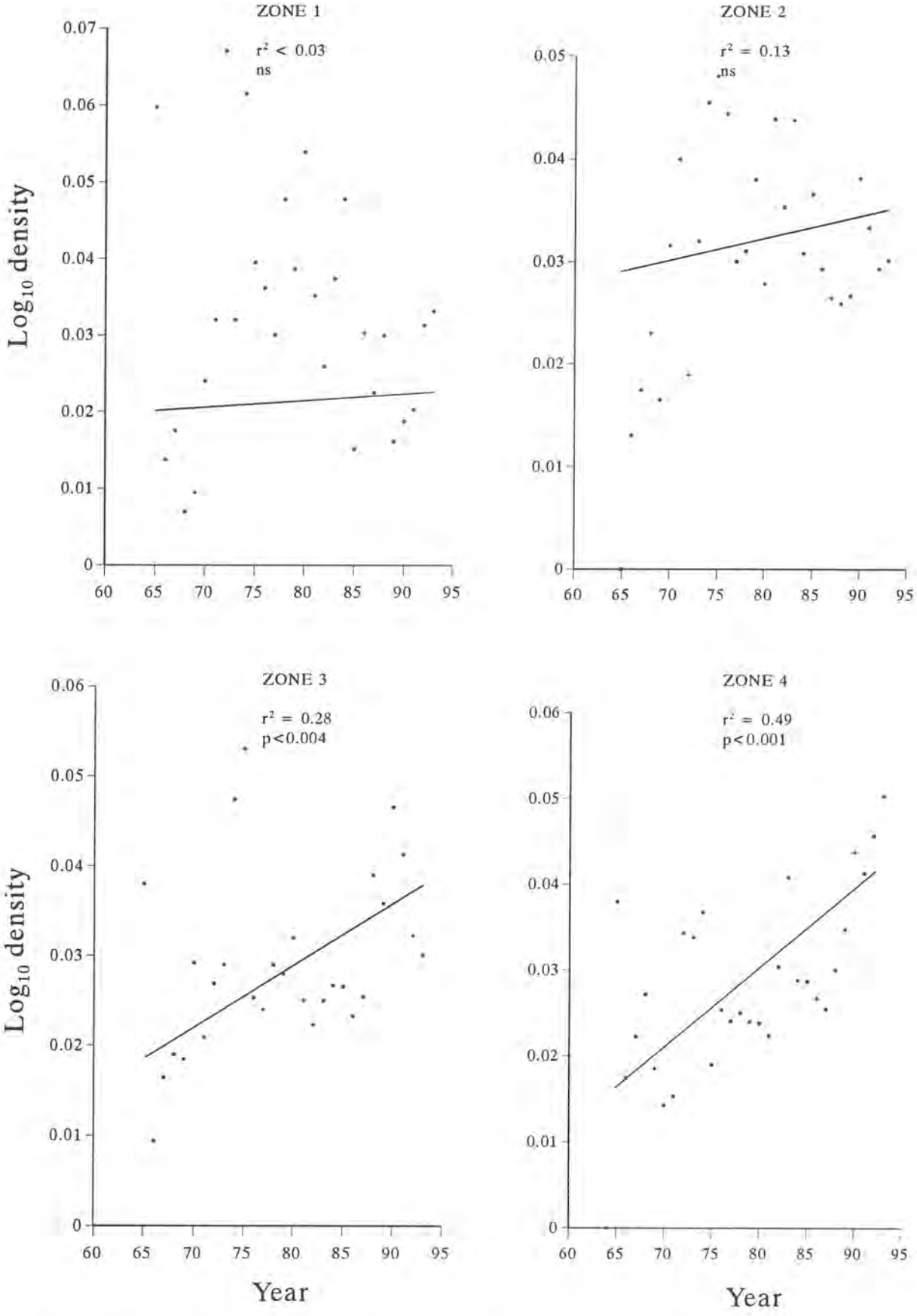

Fig 3.g ANCOVA, $F_{3,29}$=1.79, ns.

WREN:WOODLAND

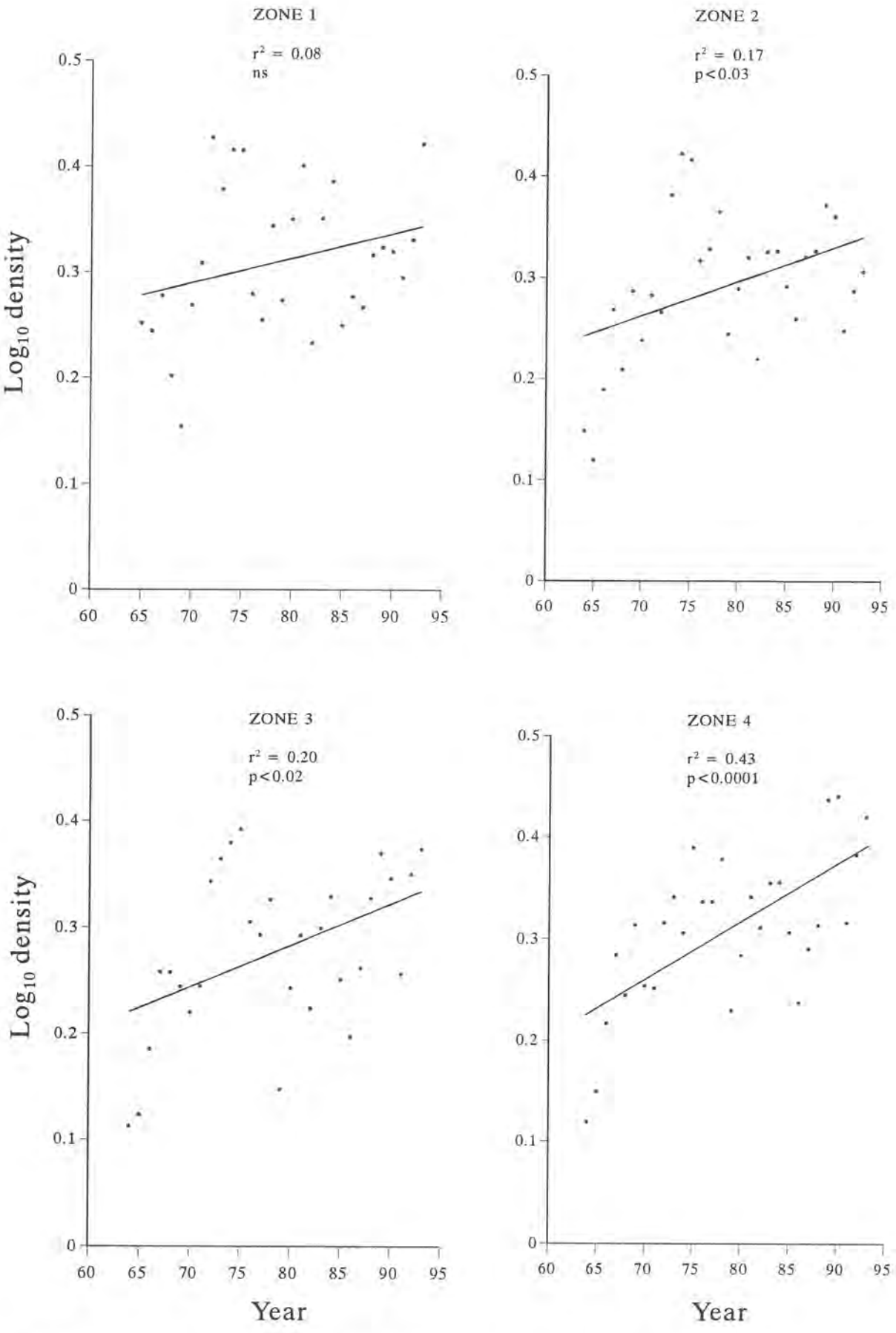

Fig 3.h ANCOVA, $F_{3,29}=0.97$, ns.

ROBIN:WOODLAND

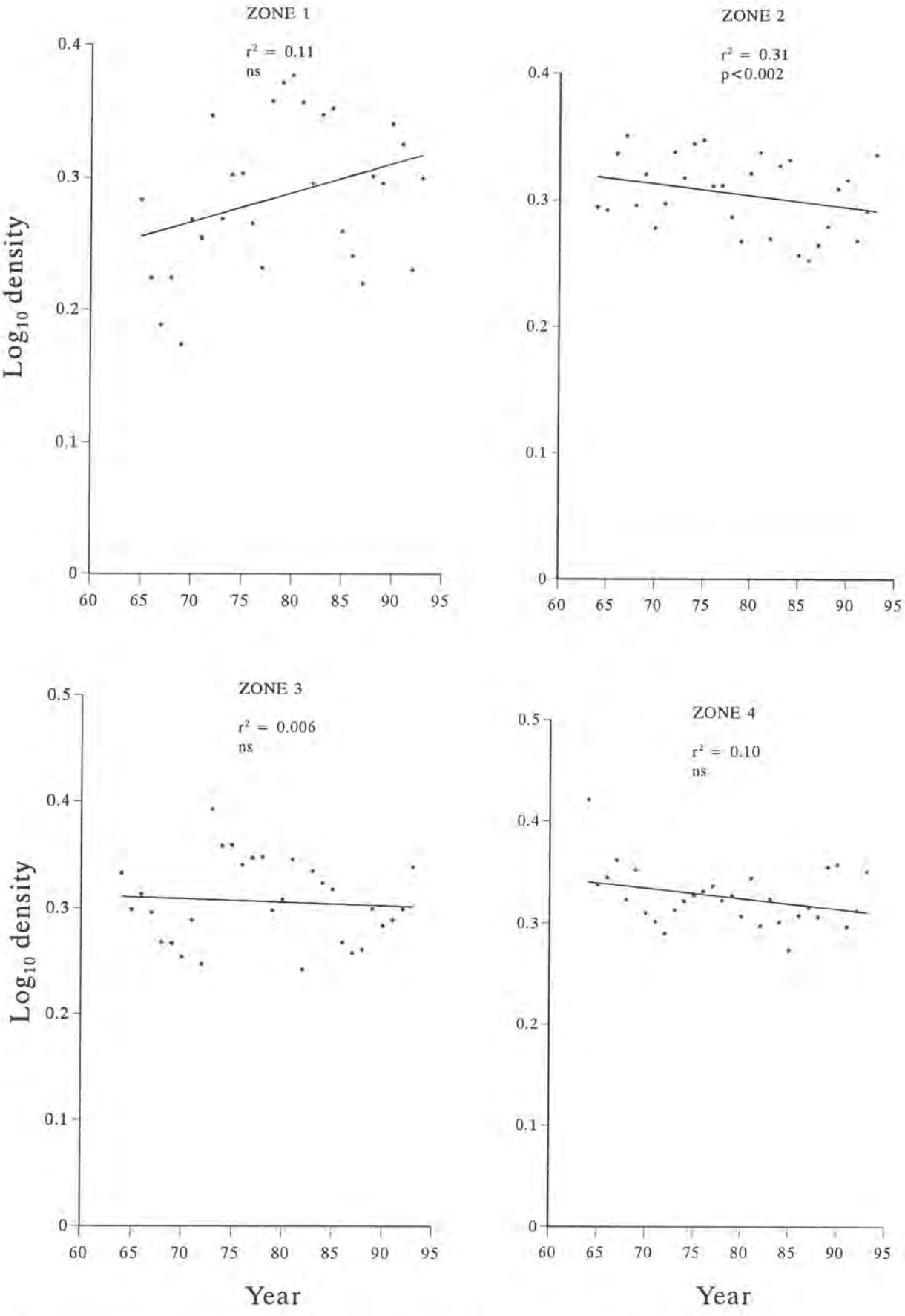

Fig 3.i ANCOVA, $F_{3,29}$=0.98, P<0.0004

BLACKBIRD:WOODLAND

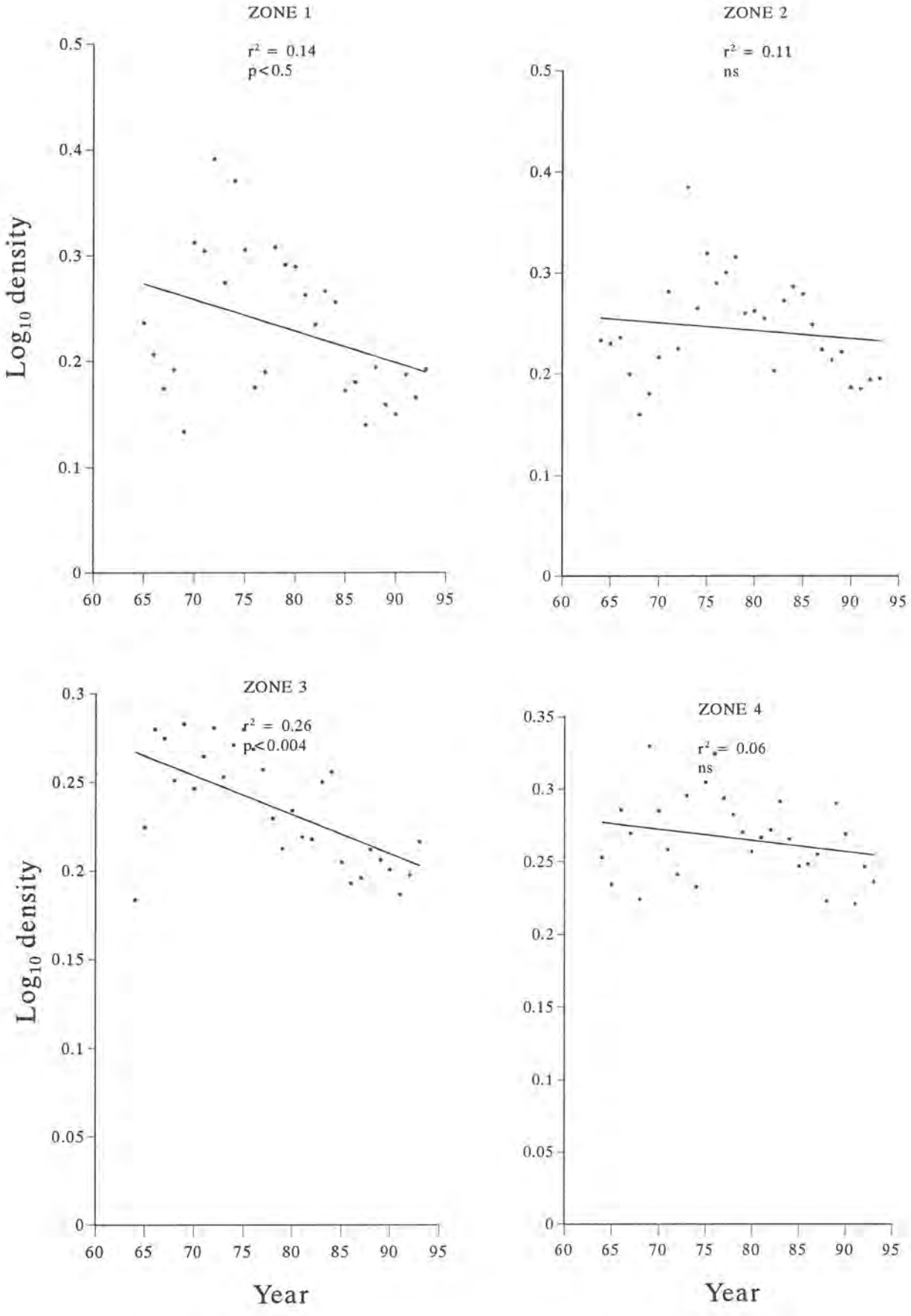

Fig 3.j ANCOVA, $F_{3,29}$=0.98, P<0.0004

SONG THRUSH:WOODLAND

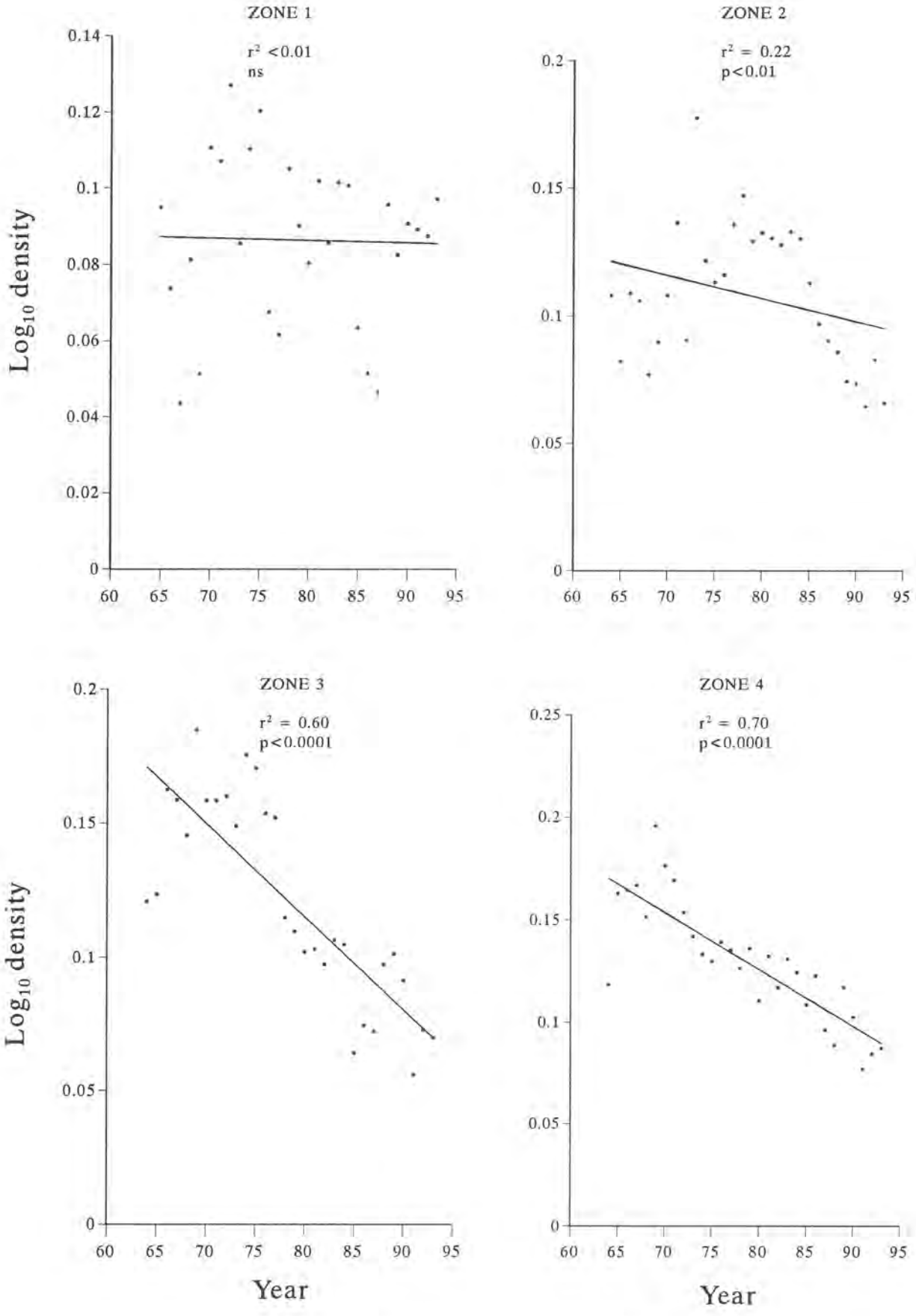

Fig 3.k ANCOVA, $F_{3,29}=11.3$ $P<0.0001$.

MISTLE THRUSH:WOODLAND

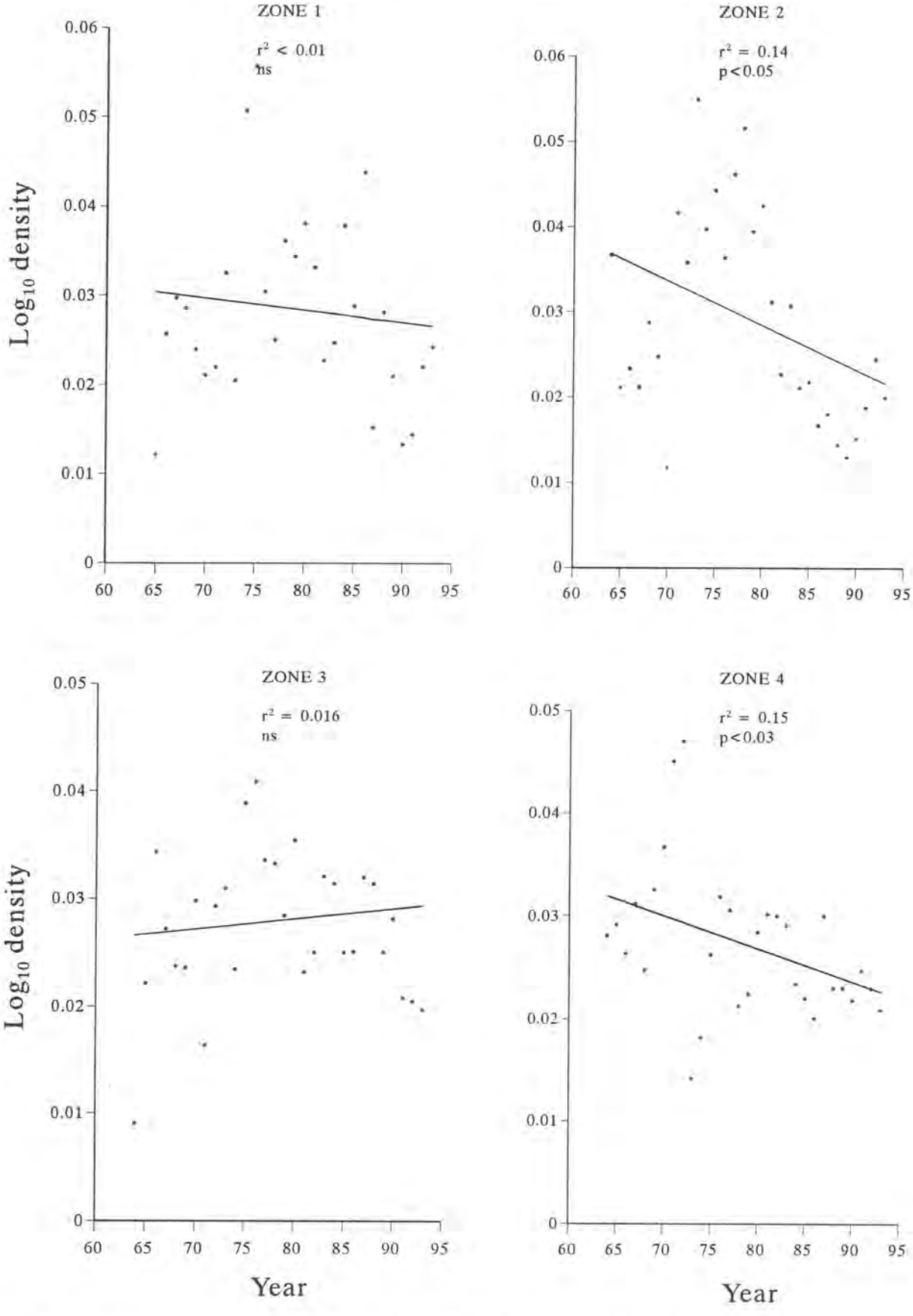

Fig 3.1 ANCOVA, $F_{3,29}$=1.84, ns.

WILLOW WARBLER:WOODLAND

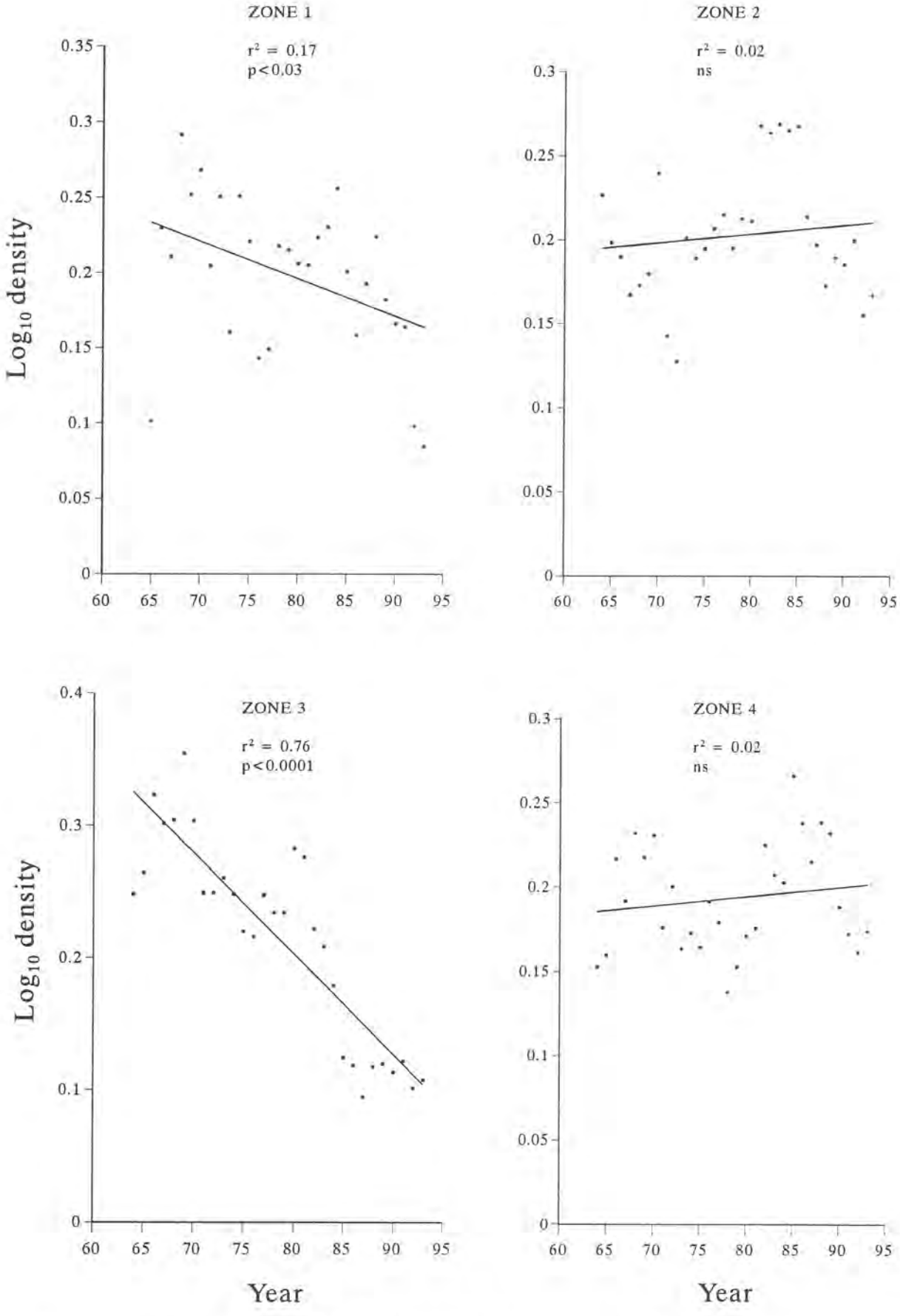

Fig 3.m ANCOVA, $F_{3,29}=20.4$, $P<0.0001$.

CHIFFCHAFF:WOODLAND

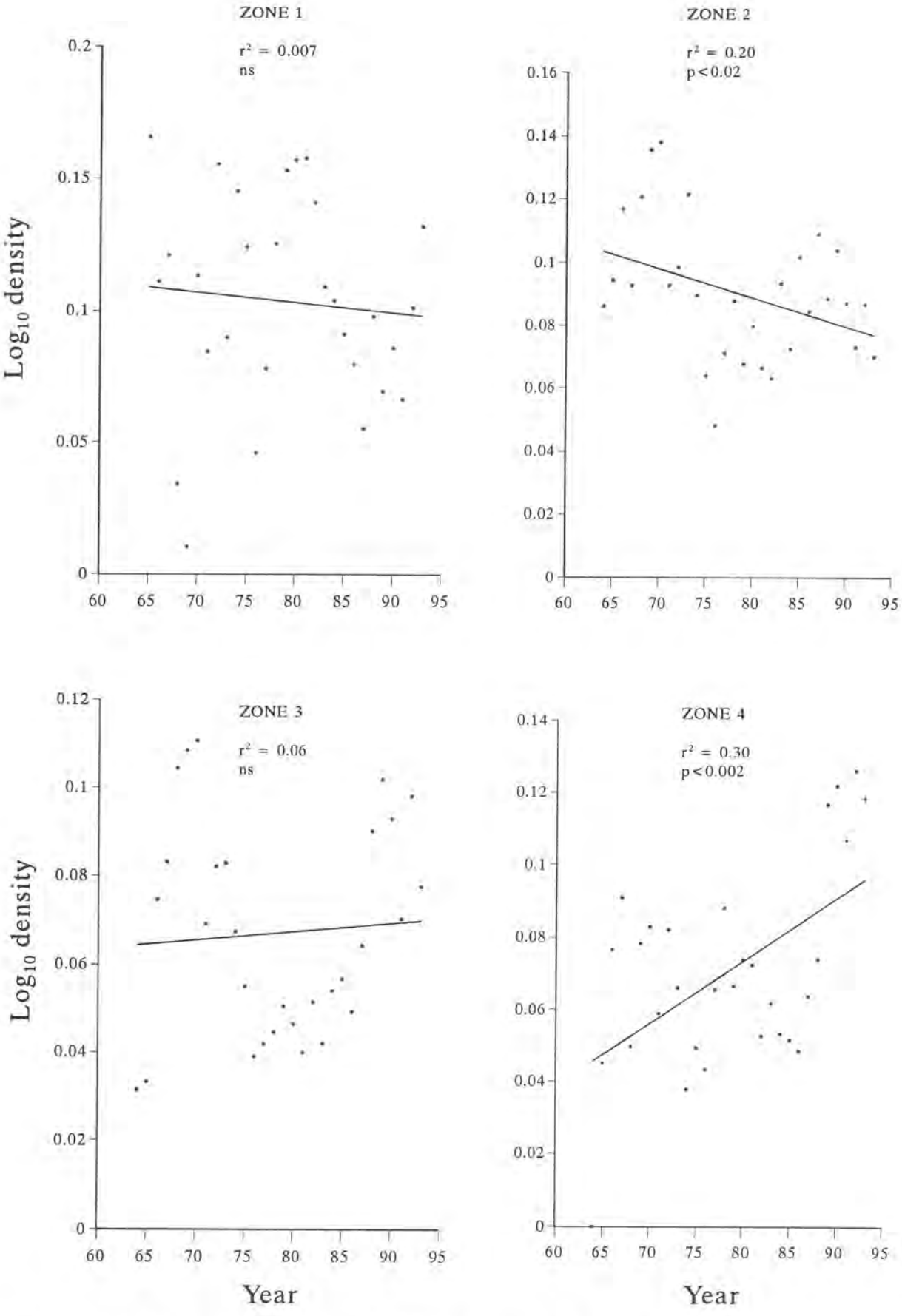

Fig 3.n ANCOVA, $F_{3,29}=5.29$, $P<0.003$

GOLDCREST:WOODLAND

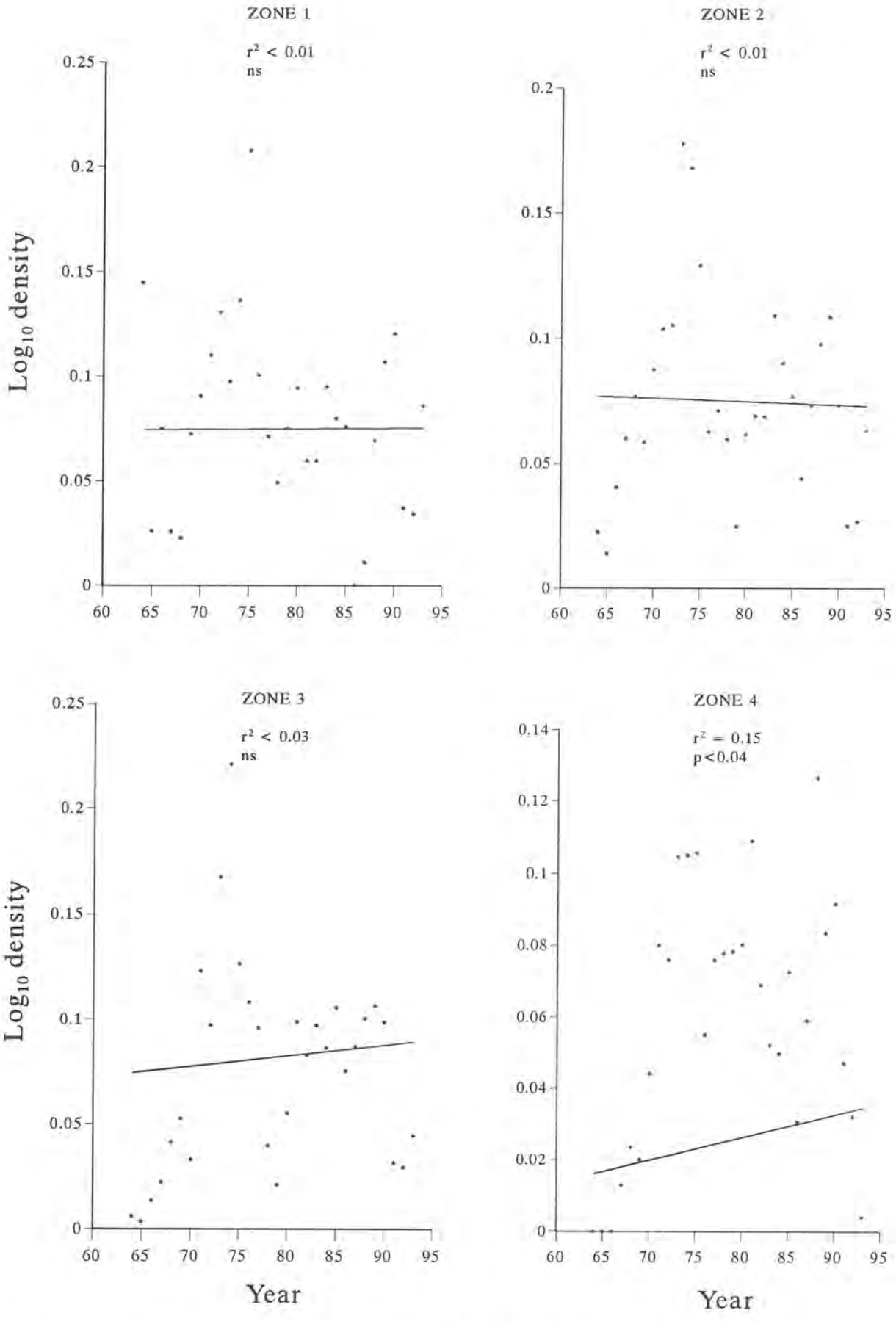

Fig 3.o ANCOVA, $F_{3,29}=0.31$, ns

SPOTTED FLYCATCHER:WOODLAND

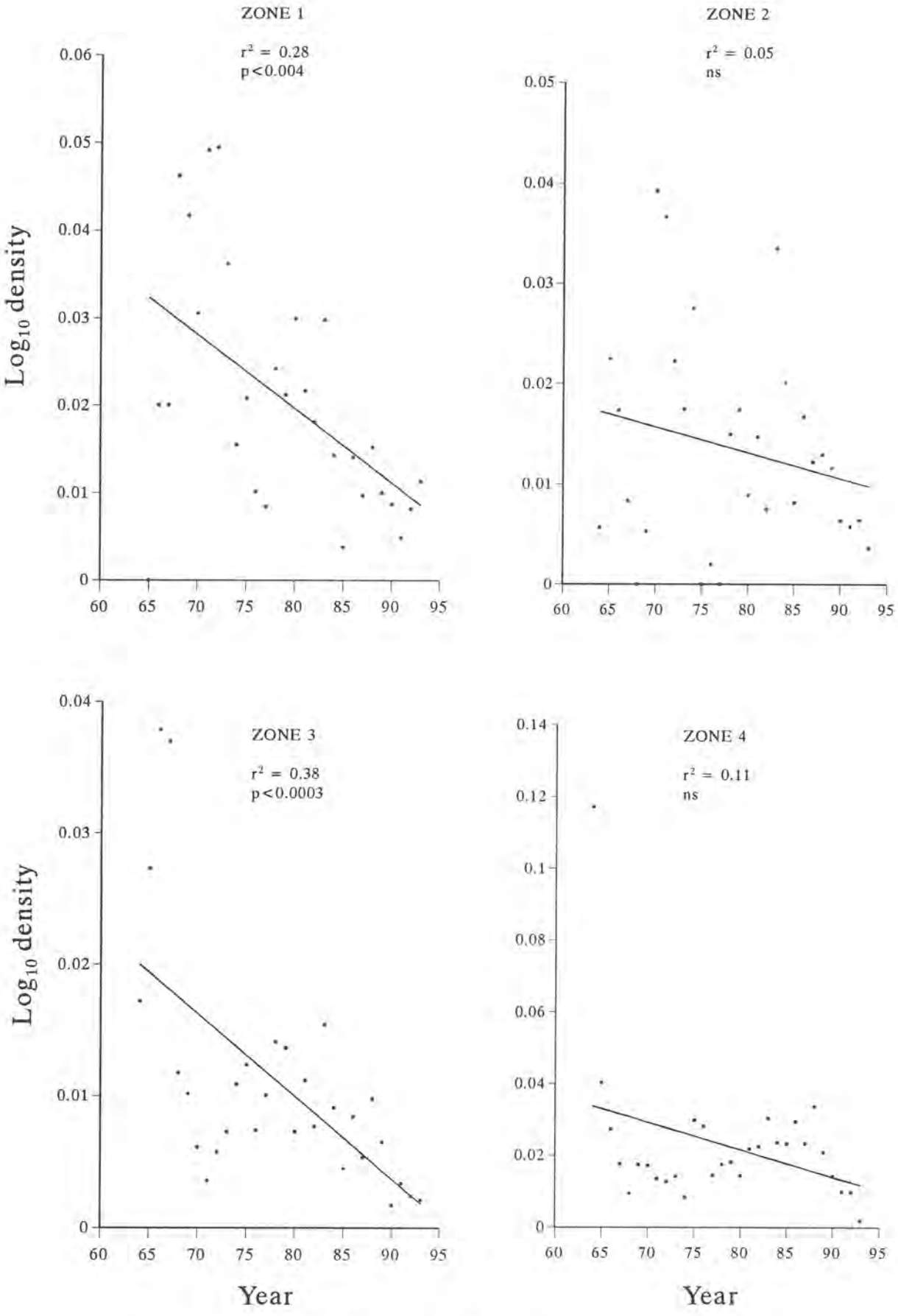

Fig 3.p ANCOVA, $F_{3,29}$=0.91, ns.

DUNNOCK:WOODLAND

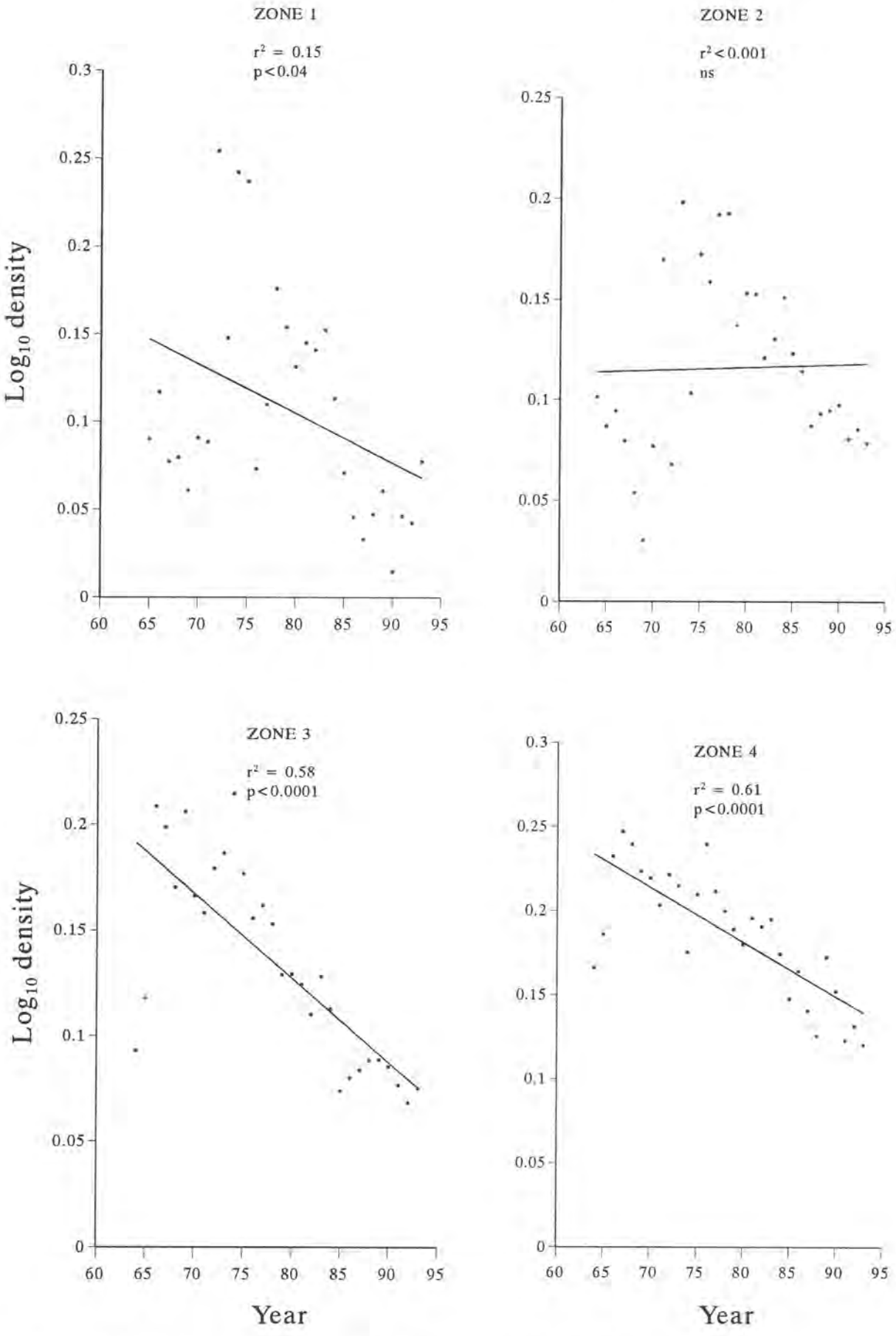

Fig 3.q ANCOVA, $F_{3,29}=4.32$, $P<0.007$.

TREE PIPIT:WOODLAND

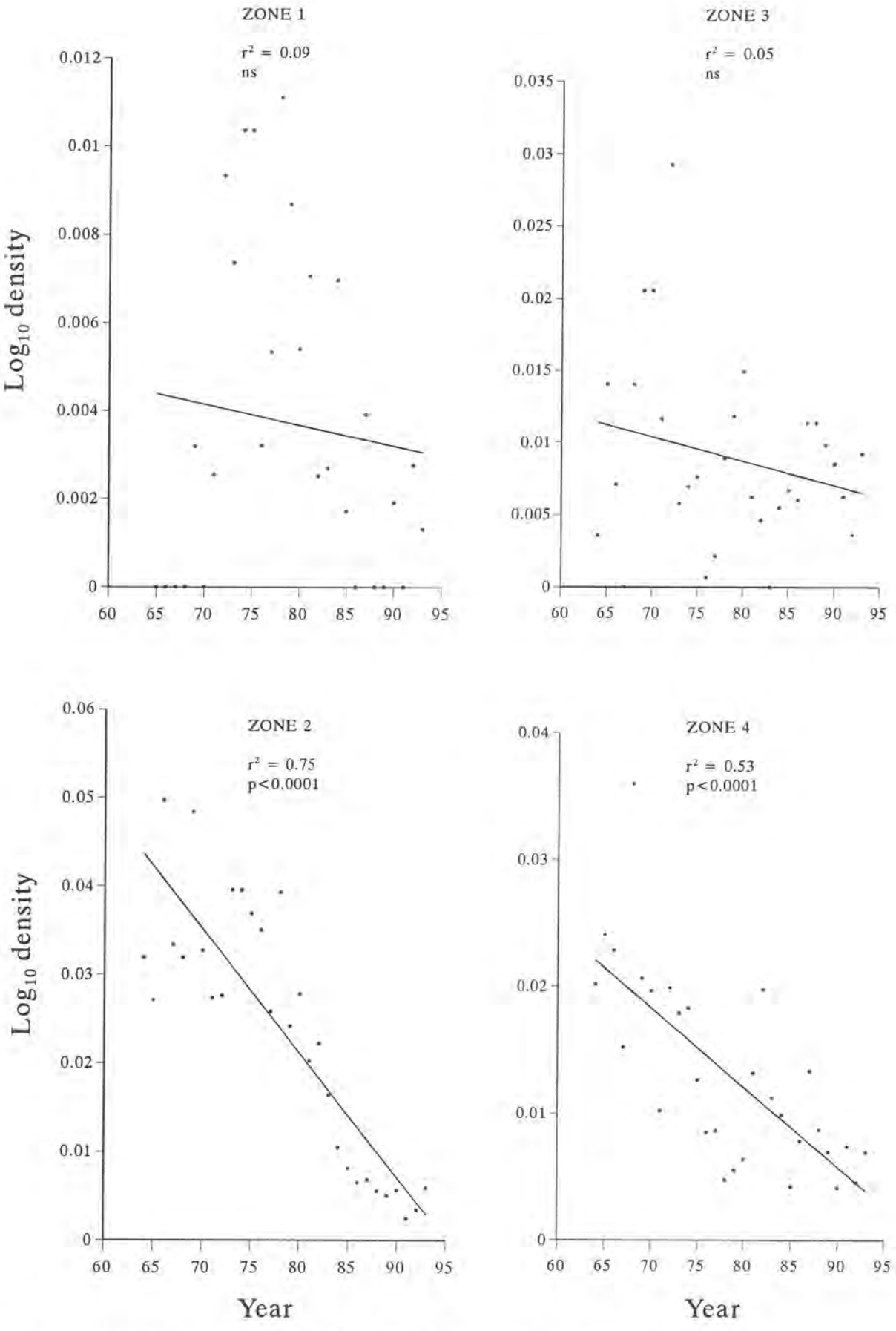

Fig 3.r ANCOVA, $F_{3,29}=4.35$, $p<0.007$.

STARLING:WOODLAND

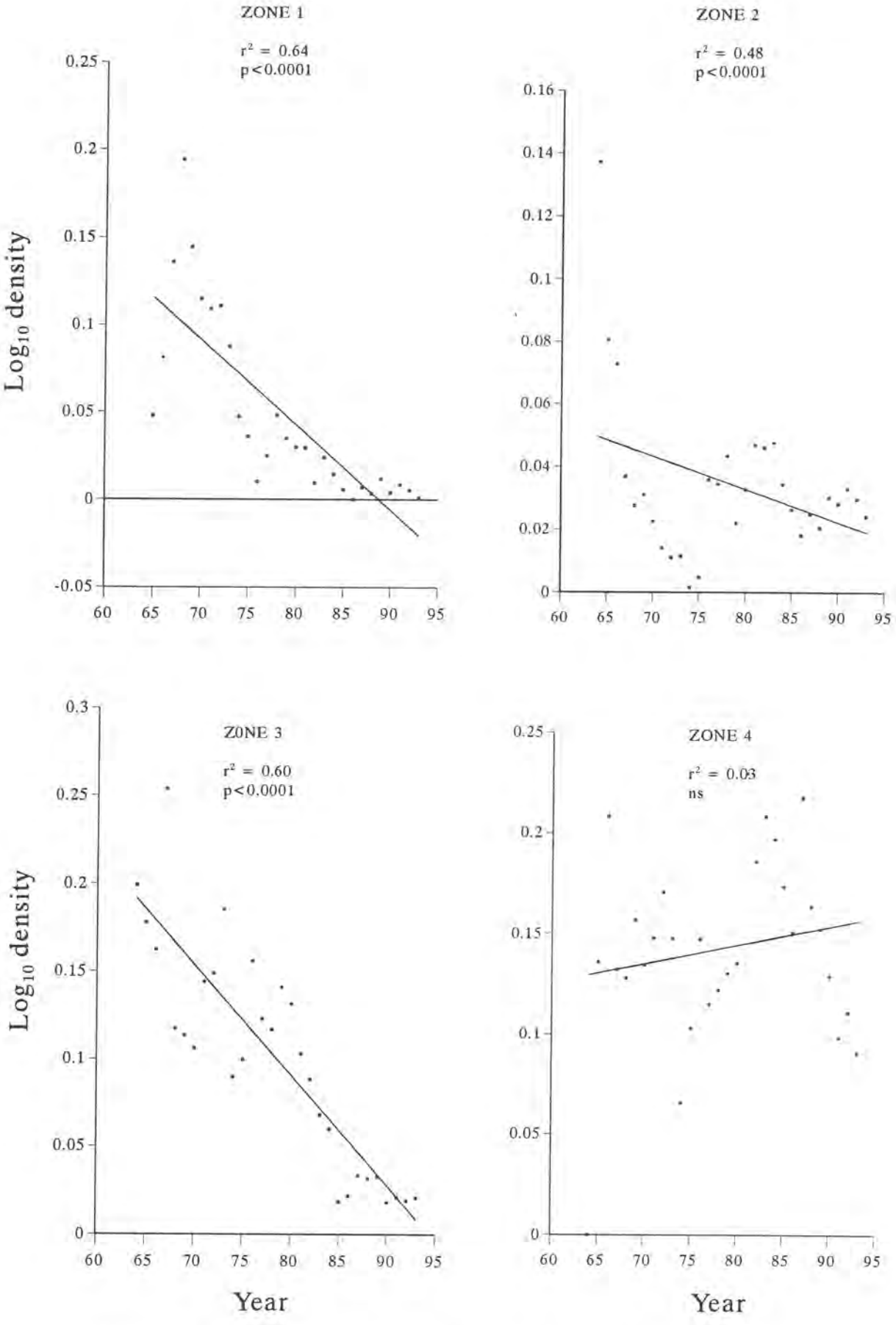

Fig 3.s ANCOVA, $F_{3,29}=11.8$, $P<0.0001$.

TREE SPARROW:WOODLAND

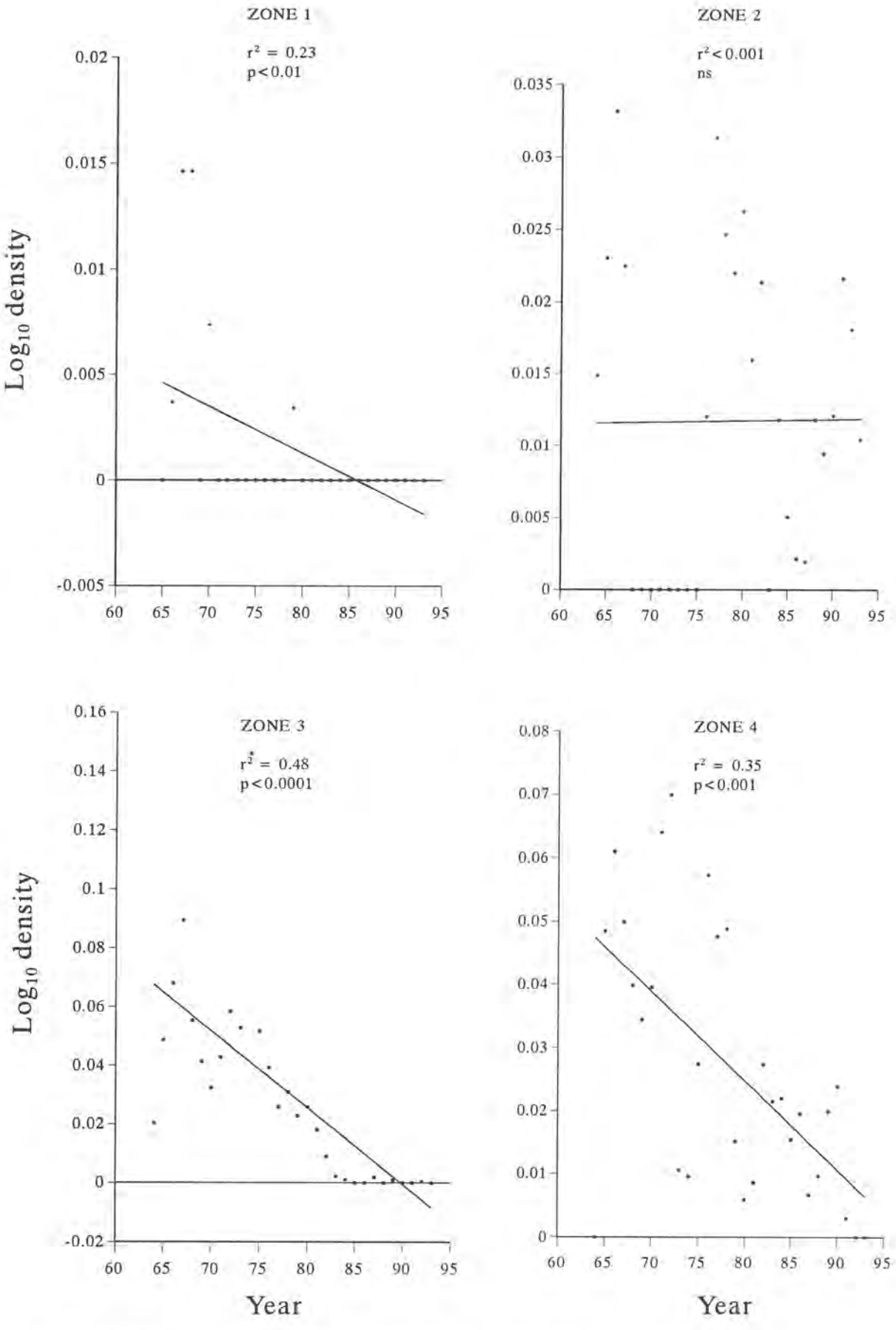

Fig 3.t ANCOVA, $F_{3,29}=13.13$, $P<0.0001$.

GREENFINCH:WOODLAND

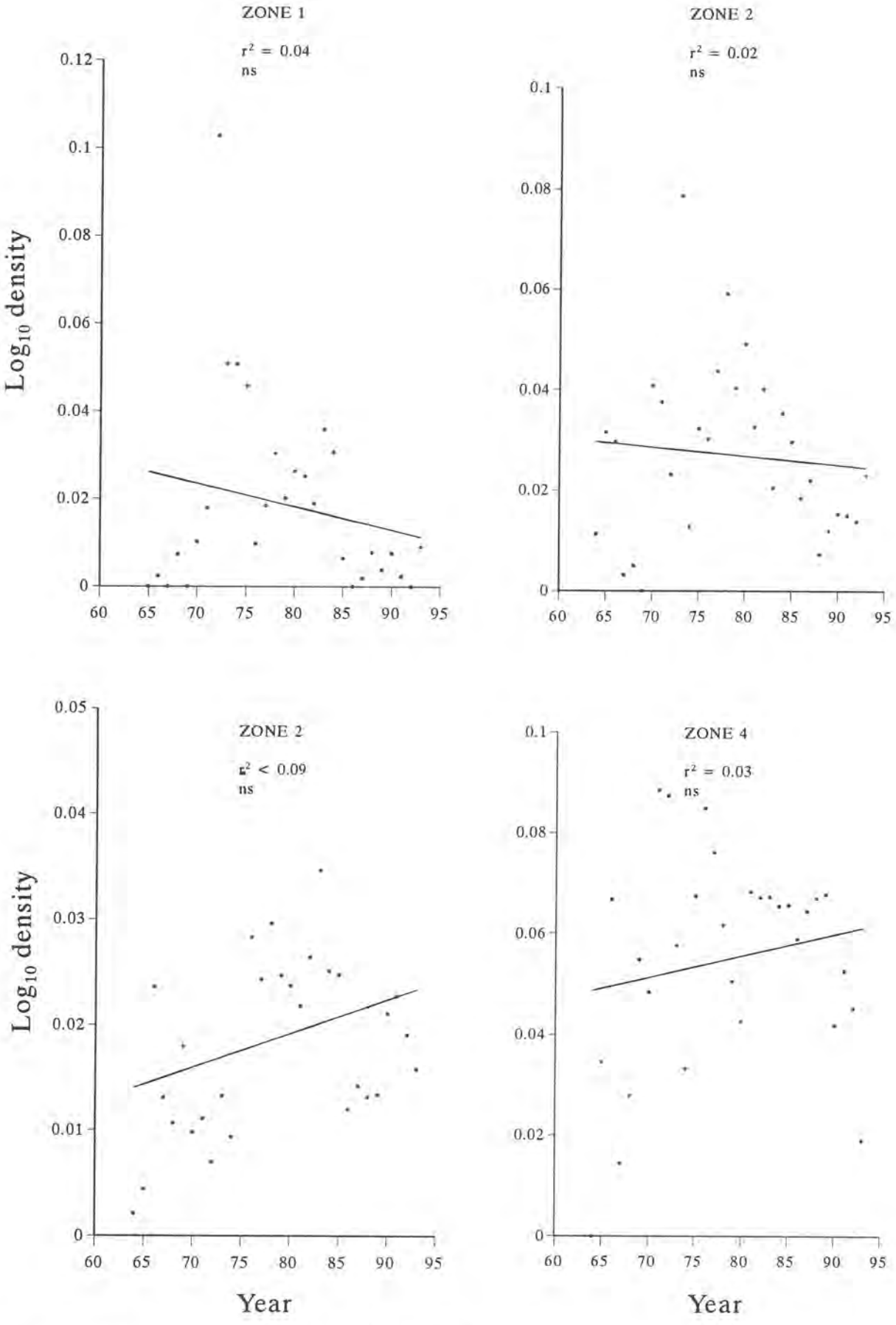

Fig 3.u ANCOVA, $F_{3,29}$=1.08, ns.

BULLFINCH:WOODLAND

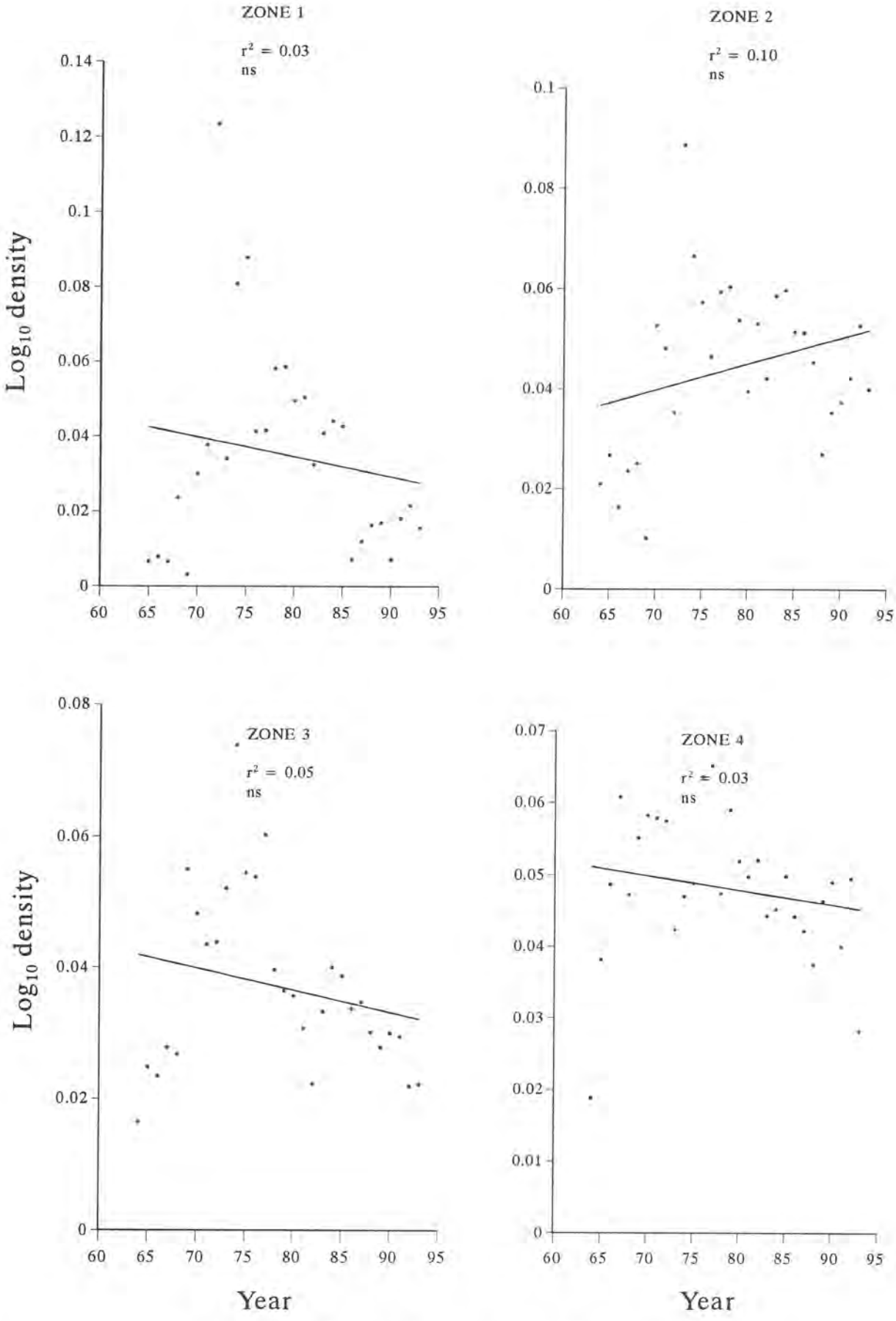

Fig 3.v ANCOVA, $F_{3,29}$=1.55, ns.

CHAFFINCH:WOODLAND

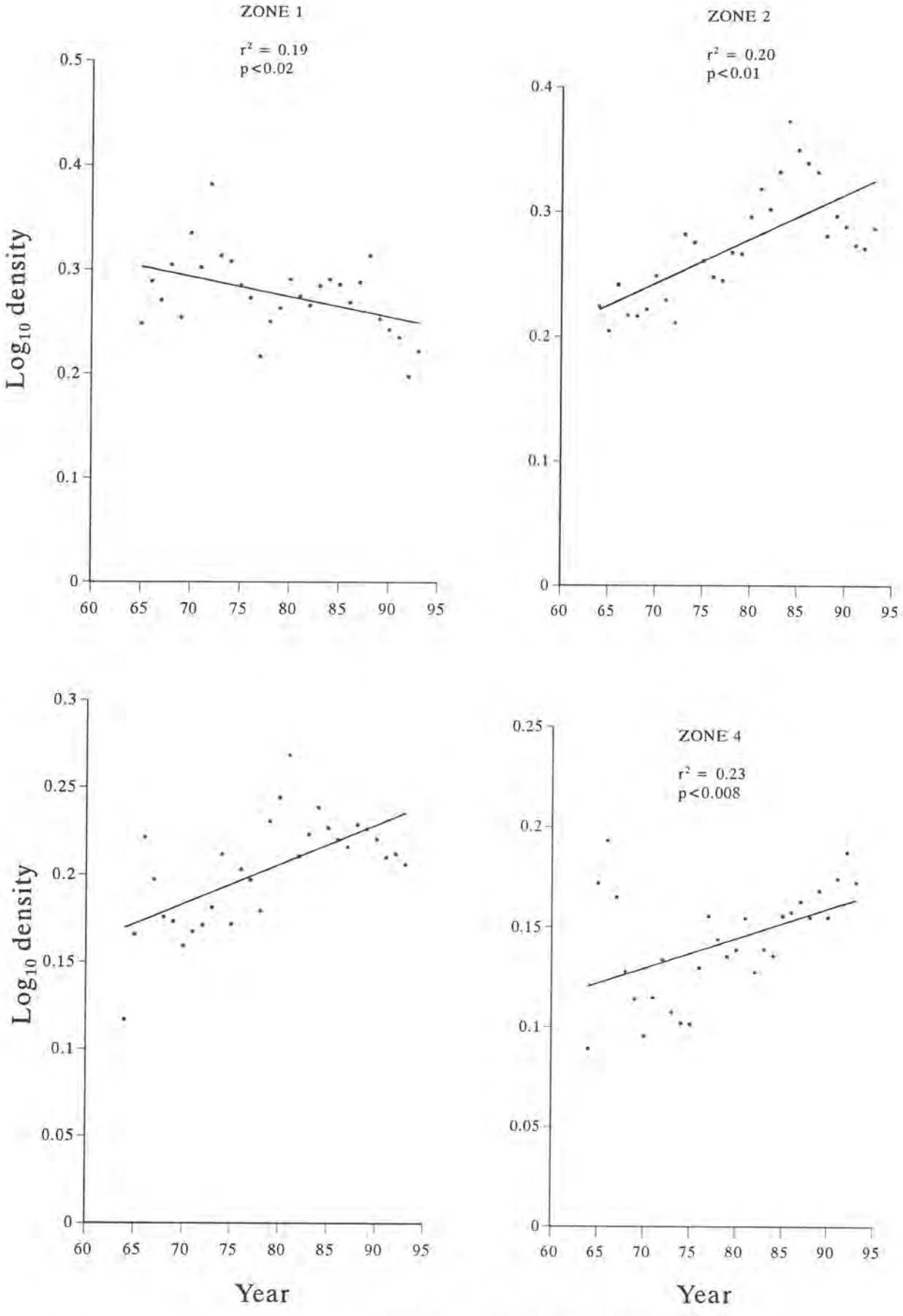

Fig 3.w ANCOVA, $F_{3,29}=14.19$, $P<0.0001$.

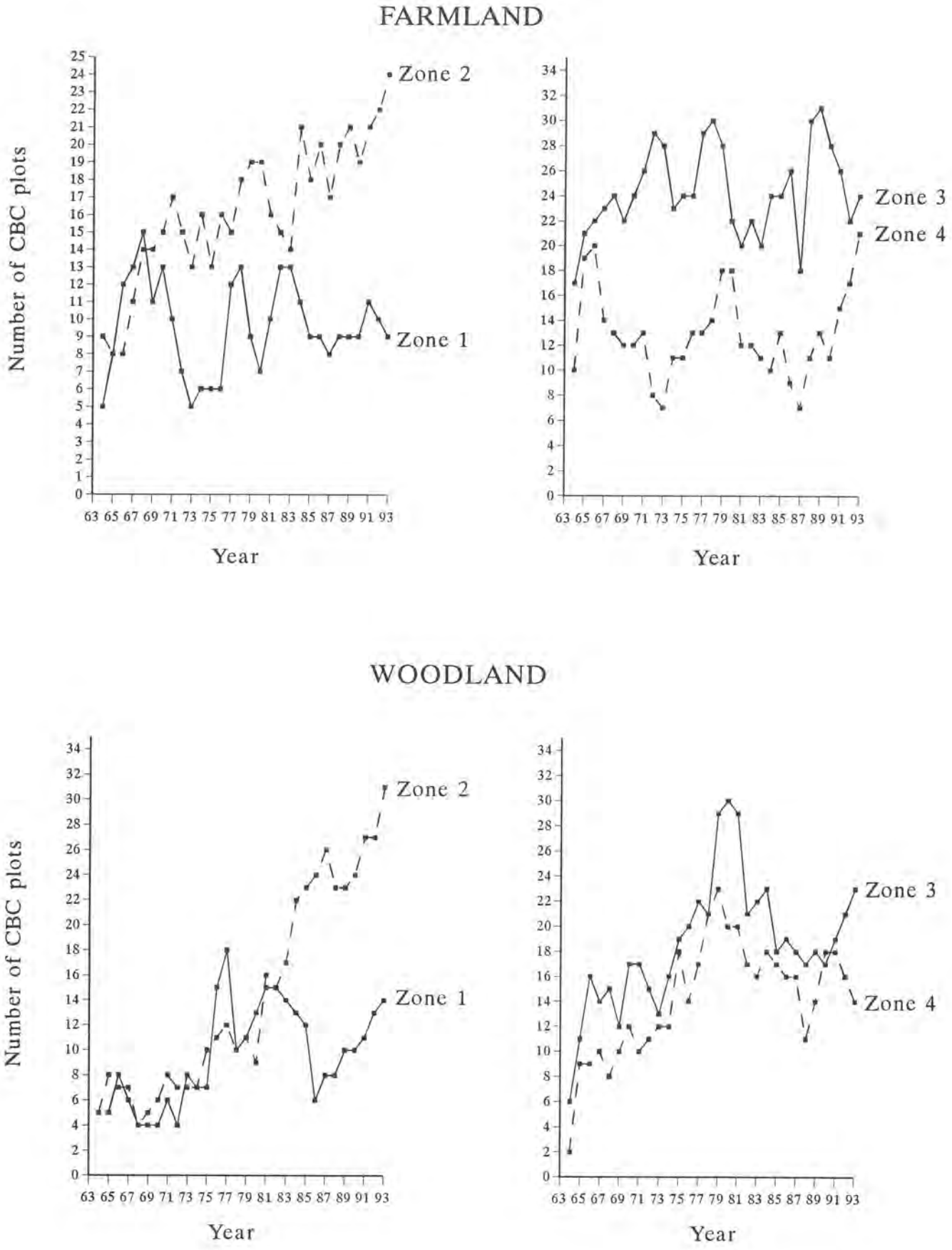

Fig 4. Annual number of farmland and woodland plots used in the analysis in each zone, between 1964 and 1993.

Front cover: Sparrowhawk, by Sarah Kelman / BTO; Back cover: Sparrowhawk, by Edmund Fellowes / BTO

An analysis of associated trends in Sparrowhawk abundance and potential prey species in woodland and farmland habitats.

This study used data from the Common Birds Census to test for correlations between temporal trends in the abundance of Sparrowhawks and the abundance of a range of potential prey species during the period 1964 to 1993.

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