FIGURE 1

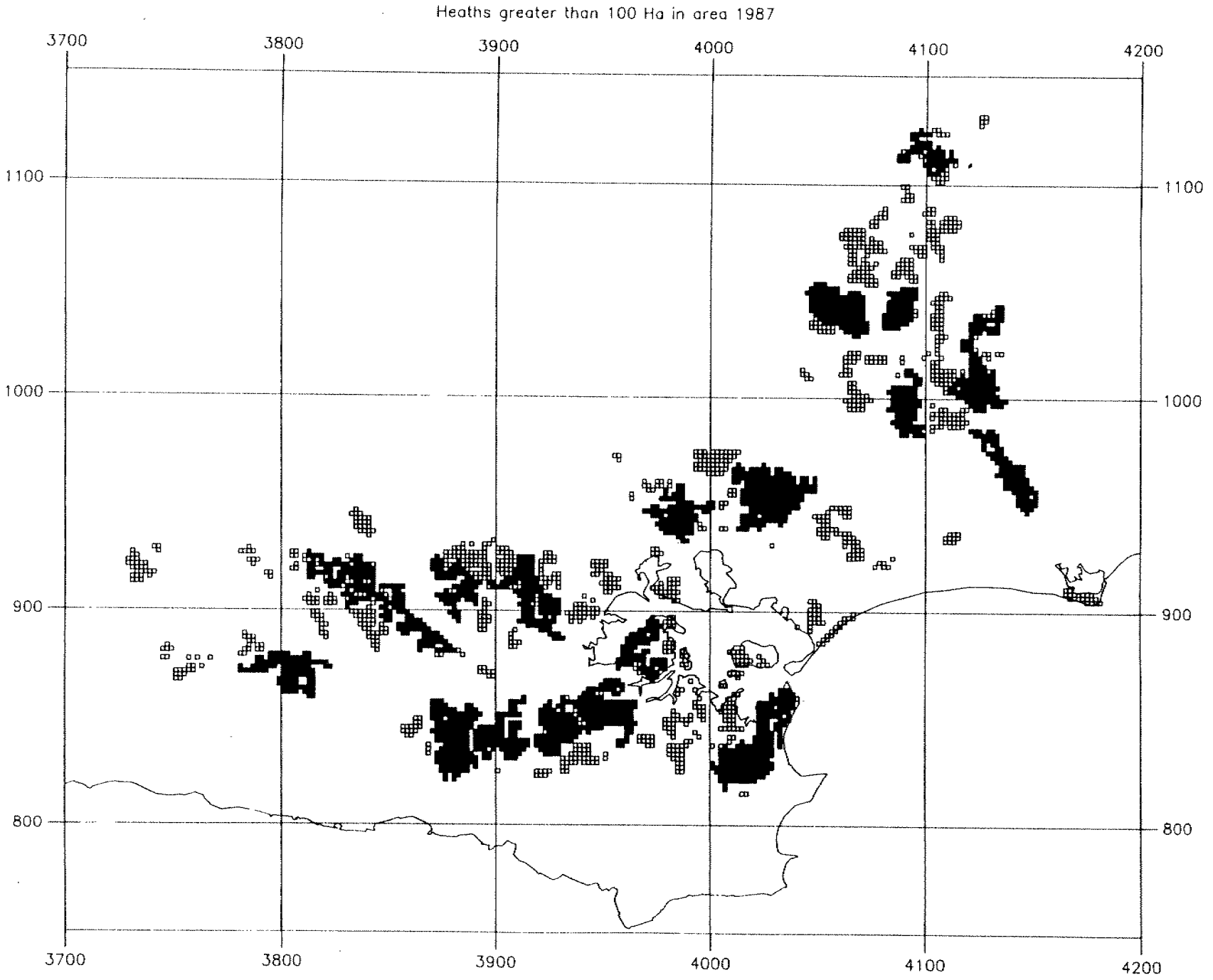
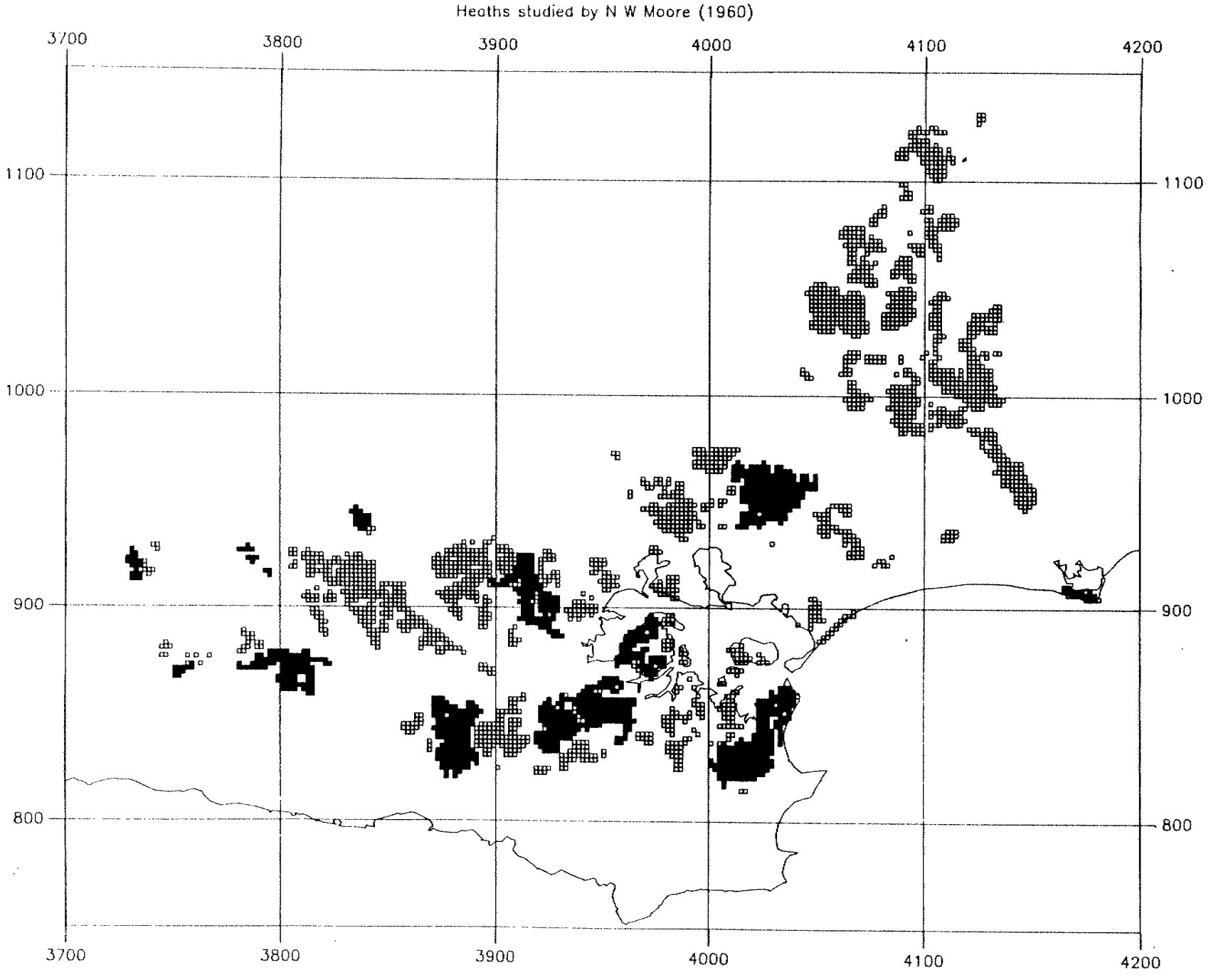

Heaths greater than 100 Ha in area 1987
3700
3800
3900
4000
4100
4200
1100
1000
900
800

FIGURE 2


Heaths studied by N W Moore (1960)
3700
3800
3900
4000
4100
4200
1100
1000
900
800

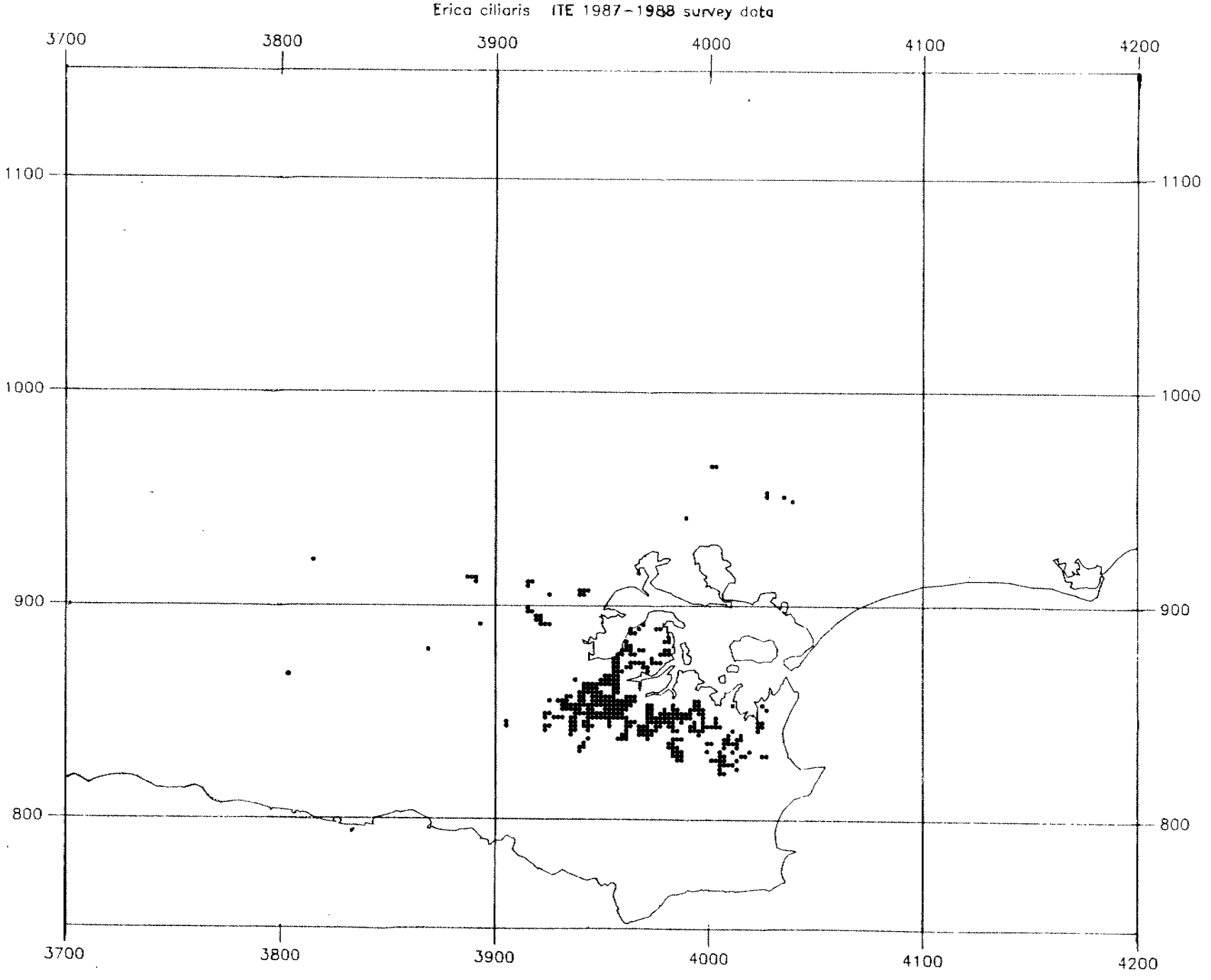
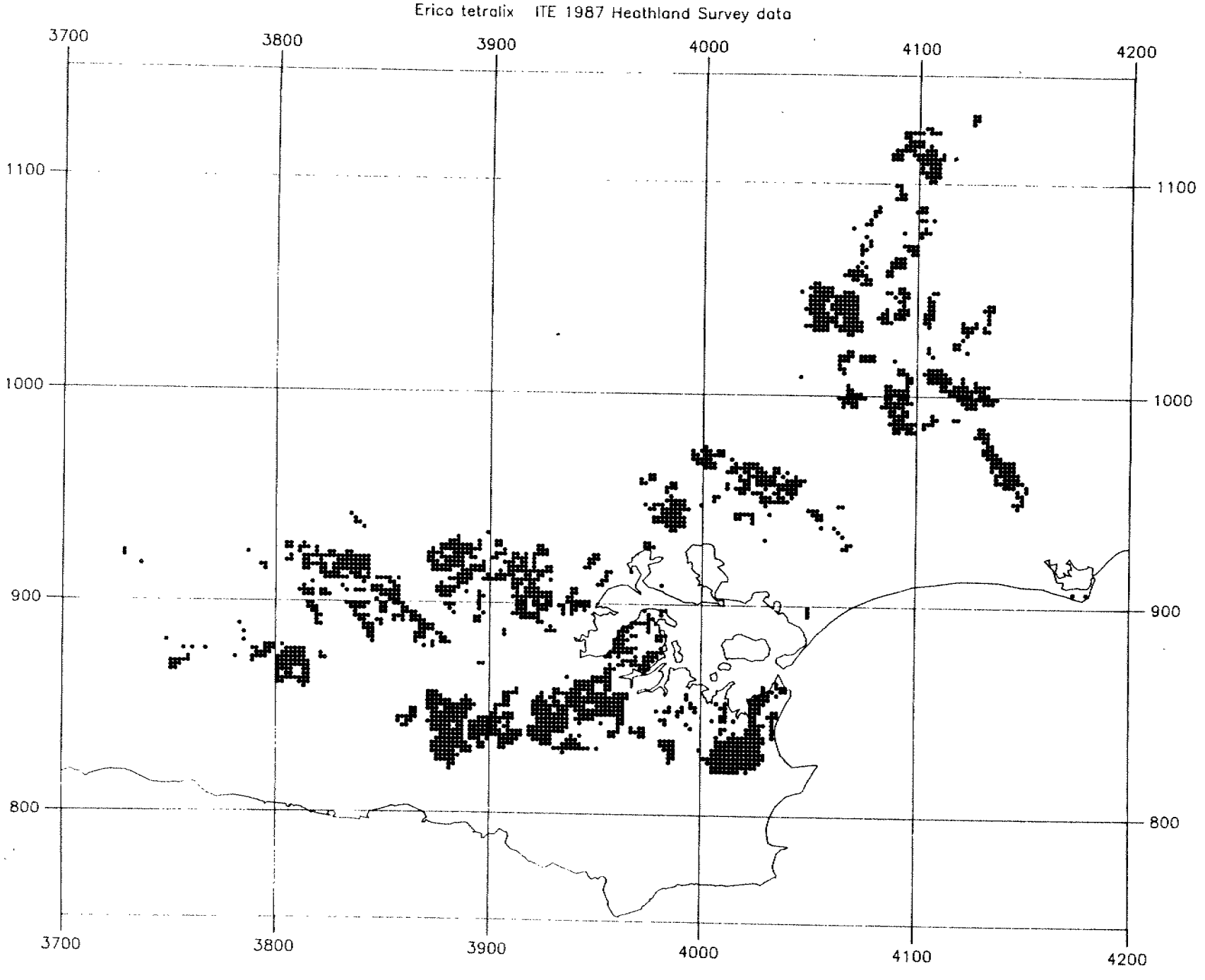

Erica ciliaris ITE 1987-1988 survey data
3700
3800
3900
4000
4100
4200
1100
1000
900
800

FIGURE 4


Erica tetralix ITE 1987 Heathland Survey data
3700
3800
3900
4000
4100
4200
1100
1000
900
800

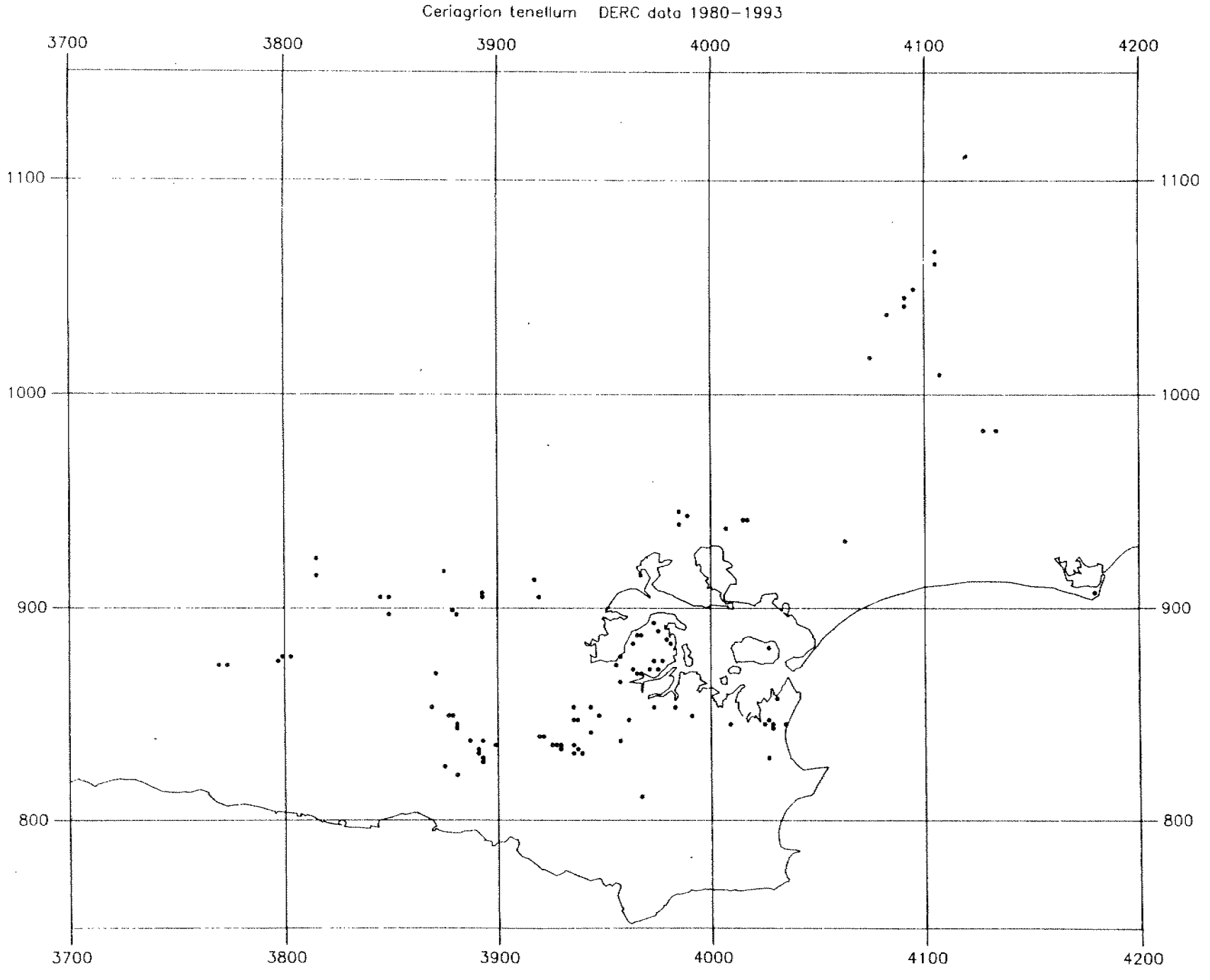
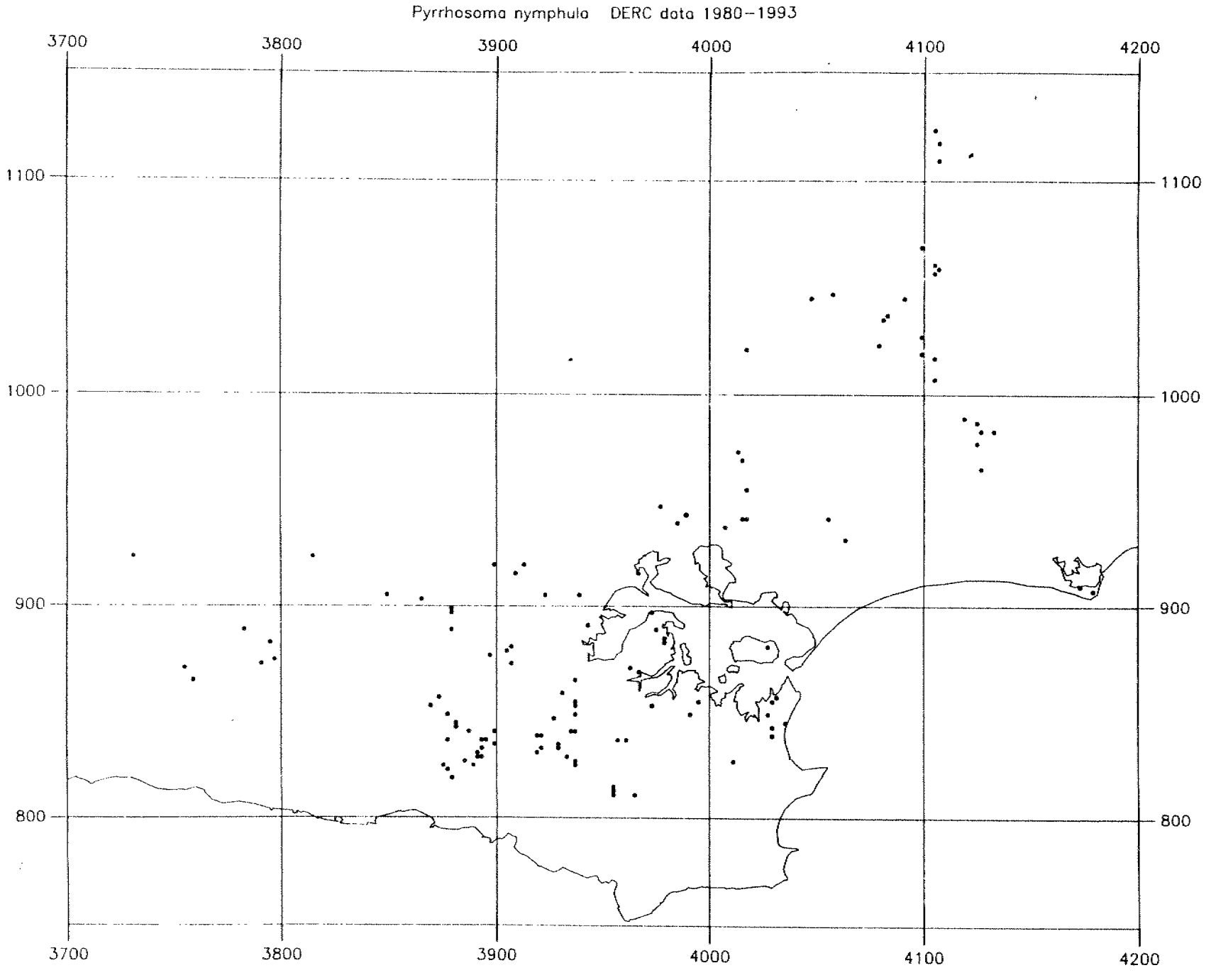
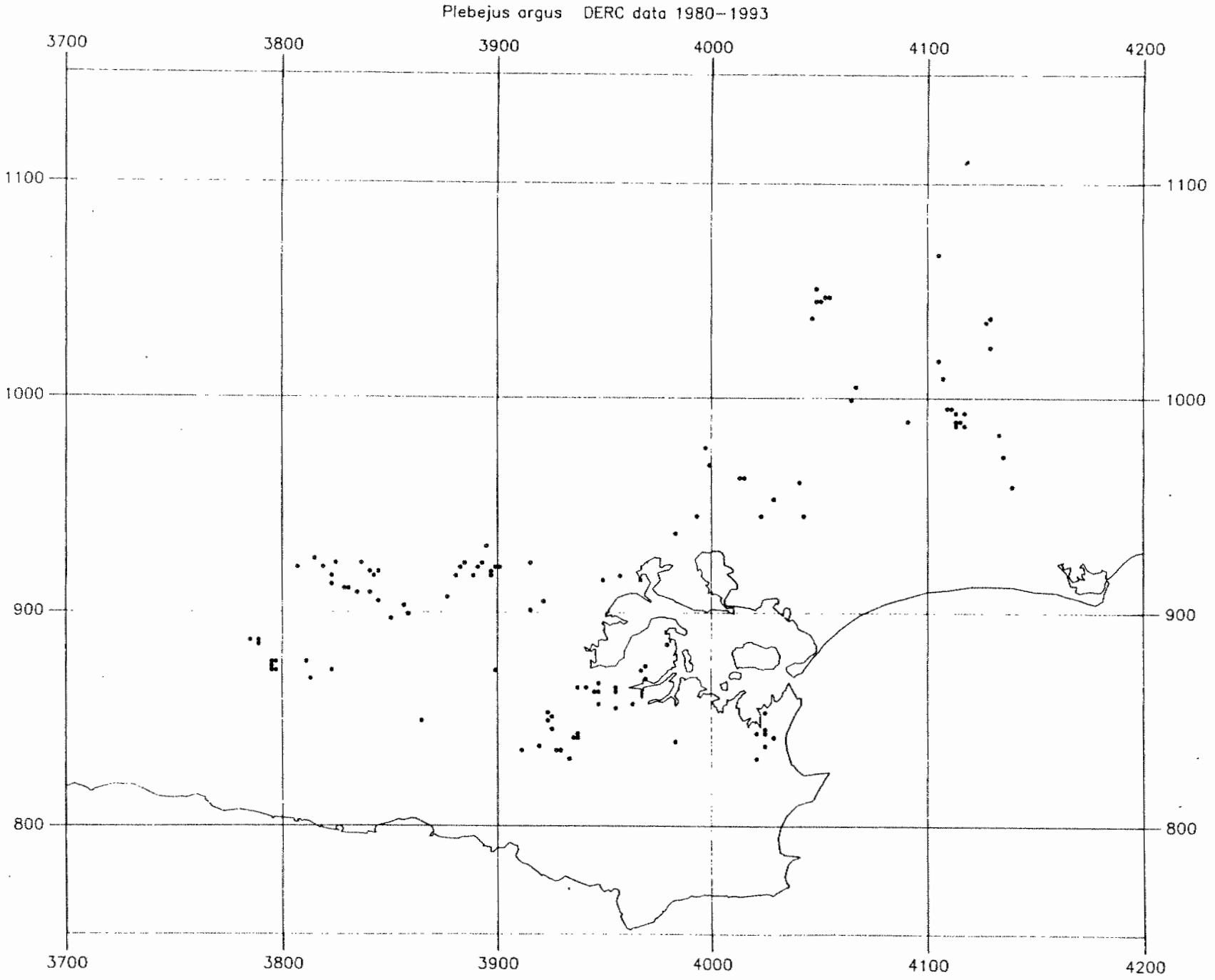
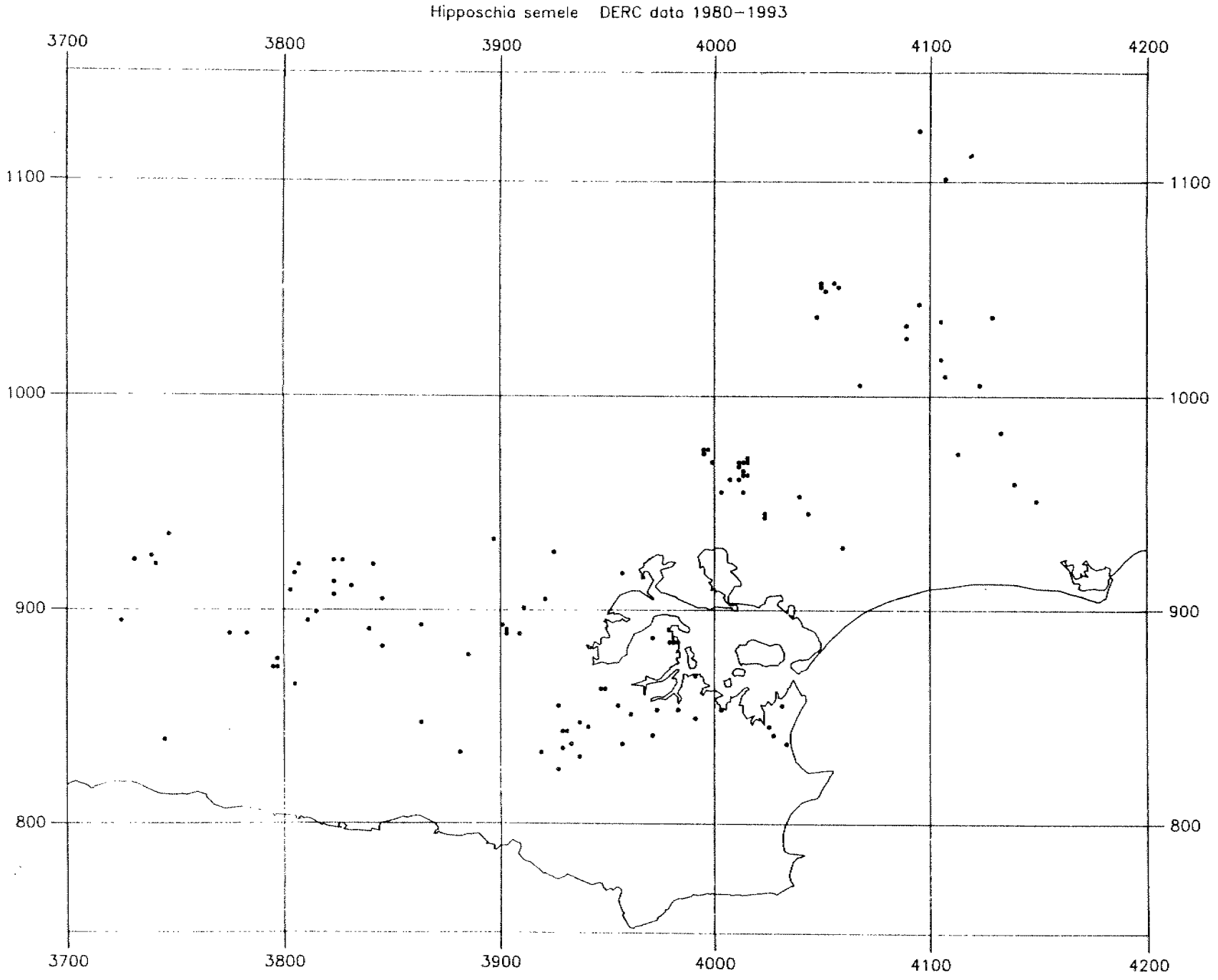

Ceriagrion tenellum DERC data 1980–1993
3700
3800
3900
4000
4100
4200
1100
1000
900
800

FIGURE 6


Pyrrhosoma nymphula DERC data 1980–1993
3700
3800
3900
4000
4100
4200
1100
1000
900
800


Plebejus argus DERC data 1980–1993
3700
3800
3900
4000
4100
4200
1100
1000
900
800


Hipposchia semele DERC data 1980–1993
3700
3800
3900
4000
4100
4200
1100
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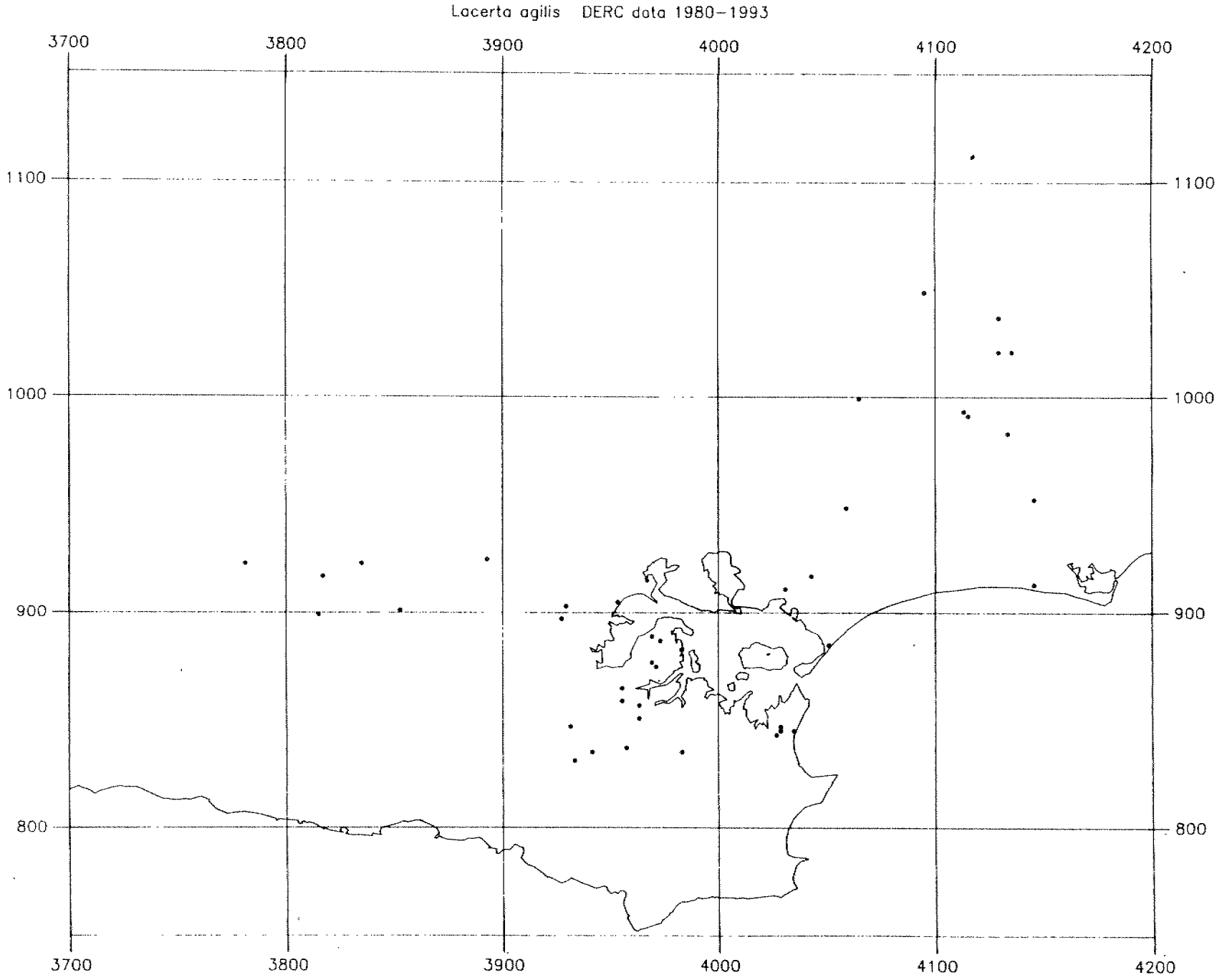
900
800


Lacerta agilis DERC data 1980–1993
3700
3800
3900
4000
4100
4200
1100
1000
900
800

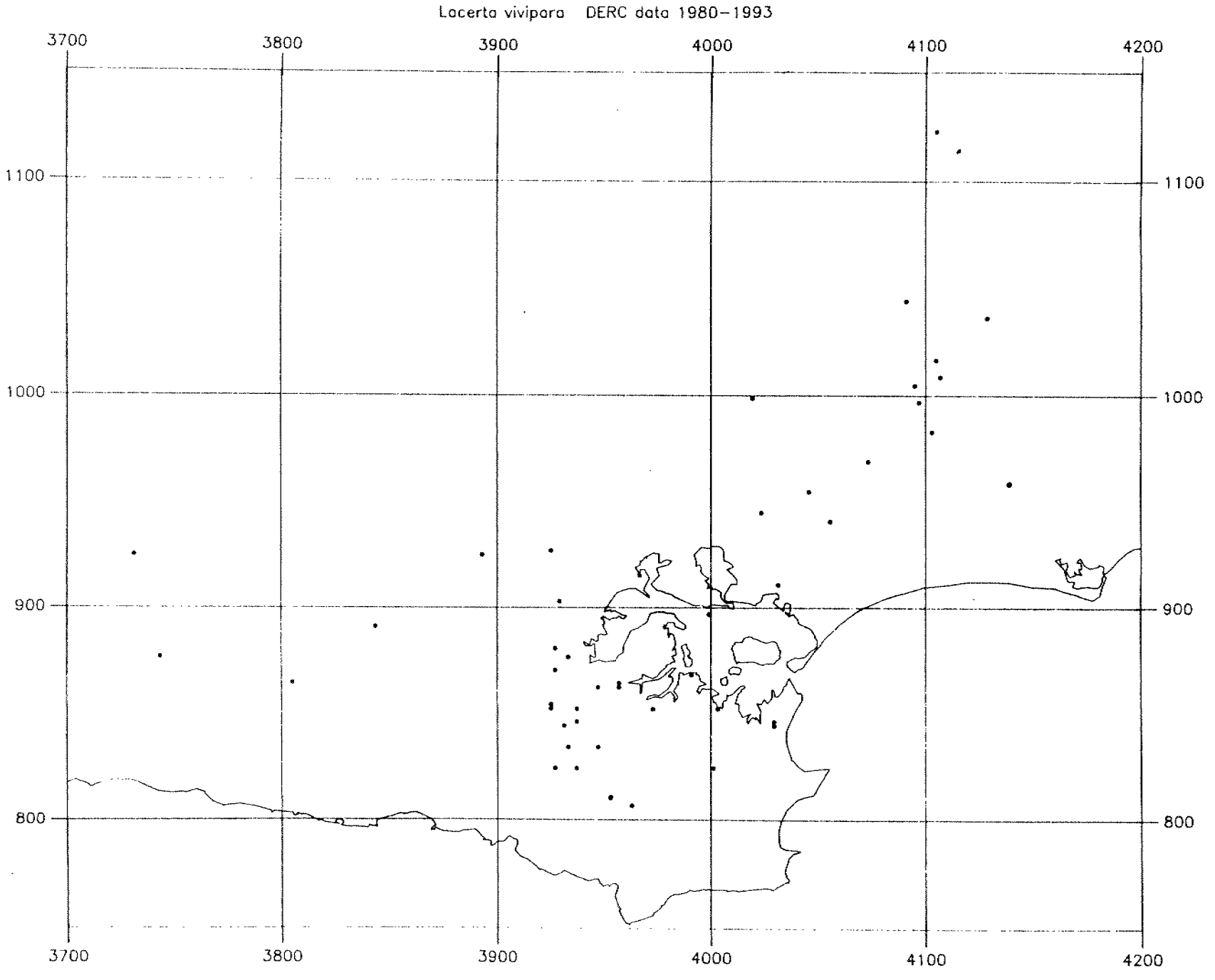

Lacerta vivipara DERC data 1980–1993
3700
3800
3900
4000
4100
4200
1100
1000
900
800

FIGURE 11

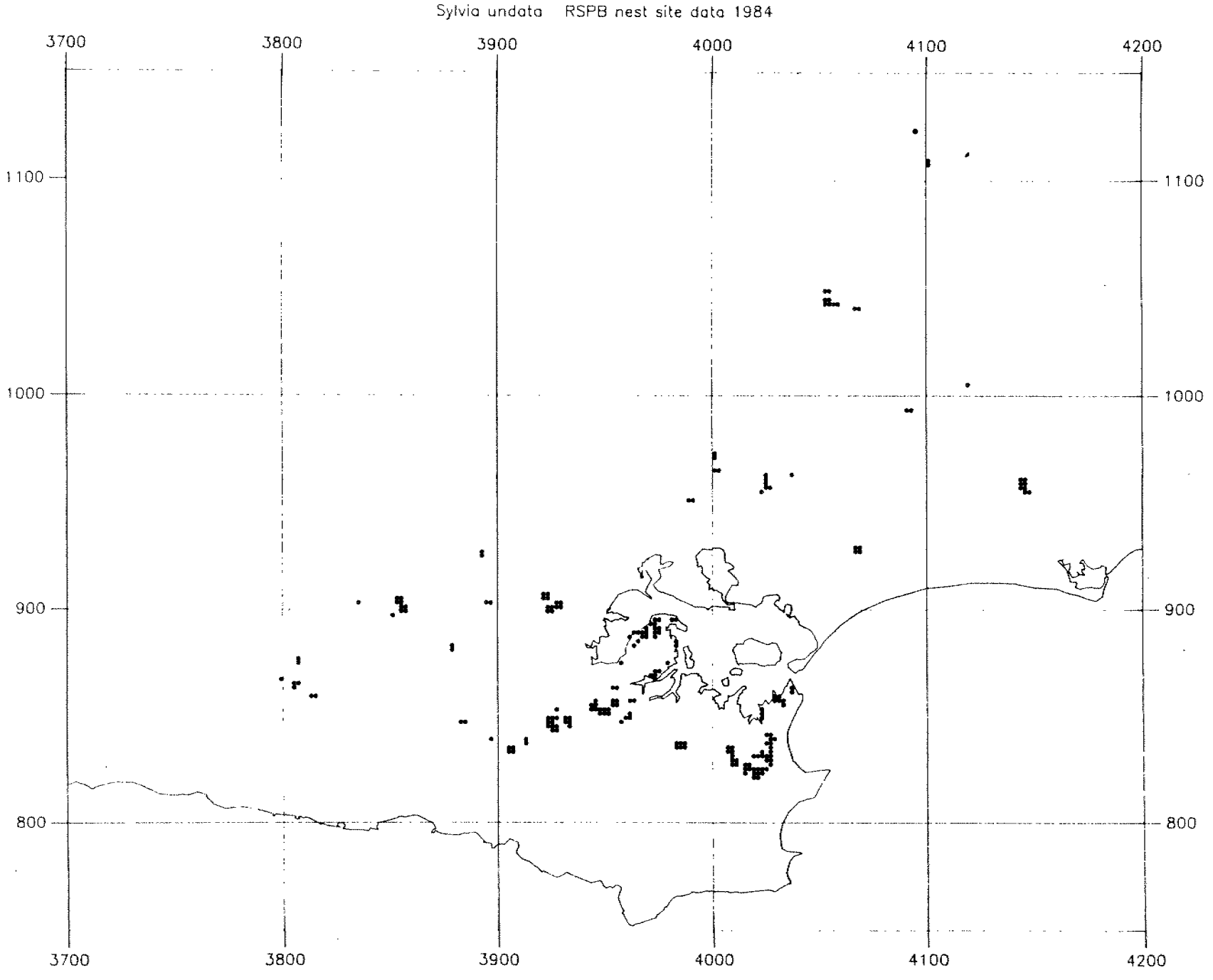
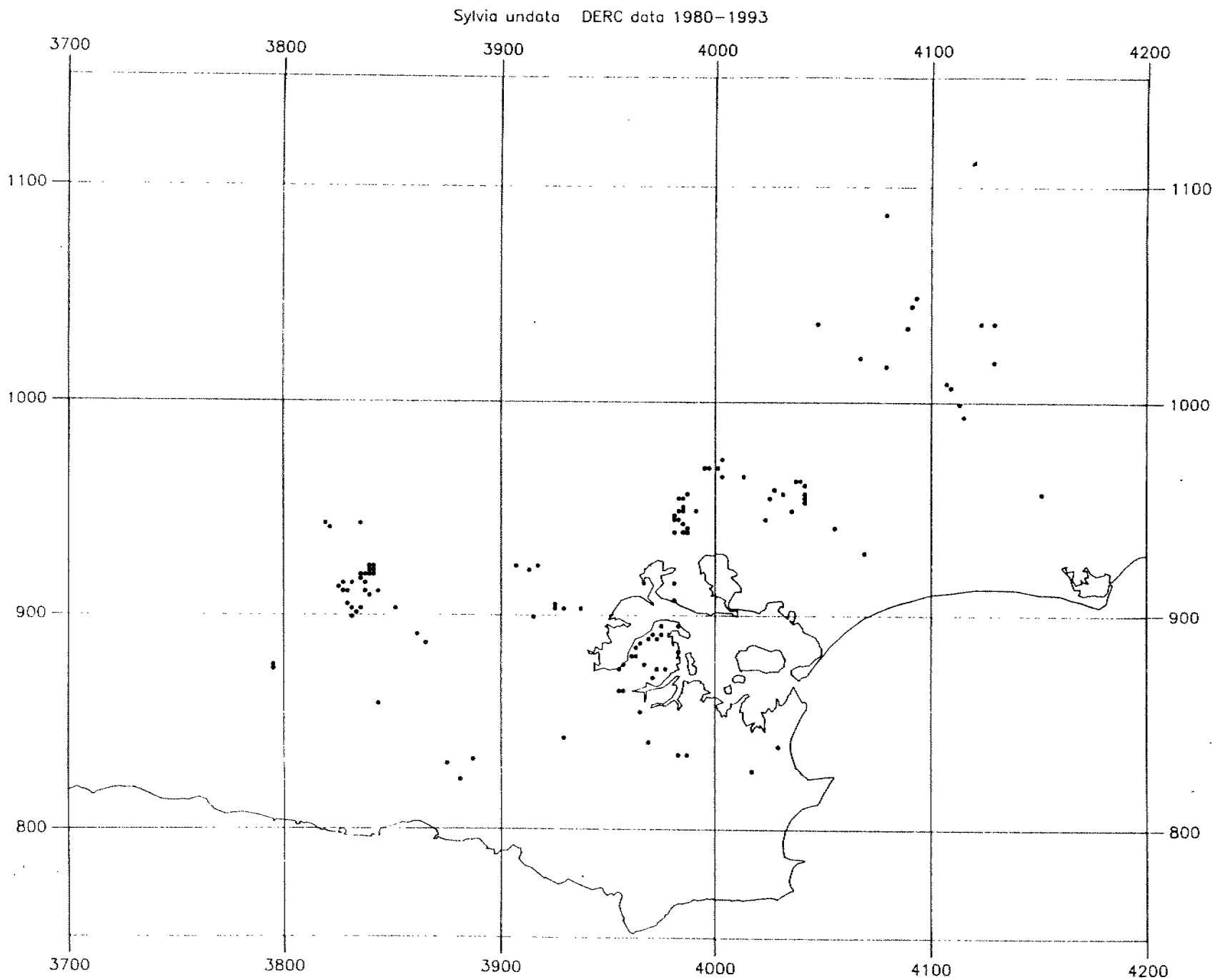

Sylvia undata RSPB nest site data 1984
3700
3800
3900
4000
4100
4200
1100
1000
900
800

FIGURE 12


Sylvia undata DERC data 1980–1993
3700
3800
3900
4000
4100
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1100
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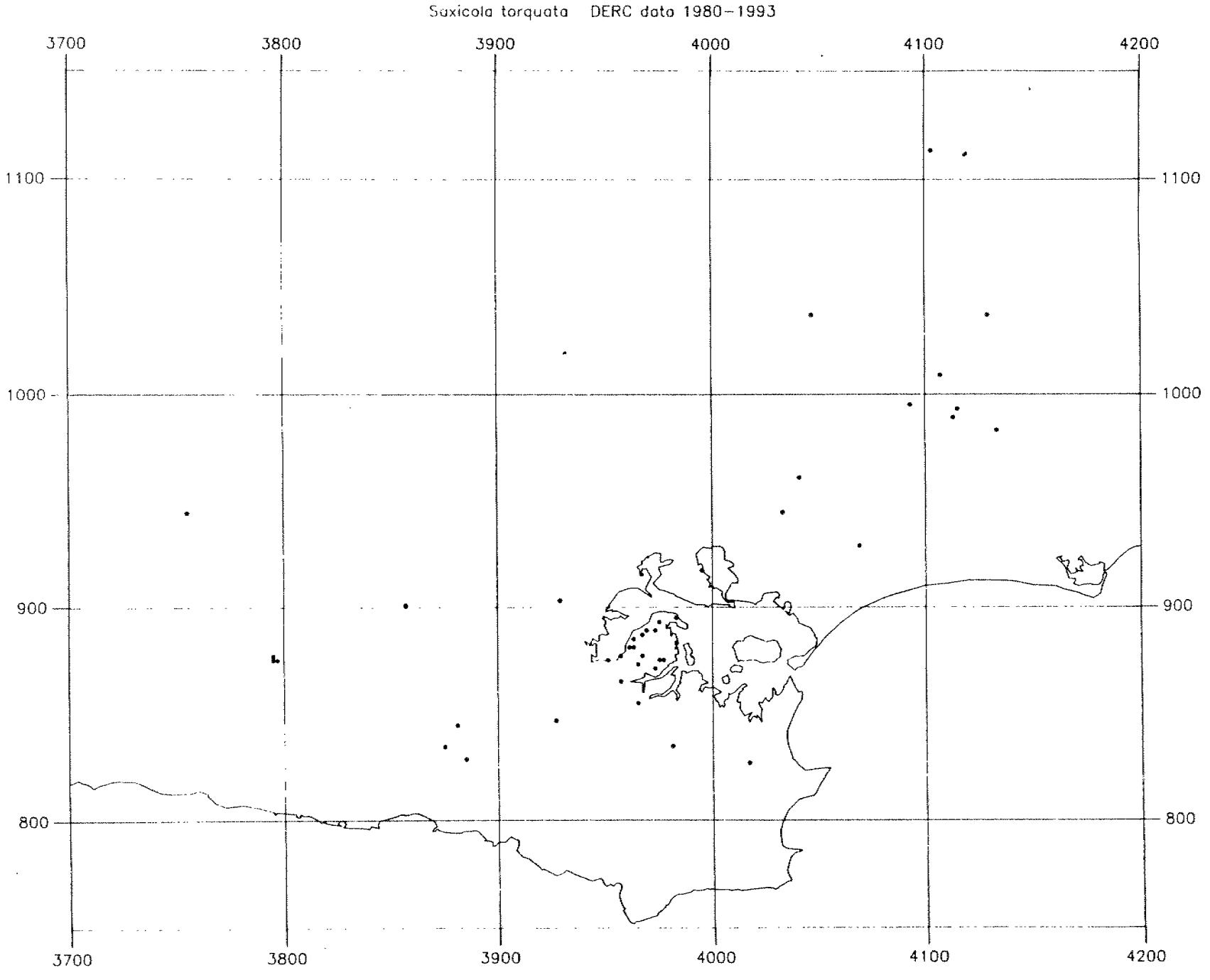

Saxicola torquata DERC data 1980–1993
3700
3800
3900
4000
4100
4200
1100
1000
900
800

4 RESULTS

4.1 Current distribution of indicator species

For 12 of the 13 heaths where Moore compared the occurrence of 4 heathland animal species with 4 more widespread species (Figure 9 in Moore 1962) the same exercise has been repeated (Table 4). The current exercise has omitted the outlying heath at Blackdown to the west of Dorchester.

Seven of the heaths can be regarded as large (>100 ha). On four, Decoy Heath, Middlebere/Creech Heaths, Arne Heaths and Studland/Godlingston Heaths there has been no change. Moore recorded 4 heathland species in 1960 and 4 remain today. Canford Heath which originally contained all 4 species appears to have lost one, *Lacerta agilis*; however, this species is known to be present on that heath, despite its absence from the DERC records.

Winfrith lacks *Lacerta agilis* in the recent data and possibly lacked it in Moore's survey. Winfrith is the second smallest of the large heaths and the most isolated. Arne is smaller but is close to other large heaths, notably Middlebere. It is also a nature reserve and has been intensively managed by the RSPB. These reasons may account for the continued presence of all the indicator species at Arne.

Povington Heath formerly contained all four heathland indicators and appears to have lost two, *Lacerta agilis* and *Plebejus argus*. *P. argus* was recorded here in 1993 by ITE and it is probable that *L. agilis* still occurs there.

Duddle Heath lacked all of the indicator species in Moore's survey and still lacks them. Although a medium sized heath (42.5ha), this is an isolated heath at the western edge of the main heathland area.

Warmwell Heath and Black Hill are two similar sites. Moore recorded two heathland indicators from Warmwell Heath in 1960; today none remains. The number of heathland species on Blackhill has decreased from 3 to 1, only the Dartford Warbler remaining.

Hengistbury Head is similar. It is a medium-sized site lying at the eastern-most point of the heathlands and is well isolated from other heathland. Moore recorded only one heathland indicator and only one remains, namely *Ceriagrion tenellum*.

The classic effect of fragmentation is shown by the Southover-Pallington groups of heaths. In Moore's time these three heaths were a single heath from which he recorded three of the heathland indicators. Today as a result of fragmentation none of the heathland indicators remains.

The changes in four species which are not stenotypic heathland species are also interesting. Duddle Heath still retains *P. nymphula*, *H. semele* and *L. vivipara*. From containing all four species Warmwell heath now retains only *P. nymphula*. The Southover-Pallington group has lost all four species. Thus as a result of fragmentation this heath has lost all eight species. Blackhill formerly contained 2 of the 4 widespread species but now contains none. Povington Heath appears to have lost *L. vivipara*, (a decline from four to three) but this may be apparent and due to a lack of records. Likewise Arne, Studland and Canford Heaths appear to have lost this species but this lack of

Table 4

A comparison of the presence of 8 heathland indicator animals between 1960 and 1980-93. H = stenotypic heathland species; G = more widespread species not completely dependent on heathland.

Heath No	Name	1960 H	1960 G	Area 1960	1980-93 H	1980-93 G	1987 Area (ha)
4	Duddle H	0	3	42	0	3	42.5
7	Warmwell	2	4	37	0	1	32.9
12	Winfrith	3	3	131	3	3	277.7
14	Southover)						(6.7
15	Pallington)	3	4	31	0	0	(1.8
17	Pallington)						(2.0
27	Blackhill	3	2	72	1	0	51.6
31	Povington	4	4	1159	2	3	499.3
40	Decoy/Northport	4	4	270	4	4	302.7
46	Middlebere	4	4	883	4	4	699.5
56	Arne	4	4	335	4	3	233.0
81	Studland/Godlingston	4	3	706	4	3	602.4
91	Canford	4	4	872	3	3	470.6
141	Hengistbury	1	4	37	1	1	33.7

records is probably the reason. Hengistbury Head formerly contained all four species but now only contains *P. nymphula*.

Several general features are apparent in the data. Over the thirty years most of the heaths have been reduced in area (Table 4). Over the same period there as been a decline in the number of the indicator species present on all sites. Whereas there was no significant relationship with area in 1960 the number of species now correlates significantly with heathland site area (Spearman Rank Correlation $r_s = 0.810$; $p < 0.005$).

It should be noted that in general the small heaths selected by Moore lie at the periphery of the Dorset Heathlands and hence it is difficult to separate the effects of area and isolation. It is likely that isolation in combination with changes in the quality of the heath are responsible for the decline in species number (This aspect is still under analysis). For 1960 the plot of species against area (Figure 15a) shows a rapid increase in species number with area on the small sites and a levelling off on the large. With only 8 species the asymptote is soon reached. However, when this figure is compared with the current figure (Figure 15b), it can be seen that although the large sites have tended to loose species, this is at a slower rate than the small sites. The latter group of sites has lost species very rapidly. These conclusions confirm the predictions made by Moore (1962) that species losses would continue to occur on the Dorset heathland patches.

A variety of effects may be at work. First, isolated sites may be expected to loose species in the way predicted by biogeographic theory. Secondly, this loss may be accelerated by changes on these sites due to succession and invasion which will affect a greater proportion of the site than on large sites (Webb & Vermaat 1990). Thirdly, the capacity of the large heaths to provide immigrants to sustain populations on the smaller heaths may have declined. Such a decline could be caused by an increase in scrub and woody vegetation on the large heaths. In the 1987 Dorset heathland Survey it was noted that there had been a 15% increase in scrubby vegetation since the similar survey in 1978 (Webb 1990).

It is also interesting to note that in general the heaths appear to have lost the least mobile species. On those heaths where only one species remains, it is either the Dartford Warbler or one of the two Odonata species. These must be regarded as the most mobile of the eight indicator species. Possibly *Plebejus argus* and *Lacerta agilis* can be considered as the least mobile.

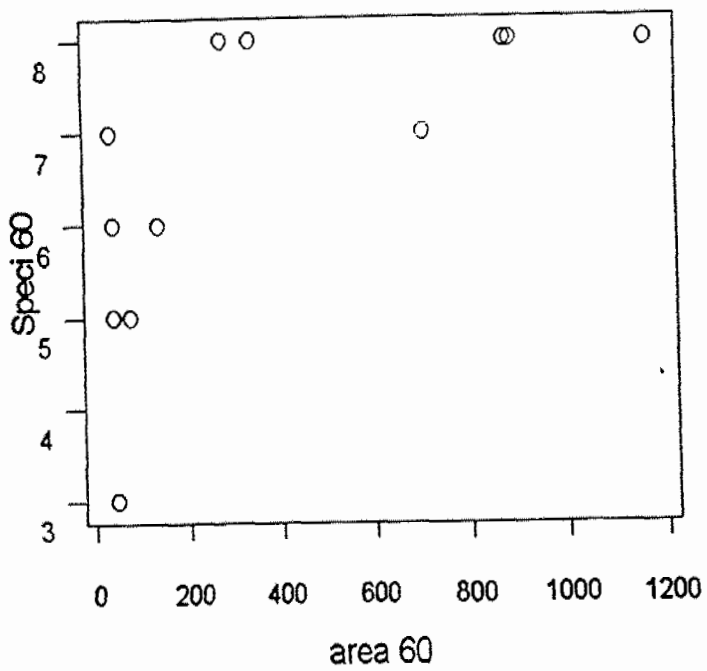
4.2 Effects of isolation

The smaller sites chosen by Moore lie at the periphery of the Dorset heathlands. Immigration to these sites is to some extent directional in contrast to a small site lying in the middle of the Dorset heaths where there are other heaths encircling the site to provide a source of colonists. Currently we are attempting an analysis to examine the relationship between the number of species and the distance from the centre of the Dorset Heaths. This should be possible using computer software suitable for the analysis of the pattern of movements shown by radio-tagged animals.

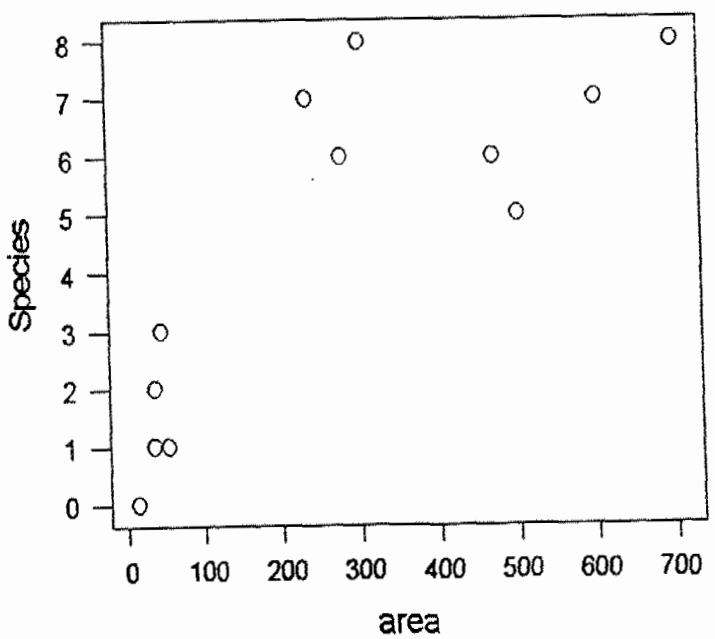
FIGURE 15

Graphs in which the number of heathland indicator species has been plotted against the area (ha) for the heaths surveyed by Moore (1962) in 1960 (a) and in 1990 (b)

a)



b)



5 DISCUSSION

5.1 Indicator species

Moore used his ten indicator species to assess the effects on land use change on the flora and fauna of the Dorset heathlands. By and large, he considered major changes in land use where the heathland had been converted to another use such as forestry or agriculture. In some cases, despite the change in use remnants of heathland remained and the potential for some of the indicator species to persist also remained. However, changes in the quality of the heathland biotope such as those arising from succession or the effects of conservation management are more subtle and it is difficult to recognise species which will show measurable responses to this type of change.

Moore showed (Moore 1962 Table 4) that where there was a land use which involved little or no modification to the heathland such as grazing, military ranges or golf courses few if any of the ten indicator species were lost. Much the same was true of newly afforested areas. On new mineral workings and in mature plantations all the species were lost. Farmland with hedgerows and gardens occupied an intermediate position with the two species of lizard often remaining. The lizards disappeared from young plantations but some species such as the Silver-studded blue (*Plebejus argus*) sometimes persisted in forest margins and along ride edges.

5.2 Characteristics of Moore's Indicator Species

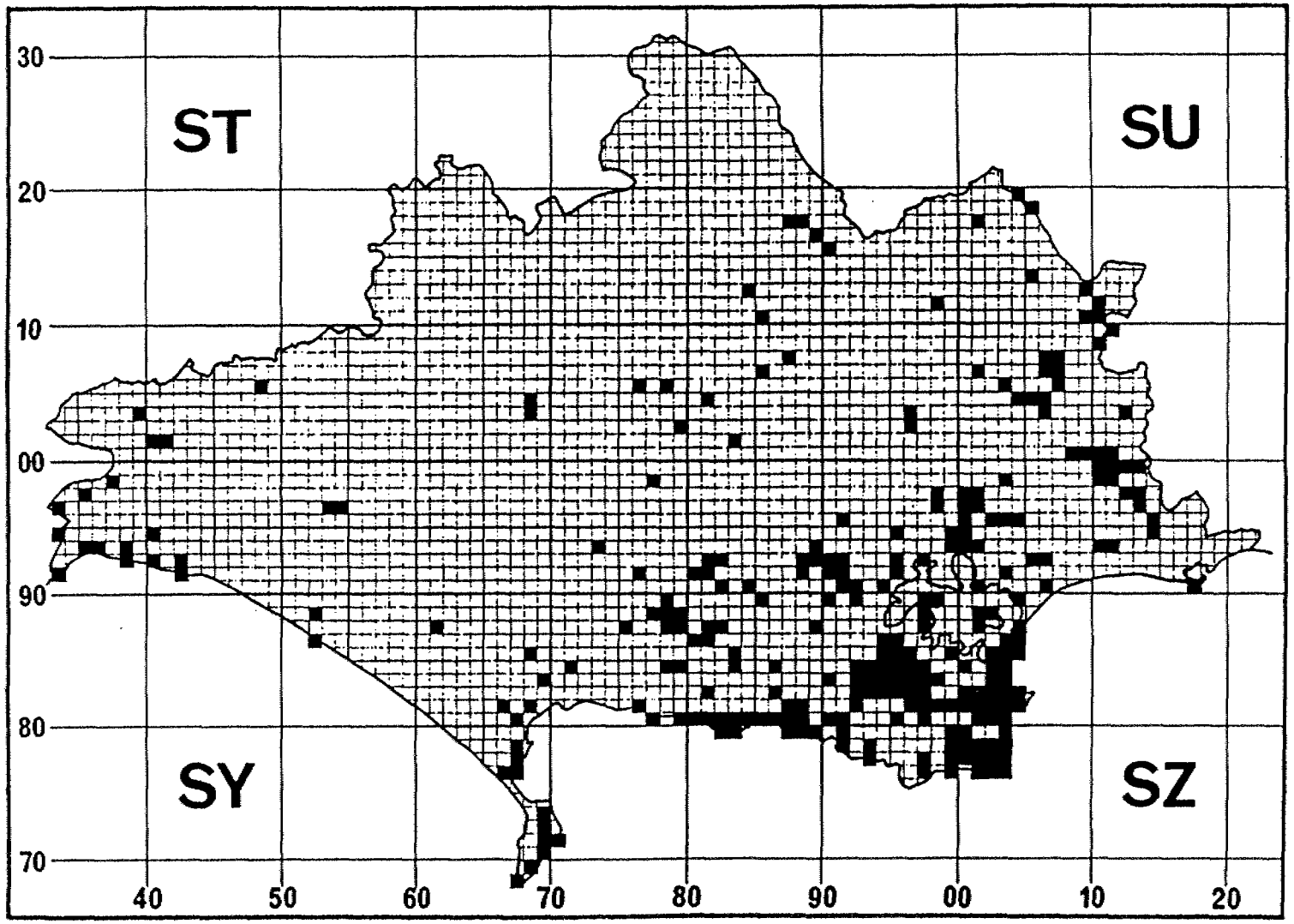
The characteristics of Moore's indicator species are worth considering since in two cases views on the species have changed. Dorset Heath (*Erica ciliaris*) has its British stronghold on the Purbeck heaths. As a result of extensive survey work its current distribution is well known (Figure 4) (Chapman & Rose 1994 in press). Formerly, it was thought to be a species whose range was more extensive, but research has shown that this species colonised the Wytch area about 3500 years ago and that it has been slowly expanding (Chapman & Rose 1994 in press). The main concentration of plants remains in Purbeck but outlying plants have been located elsewhere (Figure 4).

The status of the Grayling (*Hipparchia semele*) on the Dorset heaths is widely thought to have changed since Moore's survey. In 1960 is was more abundant on dry grasslands and is considered to have declined (Thomas & Webb 1984). Maps prepared by DERC for 1970-1979, 1980-1989 and post 1990 (Figs 16-18) detail these changes. Although the Grayling has declined markedly on the dry calcareous grasslands over the last thirty years, there have been fewer changes on the heathlands; indeed, the map for the 1980s suggests that there may have been an increase but this can probably be ascribed to the operation of an intensive butterfly recording scheme during this period.

The value of the Dartford Warbler is also problematic as a heathland indicator. This species is present on these heaths throughout the year and there is a small but not assessed degree of immigration from the mainland of Europe. The Dartford Warbler is prone to population crashes following severe winters and exhibits typical density-independent mortality characteristic of species living at the edges of their range. From a low in 1962 the population has slowly built up, despite intervening hard winters, to its highest density for many decades. This type of population dynamic makes this species less useful as an indicator. It is not clear what is the carrying capacity of the

Distribution of Grayling (Hipparchia semele) pre-1980

FIGURE 16



Distribution of Grayling (Hipparchia semele) 1980-89 FIGURE 17

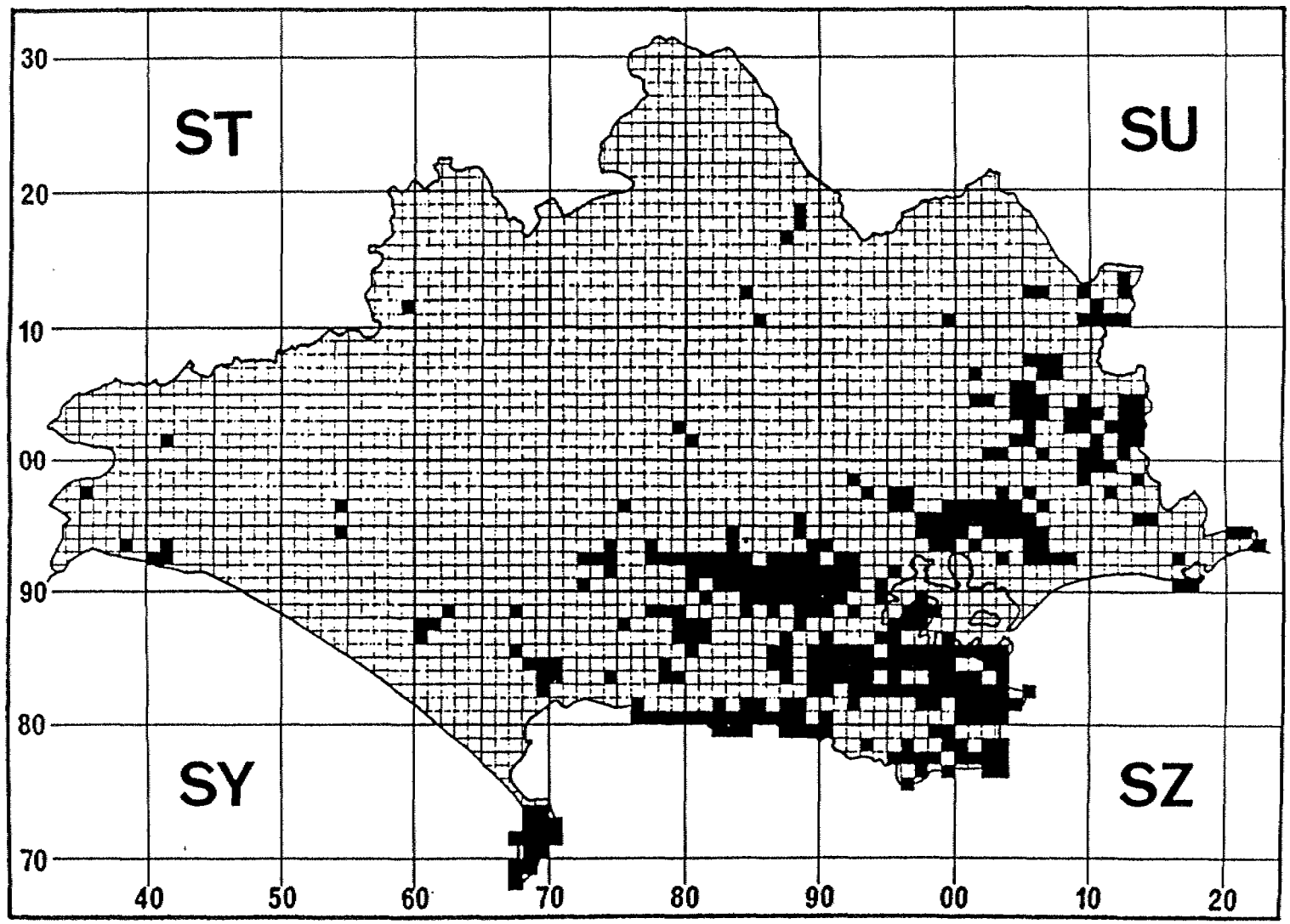
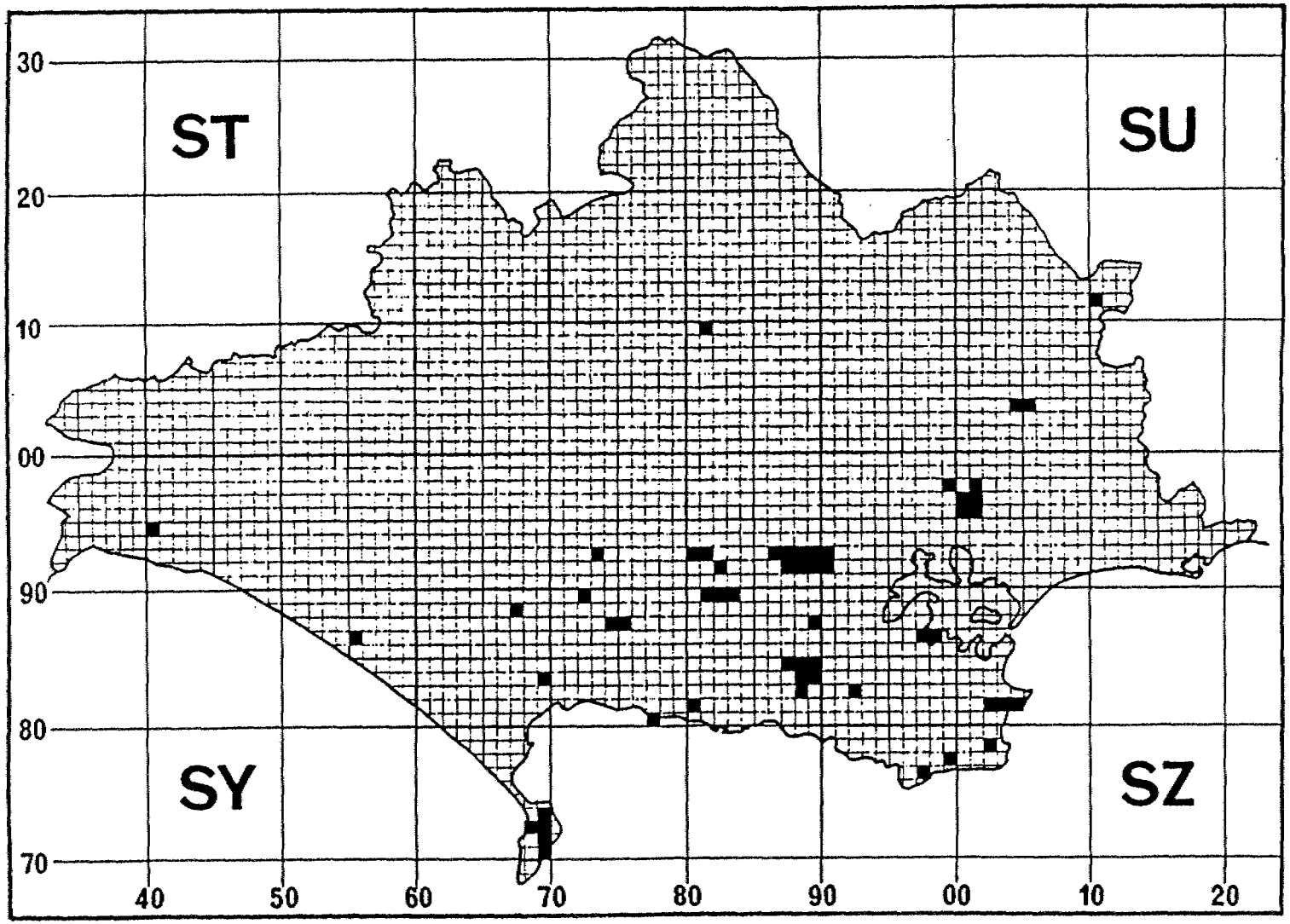


FIGURE 18

Distribution of Grayling (Hipparchia semele) 1990-93



Dorset heaths for this species since under current conditions the amount of habitat available never seems to be a limit to its density.

5.3 The Distribution of DERC Records

To gain an impression of how strongly the Moore Indicator species were associated with "good quality " heathland we performed a simple analysis in which the 200 x 200 m grid squares of the Dorset Heathland Survey in which the species occurred were classified into one of three types; namely, not heathland, heathland occupying < 50% of the square and heathland occupying >50% of the square.

For the two dragonflies, it can be seen that although both species are present in all three types of square, there is a tendency for *C. tenellum* to occur in the heathland squares. Much the same pattern is evident for all the other six species. *P. argus* occurs predominantly on heathland and so do both Dartford Warbler and Stonechat. The distribution of records for lizards show the *L. vivipara* occurs widely off the heathlands.

This exercise demonstrates what could be done to identify a set of species which could serve as indicators, but the result is subject to bias depending on the number and the distribution of localities from which the records originate.