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# THE EFFECTS OF COLLISIONS WITH OVERHEAD LINES ON BRITISH BIRDS: AN ANALYSIS OF RINGING RECOVERIES

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# THE EFFECTS OF COLLISIONS WITH OVERHEAD WIRES ON BRITISH BIRDS: AN ANALYSIS OF RINGING RECOVERIES.

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## SUMMARY

1. Literature concerning the problem of birds colliding with overhead lines is of two types: individual reports of rare or unusual birds colliding with overhead lines, and intensive local surveys which involved the collection of corpses and observations of overhead lines.

2. The only previous national survey of birds colliding with overhead lines was an analysis of the Swedish ringing recovery data. That survey was based on a relatively small number of recoveries caused by overhead lines.

3. For the present report, we aimed to analyse the very large set of recovery data from the British ringing scheme in order to document patterns of collisions with overhead lines within Britain and Ireland. Particular attention is paid to species with over 10 "hit wire" recoveries and species specially protected under Schedule 1 (Part 1) of the Wildlife and Countryside Act.

4. Methods for the trapping and ringing of birds are described briefly, together with the operation of the British Trust for Ornithology (BTO) Ringing Scheme. A brief history of the development of the ringing scheme is presented, in terms of increase in totals of ringed and recovered birds over time.

5. Procedures used for the computerisation of the ringing recovery data are described. Computer data fields are shown in Table 1, and recovery processing is explained in Appendix 1. Recoveries that are inaccurate or unreliable in any way are excluded from analysis, the exclusions being made following a standard set of rules.

6. Six categories of reported causes of death are studied: "found dead", "hit wire", "hit building", "hit window", "road accident" and "rail accident". EURING finding circumstance codes used to identify each of these are listed in Table 2.

7. The "hit wire" category contains all electrocution recoveries and all recoveries resulting from collisions with any thin man-made structure. The proportion of these recoveries attributable to structures other than overhead lines was checked by examining the qualifying text information for about two thirds of all "hit wire" recoveries. We conclude that the effects of spurious "hit wire" recoveries on the outcome of analyses are negligible. For example, only 0.5% of Mute Swan "hit wire" recoveries did not result from collisions with overhead lines while the comparable figure for Blackbird is 4.1%

8. To reduce biases caused by man-related mortality categories, collision deaths are expressed as a percentage of themselves plus the relatively unbiased "found dead" recoveries (ie. birds found dead from unknown cause). This proportion is referred to as a cause of death index. For example:

$$\text{hit wire index} = \frac{\text{"hit wire" recoveries} \times 100}{\text{"found dead"} + \text{"hit wire" recoveries}}$$

9. All species with 10 or more "hit wire" recoveries are selected for detailed analysis; a total of 46 species fulfil this criterion. Species with fewer than 10 "hit wire" recoveries are considered more briefly, but it should be noted that some of these are of special conservation interest.

10. For all species, collision mortality indices have been calculated and compared. For more detailed analysis, separate hit wire indices have been calculated for

regions of Britain and Ireland, calendar months, decades since 1954 and age classes. The regional divisions used are shown in Figure 1.

11. Chi-square is used to test for significent differences in cause of death indices between categories. Where this variation is significant, Haberman's method is used to locate the source of the variation. Trends are tested by calculating Spearman rank correlation coefficients ($r_s$); while Kendall's coefficient of concordance (W) is used to test the degree of similarity between species in the patterns of variation in the hit wire index.

12. Interpretation of the cause of death indices is discussed in detail. Direct quantitative comparisons between indices for different causes of death cannot be made due to differences in the reporting probabilities of recoveries with different causes of death. However, by taking account of obvious differences in reporting probabilities, some qualitative comparisons of the relative importance of different causes of death are possible.

13 Comparisons of individual cause of death indices between categories depend on the assumption that the ratio of the reporting rates for the specific cause of death category and the "found dead" category is the same in the samples to be compared. Small deviations from this assumption are unlikely to affect the conclusions reached (Figure 2). This applies both to comparisons between species and comparisons between categories within species.

14. Values of the cause of death indices might also be affected by errors in identifying the correct cause of death made by reporters of ringing recoveries and by variations in the composition of the ringed sample. The likely effects of such biases are discussed.

15. Hit wire indices are high for raptors and large waterfowl but low for passerines. Other groups are intermediate. There is a significant positive correlation between the hit wire index and the average weight of the species (Figure 3). This may be because manoeuvrability decreases with size.

16. Mute Swan, Canada Goose and Grey Heron are all large aquatic birds having particularly high hit wire indices.

17. Raptors have high collision indices, with hit wire values being large but not proportionately higher than for other types of collision. These high indices are thought to result from the birds regularly pursuing quarry at speed.

18. Waders, gulls and terns have moderate to low hit wire indices, there being considerable variation between species. Those which breed or winter inland in large numbers are most at risk, while indices are low for the essentially coastal and estuarine species.

19. Hit wire indices are low for all passerines. Within this group, the hirundines (Sand Martin, Swallow and House Martin) have the highest hit wire indices, probably due to their habit of congregating on wires after breeding and during migration.

20. Seventeen species protected under Schedule 1 (Part 1) of the Wildlife and Countryside Act have high hit wire indices. Four of these (Hen Harrier, Merlin, Peregrine and Barn Owl) have over 10 "hit wire" recoveries and therefore a more precise index. All four are birds of prey, as are five more of the specially protected species with high hit wire indices (Golden Eagle, Goshawk, Marsh Harrier, Montagu's Harrier and Red Kite). However the latter five all have few recoveries and less precise

indices. Four specially protected large waterfowl (Bittern, Bewick's Swan, Whooper Swan and Greylag Goose) have high hit wire indices, as expected from the positive correlation between body weight and index. The remaining species are waders and allies: Greenshank and Dotterel which breed almost entirely in Scotland, and Stone-curlew and Little Ringed Plover which are summer migrants to (mainly southern) England.

21. There is a significant pattern of variation in the various collision indices between species (Tables 3 and 4). Overall, the index for road casualties is highest, followed by the index for collision with overhead wires, and with the hit window index in third place. For a variety of landbirds, however,overhead line casualties are the smallest group of these three.

22. For 12 species, the hit wire index is the highest of the collision indices. These are mainly upland and coastal species which do not commonly associate with man, so would not be expected to have high incidences of collision with road vehicles, trains, buildings, or windows.

23. Sixteen species show significant differences in hit wire indices between regions; for a further seven species with adequate data for testing, no significant regional variation is detectable (Table 5). Maps of recoveries, by species, are presented in Appendix 2. There is no statistically significant overall agreement between the regional variation in hit wire indices shown by different species. Most of the differences between species can be related to their individual ecologies.

24. Cormorant, Oystercatcher and Lapwing provide good examples of such regional variation in hit wire indices. For Cormorant, powerline deaths are more frequent in its inland winter range in southern Britain than in its

northern coastal breeding areas. In contrast, Oystercatcher and Lapwing hit wires more frequently in northern Britain where they are widespread inland during the breeding season.

25. Eleven species show significant variation in hit wire indices between months, while a further 13 species with sufficient data for testing did not show such variation (Table 6). There is significant agreement in the seasonal pattern between species, with low hit wire indices during breeding and late summer moult, and high values in spring and autumn. This pattern may be due to seasonal variation in the frequency of long distance movements. Such movements may increase the probability of collisions with overhead lines due to the flight activities involved, which include the movements of birds through areas with which they are unfamiliar. Mallard and Oystercatcher are exceptions to this overall pattern, the variations resulting from differences in their behaviour and ecology (including aerial courtship).

26. Eleven species show significant variation in the hit wire index with time period, while a further 31 species with sufficient data for testing show no such variation (Table 7). There is no significant agreement in the patterns of temporal variation between the 46 species with over 10 "hit wire" recoveries. The hit wire indices for passerine species are decreasing with time, and this is also true for all other passerine cause of death indices which are related to the presence of man. Mallard and Grey Heron show patterns of increasing hit wire index with time. For three gull species (Black-headed Gull, Lesser Black-backed Gull and Herring Gull) the hit wire index was significantly above average in the period 1965 to 1974 but has decreased subsequently. Much of this temporal variation can be attributed to changes in the patterns of ringing, both in species composition and in habitat (urban *versus* rural).

27. For seven species (out of 34 tested), hit wire indices are significantly higher for first year birds than for adults. This may be due to ecological differences or inexperience.

28. Twenty-four species have sufficient data for a more detailed investigation of variation in hit wire index with age (Table 8). Six of these show significant variation with age in the hit wire index. For Canada Goose and Mute Swan the hit wire index decreases throughout life. The variation shown by Mute Swans (Figure 4) is probably related to differences in mobility of different age classes associated with social structure.

29. We conclude that region and month are the two factors which have the strongest influence on a species' hit wire index. The former is influenced by geographical variation in species distribution in relation to density of overhead lines, and the latter to the seasonality of bird movements (migration, local dispersal or aerial display) in relation to the ecology of each species.

30. The groups of birds suffering the highest mortalities from collision with overhead lines are the large waterbirds and raptors. This is also apparent in the data for scarce species for which there are few ringing recoveries.

31. The proportion of total bird mortality that is due to overhead lines cannot be calculated from recoveries alone, since there are different reporting rates of ringed birds for different causes of death. Man-related bird deaths have a higher reporting rate than natural ones.

32. Under natural circumstances, bird populations tend to fluctuate between relatively narrow limits, with (in most cases) productivity exceeding adult mortality. In such circumstances "surplus" birds can be lost without affecting population size (as in the hunting of game species). Available information on bird population dynamics (Table 9) indicates that the species least likely to be affected by casual losses (such as overhead line casualties) are those with low annual survival but correspondingly high production of young. In contrast, long-lived species having low reproductive rates may be able to withstand only a small amount of additional mortality.

33. Finally, we assess the status of species which may be at high risk of mortality from overhead lines. The Grey Heron and most of the waterfowl are increasing slowly, except for the Mute Swan which is stable overall but showing marked regional variations (due to different levels of lead poisoning from anglers' weights). Declines in Lapwing and Stone-curlew are related to habitat changes. Concern focuses on the birds of prey, most of which are in process of recovering from earlier serious declines due to persecution and agricultural pesticides. Most of the latter still have small populations, and their slow reproductive rates make them sensitive to any additional forms of mortality.

# 1. INTRODUCTION

It has long been recognised that avian mortality can result through collisions with overhead wires, but only recently has the problem been studied in any detail. Many reports describe incidences in which birds have been known to strike overhead lines, and have generally been in response to the subsequent death of a rare species. Examples include Sage Grouse (Borell 1939), Ruddy Duck (Siegfried 1972) and Sandhill Crane (Walkinshaw 1956). Others are listed by Avery, Springer and Dailey (1978) and by Dailey (1978). Such reports often give no information on the frequency of collisions or on what proportion of total mortality is attributable to collisions with overhead lines.

More detailed surveys have involved the collection of corpses from beneath overhead lines (Scott, Roberts and Cadbury 1972) and some have also included observations of the lines. These surveys have always been carried out in areas known for birds colliding with overhead lines, or in areas holding large bird populations (James and Haak 1979, Gylstorff 1979). Such studies indicate which species in the locality are most susceptible to hitting overhead lines and the better studies calculate strike rates for the sections of line studied. From a survey of a line crossing a wetland in South Africa, Longridge (1986) calculated the collision rates for all commoner species in the area. Spur-winged Goose, the largest common species, had the highest collision rates with 0.03-0.16% of flights at the altitude of the overhead lines resulting in collision.

Observational surveys of mortality caused by collisions with overhead lines have not been made at a national level. The ringing recovery files held by national bird-ringing schemes provide an opportunity to study mortality from overhead lines at this scale, as these files include information on reported causes of death. An analysis of Swedish recovery data showed that, of 64,000 birds recovered, 1171 of 113 species had been killed through collisions with overhead lines (Stolt et al. 1986). Only 16 species in this Swedish data set had more than 10 incidences of hitting overhead lines, and few conclusions regarding the factors affecting this mortality could be reached.

The aim of the present study was to analyse the bird ringing recovery data for the British Isles to describe patterns of mortality caused by overhead lines. For all species with sufficient data, investigation was made of how the probability of striking overhead lines varied with region, season, age and year. These results are reviewed in relation to the distribution and ecology of the species concerned. Suggestions are offered on which species are most susceptible to striking overhead lines and in which areas the bird populations might be most affected by mortality caused by overhead lines. Many of the rarer species have small recovery sets and are therefore precluded from the more detailed analyses. Nevertheless, because of their small population sizes such species might be particularly vulnerable to mortality from overhead lines. Hence those species listed under Schedule 1 (Part 1) of the Wildlife and Countryside Act are considered in relation to data from similar species.

# 2. METHODS

## 2.1 The collection of ringing and recovery data

The British Trust for Ornithology (BTO) Ringing Scheme covers Britain, Northern Ireland and Eire. Birds are trapped in a variety of ways by trained and licensed ringers for the purpose of ringing. Each bird is fitted with an individually numbered ring made of a light but durable alloy and stamped with the British Museum (Natural History) address. Details of the bird's ring number, species, age, sex, date and place of ringing are then sent to the BTO. Many birds are ringed as nestlings but the majority are trapped when fully grown. The most commonly used trapping techniques are mist netting and cannon netting. Mist nets are used predominantly for catching small birds and are strung vertically between two poles in areas of high flight activity. The nets are almost invisible when viewed at an angle of 90 degrees and birds therefore fly into them and become entangled. They can be extracted quickly and safely by a qualified netter. Cannon nets are used to catch flocks of birds on the ground and their use is very tightly controlled. When a cannon net is fired, explosive charges expel projectiles simultaneously from a row of cannons. The projectiles are attached to the edge of a net which is quickly drawn over the heads of the birds, then brought to a halt by anchors on the rear end of the net. This causes the projectiles to drop, leaving the outstretched net over the flock.

The BTO Ringing Office is concerned principally with the collation and analysis of recovery reports of ringed birds. Recoveries comprise all records of ringed birds which are found dead or reported by members of the public, together with live recaptures by ringers away from the place of ringing. These recovery reports reach the BTO directly from bird ringers, BTO members and other ornithologists, and via the British Museum in the case of letters or telephone reports from members of the public. The present analysis is concerned with extracting information on avian mortality from the recovery data, so information on healthy birds reported by bird ringers is excluded. Examples of the processing of recoveries are presented in Appendix 1.

Between 1909 and the end of 1987 there were approximately 419,000 recoveries of birds ringed in Britain and Ireland, of which 5306 were attributable to deaths caused by overhead lines. Recoveries associated with such lines were spread between 145 species, though nearly half (2324) referred to Mute Swans.

### 2.2 Historical development of the Ringing Scheme

Ringing in Britain started in 1908, and by 1953 a total of 98,000 birds had been ringed and 3000 recoveries had been reported (Hickling 1983). These totals rose to 280,000 birds ringed and 8000 recovered by 1960, and are currently in the region of 19,000,000 birds ringed and 419,000 recovered (Mead & Clark 1988). Since 1950 the BTO has published an annual report on bird ringing in which totals are updated and interesting recoveries listed (eg. Spencer & Hudson 1975, Mead & Clark 1988). Prior to 1950, annual summaries consisted of a selection of recoveries published in the journal British Birds. From the above figures it will be readily apparent that modern data much outnumber the historical element.

### 2.3 The computer files of recovery data

All recoveries have been computerised on an ongoing basis since 1979, and all past recovery data have been input in a comparable way. Accuracy codes are used to distinguish records in the older data which were recorded less precisely than they are today, and also to provide a measure of confidence for modern data. Recoveries reported between 1967 and 1978 were input as punch cards and later translated

Table 1. Main fields used to store ringing recovery data on the British Trust for Ornithology's computer.

1. General information

| | |
|---|---|
| Ringing scheme | Ringing scheme identifier for birds carrying rings of foreign schemes |
| Ring-number | |
| Sex | Best estimate of true sex of bird, based on 'sex when ringed' and 'sex when found' below |
| Previous report | Indicates that a previous recovery is on file for this bird |

2. Ringing information

| | |
|---|---|
| Ringing condition | Indicates records where the bird was not a normal wild and healthy one when ringed |
| Transported | Indicates birds transported from the site of capture prior to release |
| Held | Indicates birds held for more than 24 hours between capture and release |
| Sex when ringed | Sex recorded when the bird was ringed |
| Age | Age of bird when ringed, coded as EURING age code (e.g. nestling, juvenile, adult) |
| Ringing status | Codes for breeding, at colony etc. |
| Ringing moult | Indicates whether bird was moulting flight feathers when ringed |
| Ringing extra text | Text qualifying the ringing information |
| Ringing date | |
| Ringing date accuracy | Number of days within which ringing date is known. It is normally known precisely |
| Ringing place | Country and region (county, department etc.) where the bird was ringed |
| Ringing place text | Text describing where the bird was ringed such as name of village or wood |
| Ringing co-ordinates | Latitude and longitude at which the bird was ringed, recorded to the nearest minute |
| Ringing co-ordinate accuracy | Number of minutes within which the ringing co-ordinates are known. They are normally known precisely |

## 3. Finding information

| | |
|---|---|
| Finding date | |
| Finding date accuracy | Number of days within which finding date is known |
| Finding place | Country and region (county, department etc.) where the bird was recovered |
| Finding place text | Text describing where the bird was found such as name of village or wood |
| Finding co-ordinates | Latitude and longitude at which the bird was recovered, recorded to the nearest minute |
| Finding co-ordinate accuracy | Number of minutes within which the finding co-ordinates are known |
| Finding condition | Whether bird was dead, sick, healthy etc when found |
| Finding circumstances | Cause of recovery (death). See Table 2 |
| Finding extra text | Text giving further information on finding condition and circumstances |
| Finding circumstances presumed | Indicates records where the cause of death could be inferred but was not determined explicitly by finder |
| Moved | Bird may have been moved by a vehicle or water between death and recovery |
| Sex when found | Sex recorded when the bird was found |
| Finding status | Codes as for Ringing Status |
| Finding moult | Indicates whether bird was moulting flight feathers when found |

## 4. Calculated information

| | |
|---|---|
| Distance | Distance between ringing and finding places in km |
| Direction | Bearing of finding place from ringing place in degrees |
| Elapsed time | Number of days between ringing and finding dates |

## 5. Names and addresses

Permit number of ringer or group
Name of ringer or group (text)
Permit number of finder  Only applies if they are a ringer
Name of finder (text)
Address of finder (text)

Except where they are described as text fields all fields are stored as numeric or coded values which are compatible with the internationally agreed EURING code (Anon 1979).
The recovery records also contain a number of other very specialised fields. These are rarely used by analysts and were not used for this report.

automatically into their current form. For these latter records co-ordinates are only held to the nearest six minutes, and text fields are not held on computer file. The fields stored for each recovery are listed and described in Table 1.

## 2.4 Exclusion of inaccurate and unreliable data

For the analyses in this report, data were excluded when these were thought to be unreliable, misleading or inaccurate. Thus only records fulfilling the following conditions are included:

1. Birds that were healthy at ringing and were not transported or held for over 24 hours after ringing.
2. Birds for which the ringing date is accurate to within 16 days either side of the date recorded (accurate to one month).
3. Birds for which ringing co-ordinates are recorded as being accurate to within 6 minutes.
4. Recoveries for which the finding date is accurate to within 16 days either side of the date recorded. In some cases the finding date of a recovery is not stated explicitly by the finder, and the date of the letter reporting the recovery is entered. Such recoveries are included.
5. Recoveries for which the finding co-ordinates are accurate to within 6 minutes and have not been altered for reasons of secrecy.
6. Recoveries in which the bird's body was not moved (intentionally or unintentionally) after death and prior to finding.

## 2.5 Reported causes of death

Some recoveries from members of the public involve birds found while still alive, usually in a sick or injured condition. Many such birds die later, and nearly all would have done so

Table 2. EURING codes for reported causes of death (finding circumstances).

Each code consists of a two digit number, the first digit indicating a primary category and the second a secondary category within it. All primary categories are shown together with secondary categories within primary codes 3 and 4, as some of these are relevant to this report. Codes used for the analyses in this report are shown in bold type. For further information see text.

Code 0 and 9 Unknown and miscellaneous

Code 1 Shot

Code 2 Intentionally taken by man (not shot)

Code 3 Killed accidentally through human agency ('pollution')

- 30 Oil
- 31 Discarded human materials (e.g. fishing line)
- 32 Human artefacts still in use but not covered below (e.g. barbed wire)
- 33 Entangled in crop protection nets
- 34 Caught in trap set for other vertebrates (e.g. fishing nets)
- 35 Electrocuted
- 36 Radio-activity
- 37 Identified chemical pollution
- 38 Unidentified chemical pollution

Code 4 Killed accidentally through human agency (not 'pollution')

- **40** Road accident
- **41** Rail accident
- **42** Aircraft accident
- **43** Collision with THIN man-made structure (principally overhead lines but also radio masts etc.)
- **44** Collision with transparent materials (windows etc)
- **45** Collision with THICK man-made structure (buildings, bridges etc.)
- 46 Entered building (excluding traps and nestboxes)
- **47** Attracted to lights
- 48 Recovered as a result of active human occupation (e.g. agricultural machinery, quarry blasting)
- 49 Drowned in artificial water container

Code 5 Natural Causes (diseases and parasites)

Code 6 Predated other than by man

Code 7 Other natural circumstances (drowned, trapped in natural cavity, severe weather etc.)

without intervention. These records are therefore treated in the same way as birds reported as dead. Known causes of death are coded from a standardised EURING code manual (Anon 1979, Table 2). The present analysis uses six mortality categories: "hit wire", "hit building", "hit window", "road accident", "rail accident" and "found dead". Each of these categories corresponds to one or more of the EURING finding circumstance codes. These codes each have a two-digit number, the first digit referring to a broad mortality cause, and the second to a more detailed category within that group.

In this analysis "found dead" refers to all recoveries in the broad category "unknown cause" together with all birds in the broad natural disease category. Most of the other mortality categories used here lie within that broad one which encompasses accidental death through man (other than pollution). There are single codes for four of the five alternative collision mortality categories, these being "road accidents" (40), "rail accidents" (41), "hit window" (44) and "hit building" (45). The remaining collision category is that of "hit wire", which forms the basis of this report.

### 2.6 <u>"Hit wire" recoveries</u>

"Hit wire" comprises two EURING codes. One is a code given to recoveries resulting from birds hitting thin man-made structures (43) and the other is the code for electrocution (35). The "hit wire" category includes all types of overhead lines as well as other thin objects such as fences, aerials, masts, rigging and poles. Some forms of electrocution are not related to overhead lines but these are very rare for wild birds. To assess the number of recoveries in the "hit wires" category which do not relate to overhead lines, we examined the text fields for all such recoveries. Since 1979 all incidences of "hit wire" or electrocution arising from overhead lines have been entered without additional comments, while other causes of death in this category have accompanying text fields. Birds reported as electrocuted comprise less than 1% of "hit wire" recoveries and the numbers of recoveries attributable to thin man-made objects which do not involve overhead lines are also very few and unlikely to affect the conclusions from the analyses presented here. Two of the 12 electrocution recoveries for Mute Swans are from electric fences, and only 10 of 2314 recoveries from collisions with thin man-made structures (code 43) are not due to overhead wires. Thus only 0.5% of Mute Swan recoveries coded as electrocuted or hit thin man-made structure are not attributable to overhead lines. Blackbirds may be less susceptible to colliding with overhead lines but more so to hitting fences. However only 4.1% of all Blackbird recoveries falling within our "hit-wire" category are not attributable to overhead lines.

The information associated with ringing recovery reports does not allow different types of overhead lines to be distinguished. This is because the information coded must be based on the report of an unqualified member of the public. Due to the limited resources available, only recovery reports of exceptional interest can be followed up by supplementary correspondence. Thus the results in this report apply to overhead lines in general and it is not possible to assess the relative importance of National grid lines and Area board lines, or the effects of power lines relative to telephone lines.

### 2.7 The hit wire index

To compare the incidence of "hit wire" reports between recovery samples it was necessary to standardise the frequencies of "hit wire" recoveries in some way. In principle it would have been desirable to consider numbers of "hit wire" recoveries as a proportion of the number of ringed birds at risk, but this was not possible due to the lack of computerised data on numbers ringed and to the complexities of the analyses required. An alternative approach would have been to consider "hit wire" recoveries as a percentage of all the recoveries in a sample; but such results would be difficult to interpret because other major causes of death may vary greatly between samples, hence masking the patterns of interest. For example, numbers of hunting recoveries of quarry species might differ markedly between regions, giving rise to differences in the percentage of "hit wire" recoveries which did not reflect genuine differences in the probability of collisions. The "found dead" category of recoveries is generally not subject to such marked variation as those dealing with known causes of death; therefore the former is used for standardisation, following the approach of Coulson and Brazendale (1968). A hit wire index was calculated as follows:

$$\text{Hit wire index} = \frac{\text{hit wire recoveries} \times 100}{\text{found dead} + \text{hit wire recoveries}} \qquad (1)$$

Similar indices were calculated for the other forms of mortality to allow comparisons with the "hit wire" values. The hit wire index was used to compare between samples the relative proportions of recoveries attributable to collisions with overhead lines. It does not represent a percentage of total mortality.

## 2.8 Selection of species for detailed analysis

After calculating cause of death indices, a number of species were selected for more detailed analysis according to their total number of "hit wire" recoveries. All species with 10 or more "hit wire" recoveries were analysed further, where sample sizes allowed, to investigate how the hit wire index varied with region, year, season and age.

## 2.9 Standard regions, time periods and ages used for analysis

The British Isles were divided into six regions for the analysis (Figure 1). These were Ireland, Scotland, N.W.England, N.E.England, S.W.England and S.E.England. Scotland was taken as all areas of Britain north of 55 degrees latitude. The remaining areas of England and Wales were then divided into four by the 52 degrees 30 minutes north line of latitude and the 1 degree 30 minutes west line of longitude. All recoveries on these lines were regarded as north and west respectively. Recovery distributions were plotted using areas of 30 minutes latitude by 15 minutes longitude. Two maps were plotted for each species, one showing the number of "found dead" recoveries in each grid area and the other the number of "hit wire" recoveries in each grid area. For species with sufficient data, a third map was plotted to show a hit wire index for all grid areas with at least 1 "hit wire" recovery and 20 or more "hit wire" and "found dead" recoveries combined (Appendix 2).

The seasonal analyses were carried out using calendar months. For species with insufficient data for monthly analysis, four seasonal periods were used as follows: November-January (winter), February-April (spring), May-July (summer) and August-October (autumn).

To investigate variation in the index over years, divisions were chosen to coincide approximately with major changes in the numbers of electricity lines, the dates of which were provided by the CEGB. The categories used for analysis were 1909-1954, 1955-1964, 1965-1974, 1975-1984 and 1985-1987. The first period covers 46 years because of the relatively small numbers of recoveries reported in the early years of the ringing scheme. After this all periods are of ten years, except for the final three-year period.

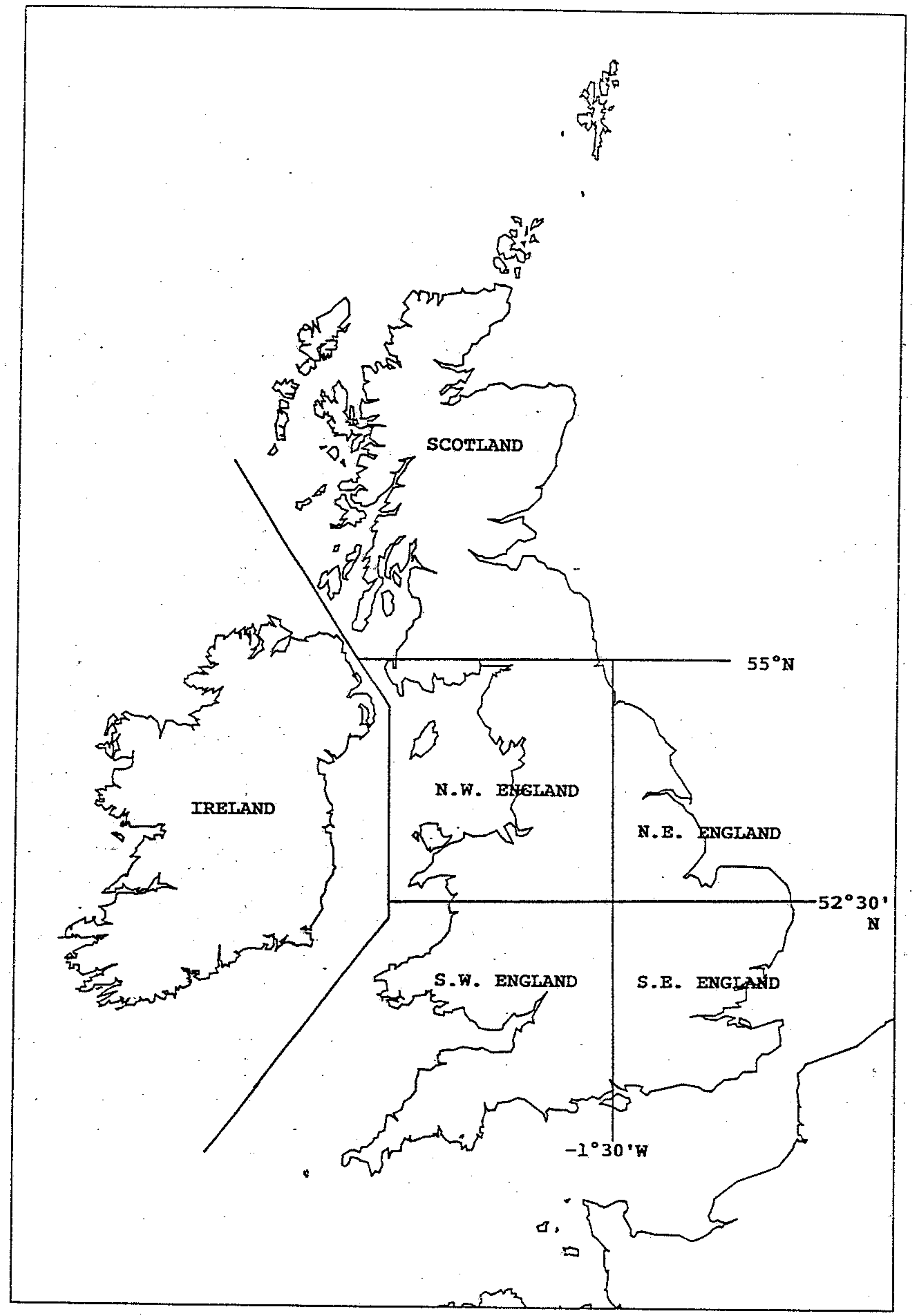



Figure 1. Regions into which the British Isles were divided for analysis.

Only recoveries of birds ringed as nestlings or for which the calendar year of birth could be determined at ringing (usually from juvenile or first year plumage) could be used for the analysis of mortality from overhead lines in relation to age. The age categories used were birth to December of the first calendar year, January to June of the second calendar year, and thereafter 12 month periods starting on July 1st. Since most birds are hatched in summer these periods are more biologically sensible than ones based on calandar years. All recoveries of birds over 10 years of age were combined into a single category. The analysis used a category termed "first-year", which is a combination of the first two categories and so corresponds to a period from birth to the end of June in the second calendar year. Hit wire indices for first year birds were also compared with those for birds older than first year, in order to investigate major differences that would have been masked in a more detailed age-related analysis due to small sample sizes.

## 2.10 Statistical methods

To compare proportions of "hit wire" recoveries between categories, the data were assembled as two x n contingency tables and tested with chi-square. Where chi-square was significant, then Haberman's method (Everitt 1977) was used to calculate a normally distributed statistic for each cell of the contingency table. If this statistic was greater than 1.96 or less than -1.96 the cell concerned was contributing significantly to the significant overall chi-square value. This allowed individual samples with significantly low or high hit wire indices to be identified. In some cases the number of cells with expected values under five exceeded 20% of the total number of cells and hence precluded analysis using chi-square. Where possible, adjacent categories were combined so that a statistically valid analysis could be carried out.

Spearman rank correlation coefficients were calculated to test the significance of trends with time and age. Kendall's coefficient of concordance (Siegel 1956) was used to test whether patterns of variation in the hit wire index were consistent between species.

## 2.11 Interpretation of results

The probability of a dead ringed bird being reported varies considerably with the cause of death. Birds shot, hunted, predated by pets, or dying for reasons associated with close proximity to man, all have a much higher chance of being reported than those dying for other reasons. To minimise the effects of recoveries from causes with a high reporting probability, we used the hit wire index to compare the frequency of "hit wire" recoveries in different recovery samples (above). Cause of death indices for different mortality factors are often not comparable even within species, due to differences in reporting probability. For example, a bird flying into a window is more likely to be reported than a bird flying into overhead lines; therefore a comparison of cause of death indices for hitting windows and hitting overhead lines would reflect differences in reporting probabilities rather than differences in numbers killed. However, an index for a single cause of death category can usually be compared both within and between species. Thus

$$\text{Hit wire index} = \frac{p\,W}{p\,W + q\,F} \times 100 \qquad (2)$$

where:

p = probability of finding a dead ringed bird killed by overhead lines

q = probability of finding a dead ringed bird with no obvious cause of death ("found dead")

W = number of ringed birds dying from electrocution or collision with overhead lines.

F = number of ringed birds dying for no obvious reason ("found dead")

Hence hit wire indices are directly comparable for all recovery samples in which p / q is equal. However, where the reporting rates p and q are not equal then the relationship between the estimated and true cause of death index in non-linear, the difference being greatest for index values around 50%. Estimated index values are not highly sensitive to small differences between p and q, and major patterns of variation in cause of death should remain apparent even if one was twice the other (Figure 2). Generally we would expect p and q to vary in parallel, so that in areas of high human activity both might increase but the ratio would remain similar.

For example, when comparing the hit wire indices for Blackbirds and Mute Swans, then the main factor to be considered is the difference between the probabilities of dead Swans and Blackbirds being found. Swans are large, white and inhabit open ground and so have a high finding probability, while Blackbirds are small, dark and inhabit areas with more dense cover, and so have a low finding probability. This difference applies to Blackbirds and Swans in both the "hit wire" and "found dead" categories so in calculating the index the effects of the different reporting probabilities for the two species are largely cancelled out.

A further potential source of error in cause of death indices is that the cause of death category may not always be correctly identified and reported by the person who found the ringed bird. For each cause of death category there will be an

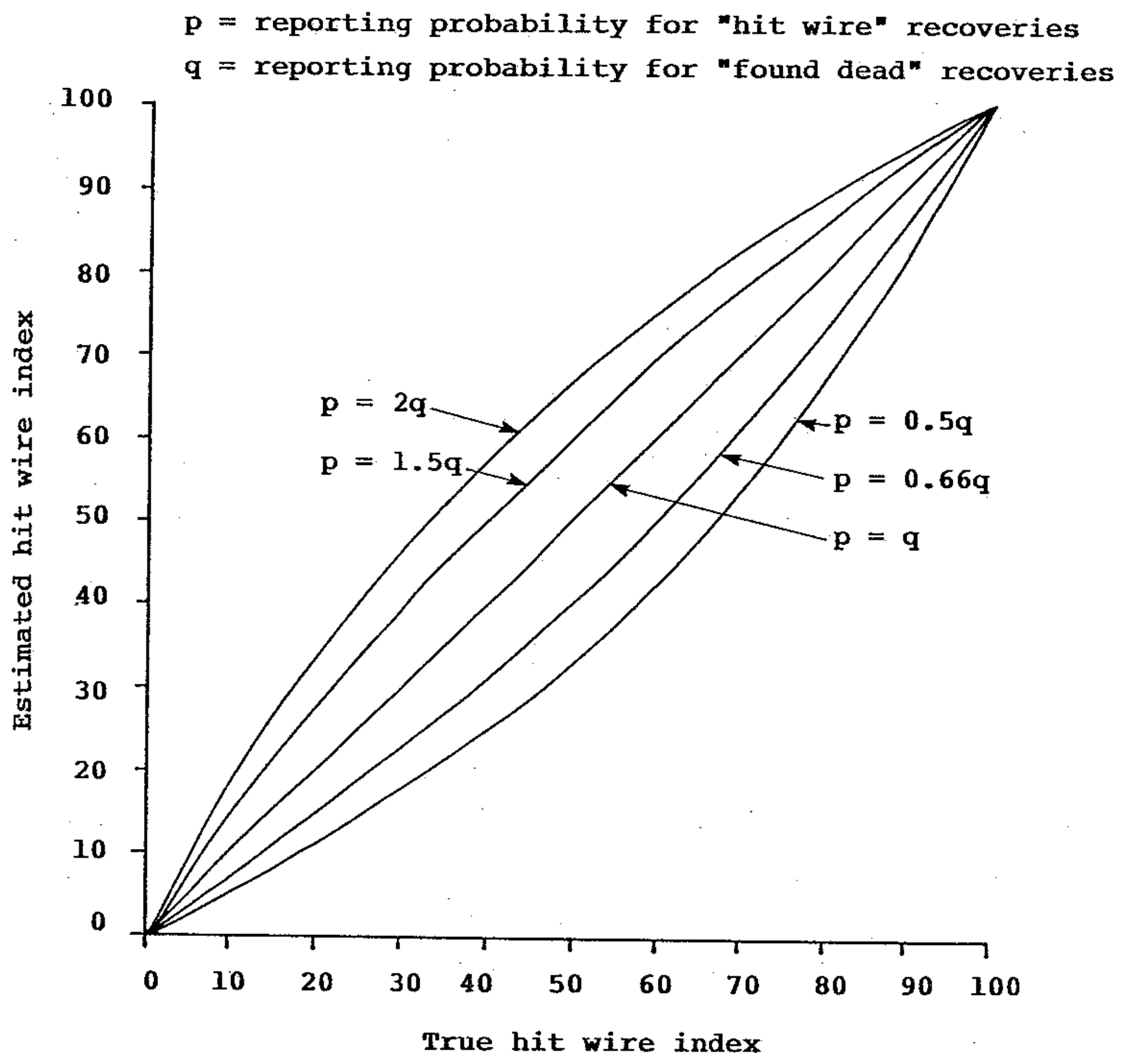



Figure 2. Relationship between estimated and true values of the hit wire index for different ratios of the reporting probabilities for "hit wire" recoveries and "found dead" recoveries.

associated probability that the cause of death is correctly identified. For example, the probability of correct assignment to the shot category will be very high (at least for legal quarry species), while the probability of identifying a poisoned bird correctly will be much lower. We simplify here, by considering just three groupings: "hit wires", "found dead" and all other causes combined. The hit wire index can then be written as follows:

$$\text{Hit wire index} = \frac{ipW + [\ kqF + mrO\ ]}{ipW + [\ kqF + mrO\ ] + jqF + (1-i)pW + (1-m-l)rO} \qquad (3)$$

where p, q, W an F are as defined for equation (2) and:

i = probability that a recovered bird which has hit wires is assigned to the correct cause of death.

j = probability that a recovered bird with no obvious cause of death was assigned correctly (found dead).

k = probability that a recovered bird with no obvious cause of death was incorrectly recorded as "hit wires". This will be close to zero.

O = number of ringed birds dying from causes other than "hit wires" and "found dead"

r = probability that a ringed bird dying from a cause other than "hit wires" or "found dead" is found and reported

l = probability that a recovered ringed bird that died from a cause other that "hit wires" or "found dead" is correctly assigned to the "all other causes" category

m = probability that a recovered ringed bird that died from a cause other that "hit wires" or "found dead" is incorrectly assigned to the "hit wire" category. This will be close to zero.

We assume that all "hit wire" recoveries which are incorrectly classified are placed in the "found dead" category. Thus:

(1 - i) = probability that recovered birds which hit wires are classified as "found dead".

Similarly:

(1-m-l) = probability that a recovered bird dying from "all other causes" is incorrectly classified as "found dead"

(1-j-k) = probability that a recovered bird which should have been classified as "found dead" is classified as "all other causes". This term does not appear in equation (3).

The terms of equation three may be further explained as follows. The numerator and the first three terms of the denominator represent the number of recoveries reported as being due to "hit wires" and made up as follows:

ipW = genuine "hit wire" recoveries
kqF = "found dead" recoveries reported as "hit wire"
mrO = "other causes" recoveries reported as "hit wire"

The last three terms of the denominator represent the number of recoveries reported as "found dead" made up as follows:

jqF = genuine "found dead" recoveries
(1-i) pW = "hit wire" recoveries reported as "found dead"
(1-m-l)rO = "other causes" recoveries reported as "found dead"

We cannot quantify the terms in equation (3); nevertheless, it provides a useful basis for assessing the potential magnitude and direction of any bias. Few recoveries are likely to be wrongly classified as "hit wires", so the terms shown in square brackets will be close to zero. It is more likely that the cause of death of birds hitting wires will not be recorded simply because the reporter did not notice or did not realise that the information was required. Similarly some recoveries of birds that died from "all other causes" will be classified as "found dead", giving rise to the final term in the denominator of equation (3). It is unlikely that many birds for which the cause of death was not obvious will have been assigned to a specific category, so j should be close to one. Thus the overall effect of misclassification of recovery causes will be to lower the index value. However, as the index is intended to be used for comparative purposes this is not a problem unless the lowering differs between recovery samples. The most likely cause of this would be where recoveries from other specific causes are misclassified into the "found dead" category. If some recovery samples had a very high proportion of recoveries in the "all other causes" category, misclassification of some of them might inflate the "found dead" category and hence lower the index. We do not believe that misclassification of recoveries is a serious problem affecting the analyses presented below.

A further point which must be considered when interpreting the recovery analyses presented here is that ringing effort and the composition of the resultant recovery sample varies in time and space. Because there were only sufficient data and resources to examine one factor at a time for this report, it is important to be aware of potential second-order effects due to changes in the recovery samples. For example, if we were comparing two time periods for a species where there had been a marked change in the regional distribution of recoveries (between areas with markedly different hit wire indices), an apparent temporal difference might result from the regional difference combined with the change in ringing effort. It has not been possible to approach this problem statistically, but it has been taken into account when interpreting the analyses.

# 3. RESULTS

## 3.1 Variation in the hit wire index between species

### 3.1.1 General patterns

Hit wire indices for species with 10 or more "hit wire" recoveries are presented in Table 3, and for species with between one and nine "hit wire" recoveries in Table 4. There were 132 species with one or more "hit wire" recoveries out of a total of 229 species for which the BTO holds ringing recoveries (Mead and Clark 1988). Eighty-seven of the 132 species had hit wire indices based on a total of at least 100 recoveries, and analyses of general patterns were limited to these species. Only seven of the 87 species had hit wire indices with values greater that 10, these being Mute Swan (27.95), Canada Goose (20.95), Hen Harrier (13.33), Merlin (12.58), Peregrine (11.01), Grey Heron (10.93) and Buzzard (10.09). Overall, the groups with the highest hit wire indices were raptors (mean 9.9, n=6) and waterbirds (mean 8.9, n=11), with shorebirds (waders, gulls and terns) being intermediate (mean 3.7, n=16) and landbirds, most of which were small passerines, having a low hit wire index (mean 1.9, n=47). Most seabirds are unlikely to spend much time flying in the vicinity of overhead wires, and few "hit wire" recoveries were recorded for this group (mean hit wire index=0.7, n=10).

The hit wire index was positively correlated with body weight (Figure 3, $r_S=0.32$, $P<0.01$). Seabirds should probably be excluded from this relationship, as they spend nearly all of their time in areas where overhead lines do not occur. When this is done the remaining species show a considerably stronger relationship between body weight and hit wire index ($r_S=0.61$, $P<0.001$). This relationship is not solely a consequence of the relatively high body weight of waterfowl and raptors, the groups which have the highest hit wire indices. Within waterfowl, raptors and landbirds there is a tendency for larger species to have higher hit wire indices,

TABLE 3 Cause of death indices for recoveries due to overhead lines, collisions with buildings, collisions with windows, Road accidents and Rail accidents. Indices are presented for all species with 10 or more recoveries attributable to overhead lines.

$$\text{Index} = \frac{\text{Recoveries from specific cause}}{\text{Total}} \times 100$$

Total = Recoveries for specific cause + "Found dead" recoveries.

For further details of calculations, see text.

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Manx Shearwater | Index | 1.11 | 0.00 | 0.00 | 0.96 | 0.15 |
| | Total | 1350 | 1335 | 1335 | 1348 | 1337 |
| Cormorant | Index | 2.16 | 0.09 | 0.00 | 0.44 | 0.31 |
| | Total | 2317 | 2269 | 2267 | 2277 | 2274 |
| Grey Heron | Index | 10.93 | 0.16 | 0.00 | 1.46 | 0.62 |
| | Total | 1436 | 1281 | 1279 | 1298 | 1287 |
| Mute Swan | Index | 27.95 | 1.54 | 0.07 | 3.84 | 1.72 |
| | Total | 8315 | 6085 | 5995 | 6230 | 6096 |
| Pink-footed Goose | Index | 3.74 | 0.00 | 0.00 | 0.66 | 0.44 |
| | Total | 471 | 454 | 454 | 457 | 456 |
| Canada Goose | Index | 20.95 | 0.40 | 0.00 | 2.06 | 0.48 |
| | Total | 1561 | 1239 | 1234 | 1260 | 1240 |
| Teal | Index | 5.59 | 0.00 | 0.00 | 0.58 | 0.29 |
| | Total | 359 | 339 | 339 | 342 | 341 |
| Mallard | Index | 4.88 | 0.12 | 0.06 | 7.25 | 1.03 |
| | Total | 1720 | 1638 | 1637 | 1764 | 1653 |
| Tufted Duck | Index | 7.02 | 0.00 | 0.00 | 5.06 | 0.00 |
| | Total | 242 | 225 | 225 | 237 | 225 |
| Hen Harrier | Index | 13.33 | 0.00 | 0.00 | 9.57 | 0.00 |
| | Total | 120 | 104 | 104 | 115 | 104 |
| Sparrowhawk | Index | 6.23 | 3.33 | 26.29 | 15.57 | 2.07 |
| | Total | 966 | 931 | 1221 | 1066 | 919 |
| Buzzard | Index | 10.09 | 0.00 | 0.00 | 15.15 | 3.92 |
| | Total | 218 | 196 | 196 | 231 | 204 |
| Kestrel | Index | 6.22 | 0.78 | 1.96 | 21.20 | 5.21 |
| | Total | 1494 | 1412 | 1429 | 1778 | 1478 |

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Merlin | Index | 12.58 | 1.42 | 13.13 | 17.26 | 0.71 |
| | Total | 159 | 141 | 160 | 168 | 140 |
| Peregrine | Index | 11.01 | 2.68 | 0.00 | 12.80 | 1.80 |
| | Total | 121 | 112 | 109 | 125 | 111 |
| Red Grouse | Index | 36.84 | 0.00 | 4.00 | 4.00 | 0.00 |
| | Total | 38 | 24 | 25 | 25 | 24 |
| Moorhen | Index | 2.34 | 0.22 | 0.00 | 17.41 | 3.56 |
| | Total | 471 | 461 | 460 | 557 | 477 |
| Coot | Index | 4.52 | 0.29 | 0.00 | 10.58 | 0.59 |
| | Total | 354 | 339 | 338 | 378 | 340 |
| Oystercatcher | Index | 3.42 | 0.05 | 0.00 | 5.69 | 0.61 |
| | Total | 2196 | 2122 | 2121 | 2249 | 2134 |
| Lapwing | Index | 7.55 | 0.27 | 0.00 | 12.96 | 0.62 |
| | Total | 1206 | 1118 | 1115 | 1281 | 1122 |
| Dunlin | Index | 4.08 | 0.00 | 0.00 | 1.40 | 0.56 |
| | Total | 368 | 353 | 353 | 358 | 355 |
| Curlew | Index | 6.55 | 0.00 | 0.00 | 7.48 | 0.80 |
| | Total | 397 | 371 | 371 | 401 | 374 |
| Redshank | Index | 2.64 | 0.13 | 0.00 | 3.93 | 0.66 |
| | Total | 777 | 758 | 757 | 788 | 762 |
| Black-headed Gull | Index | 5.22 | 0.23 | 0.10 | 6.31 | 0.94 |
| | Total | 5134 | 4877 | 4871 | 5194 | 4912 |
| Common Gull | Index | 4.36 | 0.22 | 0.00 | 15.72 | 0.00 |
| | Total | 482 | 462 | 461 | 547 | 461 |
| Lesser Black-backed Gull | Index | 4.08 | 0.09 | 0.00 | 3.71 | 0.45 |
| | Total | 2328 | 2235 | 2233 | 2319 | 2243 |
| Herring Gull | Index | 2.91 | 0.12 | 0.02 | 3.31 | 0.65 |
| | Total | 6735 | 6544 | 6537 | 6760 | 6579 |
| Great Black-backed Gull | Index | 2.46 | 0.00 | 0.00 | 3.39 | 0.33 |
| | Total | 935 | 912 | 912 | 944 | 915 |
| Barn Owl | Index | 4.34 | 0.72 | 0.54 | 38.30 | 13.09 |
| | Total | 576 | 555 | 554 | 893 | 634 |
| Tawny Owl | Index | 5.58 | 0.22 | 1.51 | 39.47 | 15.68 |
| | Total | 484 | 458 | 464 | 755 | 542 |
| Swift | Index | 5.74 | 2.10 | 1.25 | 9.82 | 2.93 |
| | Total | 1087 | 1050 | 1041 | 1140 | 1059 |

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Sand Martin | Index | 5.80 | 0.61 | 1.52 | 29.04 | 2.11 |
| | Total | 345 | 327 | 330 | 458 | 332 |
| Swallow | Index | 4.82 | 1.64 | 6.24 | 18.80 | 1.12 |
| | Total | 1389 | 1344 | 1410 | 1628 | 1337 |
| House Martin | Index | 3.16 | 0.92 | 3.38 | 11.55 | 0.00 |
| | Total | 443 | 433 | 444 | 485 | 429 |
| Pied Wagtail | Index | 1.42 | 0.87 | 6.37 | 13.80 | 1.26 |
| | Total | 1267 | 1260 | 1334 | 1449 | 1265 |
| Robin | Index | 0.50 | 0.18 | 2.57 | 19.73 | 0.54 |
| | Total | 2780 | 2771 | 2839 | 3446 | 2781 |
| Song Thrush | Index | 1.86 | 0.27 | 6.61 | 26.25 | 2.78 |
| | Total | 4840 | 4763 | 5086 | 6441 | 4886 |
| Mistle Thrush | Index | 2.97 | 0.64 | 6.20 | 19.38 | 1.74 |
| | Total | 639 | 624 | 661 | 719 | 631 |
| Blackbird | Index | 1.10 | 0.39 | 5.05 | 22.58 | 1.49 |
| | Total | 20073 | 19930 | 20909 | 25645 | 20154 |
| Blue Tit | Index | 0.36 | 0.39 | 9.33 | 22.29 | 0.34 |
| | Total | 5629 | 5631 | 6186 | 7218 | 5628 |
| Great Tit | Index | 0.60 | 0.28 | 12.15 | 17.10 | 0.70 |
| | Total | 2175 | 2168 | 2461 | 2608 | 2177 |
| Jackdaw | Index | 5.06 | 0.00 | 0.00 | 5.79 | 0.31 |
| | Total | 654 | 621 | 621 | 673 | 636 |
| Rook | Index | 2.20 | 0.00 | 0.00 | 5.26 | 1.04 |
| | Total | 682 | 667 | 667 | 704 | 674 |
| Starling | Index | 1.08 | 0.12 | 0.78 | 4.00 | 0.30 |
| | Total | 15742 | 15591 | 15695 | 16214 | 15619 |
| Chaffinch | Index | 0.93 | 0.44 | 15.01 | 26.11 | 0.02 |
| | Total | 1617 | 1609 | 1885 | 2168 | 1612 |
| Greenfinch | Index | 0.79 | 0.26 | 8.32 | 22.46 | 0.92 |
| | Total | 7386 | 7347 | 7993 | 9450 | 7396 |

Table 4 Cause of death indices for recoveries due to overhead lines, collisons with buildings, collisions with windows, road accidents and rail accidents. Indices are presented for all species with between 1 and 9 recoveries attributable to overhead lines.

$$\text{Index} = \frac{\text{Recoveries from specific cause}}{\text{Total}} \times 100$$

Total = Recoveries from specific cause + "Found dead" recoveries

For further details of calculations see text. Indices based on totals of less than 20 recoveries are shown in parenthesis.

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Little Grebe | Index | 10.00 | (0.00) | (0.00) | 10.00 | (0.00) |
| | Total | 20 | 18 | 18 | 20 | 18 |
| Fulmar | Index | 0.31 | 0.00 | 0.00 | 0.31 | 0.00 |
| | Total | 321 | 320 | 320 | 321 | 320 |
| Storm Petrel | Index | 2.53 | 0.00 | 0.00 | 1.28 | 0.00 |
| | Total | 79 | 77 | 77 | 78 | 77 |
| Gannet | Index | 0.55 | 0.37 | 0.00 | 0.37 | 0.09 |
| | Total | 1092 | 1090 | 1086 | 1090 | 1087 |
| Shag | Index | 0.20 | 0.04 | 0.02 | 0.27 | 0.09 |
| | Total | 4494 | 4487 | 4486 | 4497 | 4489 |
| Bittern | Index | (20) | (0.00) | (0.00) | (20) | (0.00) |
| | Total | 5 | 4 | 4 | 5 | 4 |
| Bewick's Swan | Index | 23.81 | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 21 | 16 | 16 | 16 | 16 |
| Whooper Swan | Index | 19.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 26 | 21 | 21 | 21 | 21 |
| Greylag Goose | Index | 13.33 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 75 | 65 | 65 | 65 | 65 |
| Barnacle Goose | Index | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 50 | 49 | 49 | 49 | 49 |
| Shelduck | Index | 1.20 | 0.00 | 0.00 | 0.40 | 0.40 |
| | Total | 249 | 246 | 246 | 247 | 247 |
| Wigeon | Index | 2.33 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 43 | 42 | 42 | 42 | 42 |

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Shoveler | Index | (5.56) | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 18 | 17 | 17 | 17 | 17 |
| Eider | Index | 0.24 | 0.00 | 0.00 | 0.61 | 0.06 |
| | Total | 1637 | 1633 | 1630 | 1643 | 1634 |
| Red Kite | Index | (16.67) | (0.00) | (0.00) | (0.00) | (16.67) |
| | Total | 6 | 5 | 5 | 5 | 6 |
| Marsh Harrier | Index | (20.00) | (0.00) | (0.00) | (11.11) | (0.00) |
| | Total | 10 | 8 | 8 | 9 | 8 |
| Montagu's Harrier | Index | (20.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 5 | 4 | 4 | 4 | 4 |
| Goshawk | Index | (40.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 5 | 3 | 3 | 3 | 3 |
| Golden Eagle | Index | (18.75) | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 16 | 13 | 13 | 13 | 13 |
| Black Grouse | Index | (33.33) | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 3 | 2 | 2 | 2 | 2 |
| Grey Partridge | Index | (20.00) | (0.00) | (0.00) | (7.69) | (0.00) |
| | Total | 15 | 12 | 12 | 13 | 12 |
| Stone-curlew | Index | (7.69) | (0.00) | (0.00) | (25) | (0.00) |
| | Total | 13 | 12 | 12 | 16 | 12 |
| Little Ringed Plover | Index | (14.29) | (0.00) | (0.00) | (14.29) | (0.00) |
| | Total | 7 | 6 | 6 | 7 | 6 |
| Ringed Plover | Index | 2.83 | 0.96 | (0.00) | 8.04 | (0.00) |
| | Total | 106 | 104 | 103 | 112 | 103 |
| Dotterel | Index | (100) | 0 | 0 | 0 | 0 |
| | Total | 1 | 0 | 0 | 0 | 0 |
| Golden Plover | Index | 13.64 | (0.00) | (0.00) | 13.64 | (0.00) |
| | Total | 22 | 19 | 19 | 22 | 19 |
| Knot | Index | 0.95 | 0.00 | 0.00 | 1.42 | 0.00 |
| | Total | 210 | 208 | 208 | 211 | 208 |
| Sanderling | Index | 3.92 | 0.00 | 0.00 | 2.00 | 0.00 |
| | Total | 51 | 49 | 49 | 50 | 49 |
| Snipe | Index | 4.13 | 0.00 | 0.00 | 8.66 | 2.52 |
| | Total | 121 | 116 | 116 | 127 | 119 |
| Greenshank | Index | (16.67) | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 6 | 5 | 5 | 5 | 5 |
| Turnstone | Index | 4.07 | 0.00 | 0.00 | 2.48 | 0.00 |
| | Total | 123 | 118 | 118 | 121 | 118 |

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Great Skua | Index | 0.67 | 0.22 | 0.00 | 0.22 | 0.00 |
| | Total | 449 | 447 | 446 | 447 | 446 |
| Kittiwake | Index | 0.83 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 600 | 595 | 595 | 595 | 595 |
| Roseate Tern | Index | 2.70 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 37 | 36 | 36 | 36 | 36 |
| Common Tern | Index | 2.41 | 0.00 | 0.00 | 0.70 | 0.35 |
| | Total | 291 | 284 | 284 | 286 | 285 |
| Arctic Tern | Index | 2.04 | 0.00 | 0.00 | 0.92 | 0.23 |
| | Total | 442 | 433 | 433 | 437 | 434 |
| Guillemot | Index | 0.23 | 0.00 | 0.00 | 0.00 | 0.23 |
| | Total | 428 | 427 | 427 | 427 | 428 |
| Puffin | Index | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 446 | 445 | 445 | 445 | 445 |
| Stock Dove | Index | 2.47 | 0.00 | 0.00 | 7.06 | 3.66 |
| | Total | 81 | 79 | 79 | 85 | 82 |
| Woodpigeon | Index | 1.02 | 0.26 | 0.51 | 7.86 | 1.02 |
| | Total | 391 | 388 | 389 | 420 | 391 |
| Collared Dove | Index | 2.72 | 1.38 | 1.38 | 14.11 | 0.35 |
| | Total | 294 | 290 | 290 | 333 | 287 |
| Turtle Dove | Index | 8.00 | 0.00 | 0.00 | 4.17 | 0.00 |
| | Total | 25 | 23 | 23 | 24 | 23 |
| Cuckoo | Index | 7.32 | 0.00 | 2.56 | 9.52 | 2.56 |
| | Total | 41 | 38 | 39 | 42 | 39 |
| Little Owl | Index | 2.34 | 0.00 | 0.00 | 28.02 | 11.17 |
| | Total | 171 | 167 | 167 | 232 | 188 |
| Long-eared Owl | Index | 2.38 | 0.00 | 1.20 | 23.36 | 7.87 |
| | Total | 84 | 82 | 83 | 107 | 89 |
| Short-eared Owl | Index | 6.38 | 0.00 | 0.00 | 13.73 | 6.38 |
| | Total | 47 | 44 | 44 | 51 | 47 |
| Kingfisher | Index | 1.92 | 2.39 | 19.37 | 24.72 | 2.86 |
| | Total | 208 | 209 | 253 | 271 | 210 |
| Great Spotted Woodpecker | Index | 0.72 | 0.00 | 12.74 | 15.43 | 1.44 |
| | Total | 138 | 137 | 157 | 162 | 139 |
| Skylark | Index | 4.49 | 0.00 | 0.00 | 15.00 | 1.16 |
| | Total | 89 | 85 | 85 | 100 | 86 |
| Tree Pipit | Index | (11.11) | (0.00) | (20.00) | (20.00) | (11.11) |
| | Total | 9 | 8 | 10 | 10 | 9 |

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Meadow Pipit | Index | 2.73 | 0.00 | 4.36 | 10.09 | 0.70 |
| | Total | 293 | 285 | 298 | 317 | 287 |
| Rock Pipit | Index | 4.69 | 1.61 | 0.00 | 7.58 | 0.00 |
| | Total | 64 | 62 | 61 | 66 | 61 |
| Yellow Wagtail | Index | 1.83 | 0.00 | 2.73 | 18.32 | 4.46 |
| | Total | 109 | 107 | 110 | 131 | 112 |
| Dipper | Index | 2.96 | 1.50 | 6.43 | 4.38 | 0.00 |
| | Total | 135 | 133 | 140 | 137 | 131 |
| Wren | Index | 0.51 | 0.26 | 2.52 | 26.98 | 0.00 |
| | Total | 389 | 388 | 397 | 530 | 387 |
| Dunnock | Index | 0.21 | 0.11 | 6.30 | 23.08 | 0.32 |
| | Total | 1894 | 1892 | 2017 | 2457 | 1896 |
| Bluethroat | Index | (100.00) | 0 | 0 | 0 | 0 |
| | Total | 1 | 0 | 0 | 0 | 0 |
| Whinchat | Index | 2.86 | 0.00 | 0.00 | 22.72 | 2.86 |
| | Total | 35 | 34 | 34 | 44 | 35 |
| Wheatear | Index | 3.92 | 0.00 | 0.00 | 4.04 | 2.97 |
| | Total | 102 | 98 | 98 | 114 | 101 |
| Ring Ouzel | Index | 3.13 | 0.00 | 0.00 | 8.82 | 0.00 |
| | Total | 32 | 31 | 31 | 34 | 31 |
| Redwing | Index | 1.54 | 0.20 | 3.77 | 9.24 | 0.20 |
| | Total | 519 | 512 | 531 | 563 | 512 |
| Sedge Warbler | Index | 1.67 | 2.48 | 14.49 | 36.22 | 2.48 |
| | Total | 120 | 121 | 138 | 185 | 121 |
| Reed Warbler | Index | 3.14 | 0.65 | 21.43 | 23.76 | 2.53 |
| | Total | 159 | 155 | 196 | 202 | 158 |
| Lesser Whitethroat | Index | 2.27 | 4.44 | 17.31 | 44.16 | 2.27 |
| | Total | 44 | 45 | 52 | 77 | 44 |
| Whitethroat | Index | 0.75 | 0.00 | 10.74 | 47.84 | 0.00 |
| | Total | 134 | 133 | 149 | 255 | 133 |
| Blackcap | Index | 1.69 | 0.00 | 15.05 | 32.95 | 0.57 |
| | Total | 178 | 175 | 206 | 261 | 176 |
| Chiffchaff | Index | 1.64 | 0.00 | 14.29 | 25.00 | 0.00 |
| | Total | 61 | 60 | 70 | 80 | 60 |
| Willow Warbler | Index | 0.38 | 0.00 | 17.20 | 28.27 | 0.76 |
| | Total | 261 | 260 | 314 | 363 | 262 |
| Spotted Flycatcher | Index | 1.12 | 0.00 | 13.73 | 21.43 | 1.12 |
| | Total | 89 | 88 | 102 | 112 | 89 |

| Species | | Hit wire | Hit building | Hit window | Road | Rail |
|---|---|---|---|---|---|---|
| Nuthatch | Index | 0.94 | 0.00 | 13.22 | 9.48 | 0.00 |
| | Total | 106 | 105 | 121 | 116 | 105 |
| Jay | Index | 0.37 | 0.73 | 1.45 | 10.26 | 1.81 |
| | Total | 272 | 273 | 274 | 302 | 276 |
| Magpie | Index | 1.37 | 0.00 | 0.28 | 9.34 | 0.55 |
| | Total | 364 | 359 | 360 | 396 | 361 |
| Chough | Index | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 50 | 49 | 49 | 49 | 49 |
| Carrion Crow | Index | 2.46 | 0.31 | 0.00 | 4.80 | 1.25 |
| | Total | 325 | 318 | 317 | 333 | 321 |
| Raven | Index | 1.15 | 0.00 | 0.00 | 2.26 | 0.00 |
| | Total | 262 | 259 | 259 | 265 | 259 |
| House Sparrow | Index | 0.26 | 0.13 | 1.72 | 16.15 | 0.39 |
| | Total | 3040 | 3036 | 3085 | 3616 | 3044 |
| Tree Sparrow | Index | 0.39 | 0.00 | 4.53 | 23.80 | 0.78 |
| | Total | 254 | 253 | 265 | 332 | 255 |
| Brambling | Index | 1.56 | 0.00 | 11.27 | 23.17 | 0.00 |
| | Total | 64 | 63 | 71 | 82 | 63 |
| Goldfinch | Index | 0.92 | 0.46 | 6.09 | 39.15 | 2.70 |
| | Total | 218 | 217 | 230 | 355 | 222 |
| Siskin | Index | 0.47 | 0.93 | 28.67 | 10.08 | 0.00 |
| | Total | 215 | 216 | 300 | 238 | 214 |
| Redpoll | Index | 1.14 | 0.00 | 7.45 | 23.68 | 2.25 |
| | Total | 176 | 174 | 188 | 228 | 178 |
| Bullfinch | Index | 0.53 | 0.63 | 23.99 | 19.86 | 1.46 |
| | Total | 949 | 950 | 1242 | 1178 | 958 |
| Snow Bunting | Index | (9.09) | (0.00) | (0.00) | (0.00) | (0.00) |
| | Total | 11 | 10 | 10 | 10 | 10 |
| Yellowhammer | Index | 0.95 | 0.95 | 11.81 | 37.24 | 5.09 |
| | Total | 211 | 211 | 237 | 333 | 220 |
| Reed Bunting | Index | 0.49 | 0.49 | 15.11 | 18.97 | 1.20 |
| | Total | 412 | 412 | 483 | 506 | 415 |
| Corn Bunting | Index | (10.53) | (0.00) | (0.00) | 37.04 | (0.00) |
| | Total | 19 | 17 | 17 | 27 | 17 |

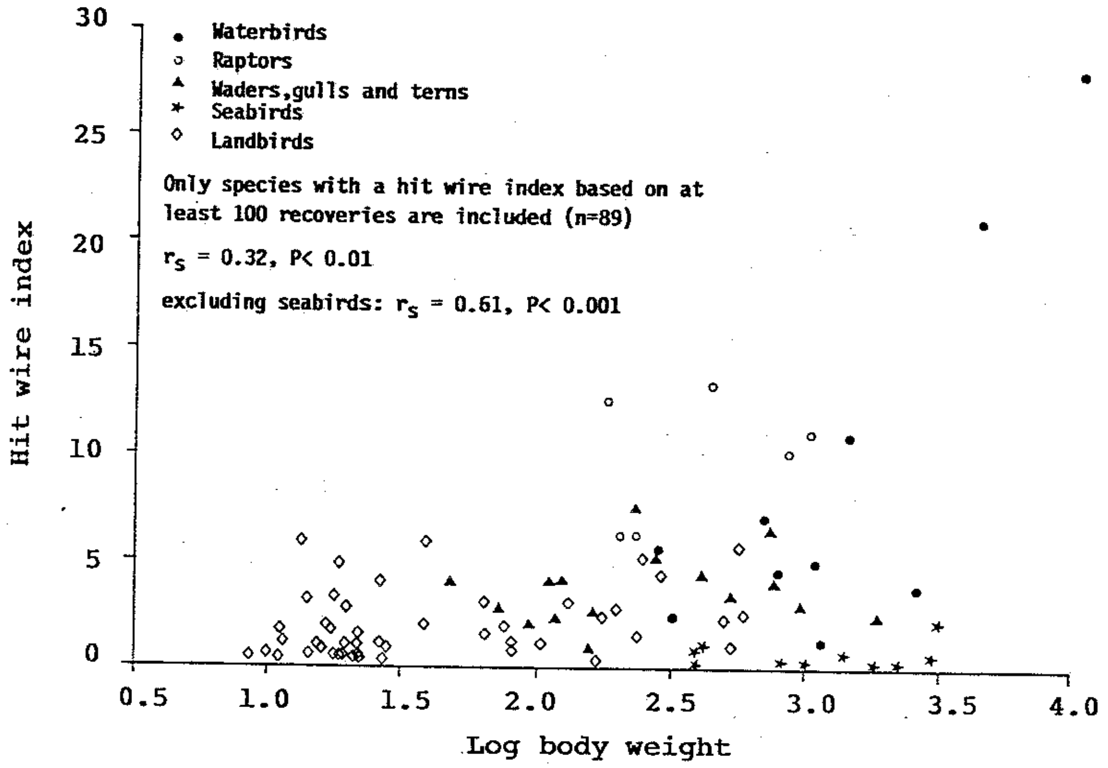



Figure 3. Relationship between the hit wire index and mean body weight.

and in the case of landbirds there are sufficient species to demonstrate the relationship statistically (n=47, $r_s$=0.32, P<0.05). This relationship may partly reflect the lower manoeuvrability of larger species. Very large birds such as swans, geese and herons may also risk electrocution through touching two wires simultaneously. However, body weight only explains a relatively small proportion of inter-specific variation in the hit wire index, and much of the rest must be attributable to the ecology and behaviour of individual species.

### 3.1.2 Waterfowl

This group includes Mute Swan and Canada Goose, the two species with the highest hit wire indices. Both species are very large and relatively unmanoeuvrable in flight, and both frequently inhabit areas where overhead lines are numerous. Pink-footed Goose has a low index (3.74) for a bird of its size, presumably due to relatively low densities of overhead lines around the main roosting and feeding areas of the ringed population, and perhaps also to the tendency of grey geese to fly relatively high when moving between roosts and feeding sites. Three ducks and Coot have moderate indices varying between 7.02 and 4.52. The low index for Moorhen (2.34) may be associated with the low and generally restricted flights made by this species, while the low index for Shelduck may result from low numbers of overhead lines on or close to their estuarine habitats.

### 3.1.3 Raptors

Raptors generally had high hit wire indices, and this was apparent even amongst those with few recoveries. Only six species - Hen Harrier, Sparrowhawk, Buzzard, Kestrel, Merlin and Peregrine - had hit wire indices based on at least 100 recoveries and for these the index ranged between 6.22 and 13.33 (Table 3). The hit wire indices for Hen Harrier (13.33) and Merlin (12.58) were particularly high relative to their body size. Hen Harrier has an index of 13.33 compared with 10.09 for the heavier Buzzard, while Merlin has an index of 12.58 compared to indices of 6.23 for Sparrowhawk of 6.22 for Kestrel. Hen Harrier and Kestrel both inhabit open moorland areas and may hunt at heights which make them particularly vulnerable to collisions with overhead lines.

Amongst species with few recoveries, the Red Kite, Marsh Harrier, Montagu's Harrier, Goshawk and Golden Eagle all had hit wire indices between 16.67 and 20.00 (Table 4). These are based on very small totals of between five and 16 recoveries; nevertheless, the fact that all these species have high indices provides some further evidence that overhead lines may be an important mortality factor for raptors. The only other raptors for which the BTO holds any ringing recoveries, and which do not have any recoveries from collisions with overhead wires, are White-tailed Eagle, Osprey and Hobby. National recovery totals for these species are extremely small, being one, 41 and 20 respectively.

Raptors have a high probability of colliding with various obstacles other than overhead lines (Section 3.2). Their high vulnerability to collisions is almost certainly associated with their methods of hunting which frequently involve the pursuit of prey at high speed. All of the raptors mentioned in this section, with the exceptions of Sparrowhawk, Buzzard and Kestrel, are specially protected under Schedule 1 (Part 1) of the Wildlife and Countryside Act. Many of these species have relatively small populations which may be vulnerable to increased mortality from factors such as overhead lines.

### 3.1.4 Waders, gulls and terns

Hit wire indices based on at least 100 recoveries could be calculated for nine waders, five gulls and two terns (Tables 3 and 4). Within this group, variation between species is related mainly to habitat. The highest hit wire indices for waders were for Lapwing (7.55) and Curlew (6.55), which spend much time inland both in winter and during the breeding season. Although Curlews have a predominantly coastal distribution in winter they often feed in fields near to the coast, and may be at risk from collisions with wires when flighting to these areas. The lowest hit wire index amongst the waders was for Knot (0.95), a species virtually restricted to large estuaries and which is thus unlikely to encounter overhead lines regularly. Similarly, amongst the gulls higher indices were recorded for the Black-headed Gull (5.22) and Common Gull (4.36) which spend more time inland than Herring Gull (2.91) and the predominantly coastal Great Black-backed Gull (2.46). Common Tern (2.41) and Arctic Tern (2.04) also had low hit wire indices as would be expected for coastal species.

### 3.1.5 Landbirds

This group includes game birds, pigeons, owls, Swift, Kingfisher, woodpeckers and passerines. There were 47 species for which a hit wire index could be calculated based on a sample of at least 100 recoveries. Most species in this group had relatively low hit wire indices, with values ranging from 5.80 (Sand Martin) to 0.21 (Dunnock). Swifts and hirundines had relatively high indices due (probably) to their aerial feeding methods, to their nesting on buildings near which overhead lines may be abundant and, in the case of hirundines, to their use of overhead lines as gathering places in late summer and on migration. Tawny Owl (5.58) and Barn Owl (4.34) also had high indices which are probably related to their nocturnal hunting behaviour. Jackdaw (5.06) had a high hit wire index relative to other corvids such as Carrion Crow (2.46) and Rook (2.20), presumably related to nesting on buildings and the consequent high probability of encounters with overhead lines. Some of the lowest indices were for species which are generally sedentary and which rarely undertake high flights, such as Wren (0.51), Robin (0.50), House Sparrow (0.26) and Dunnock (0.21). The low indices for these species may result directly from their small size and consquent high manveverability in flight as well as from their flight behaviour.

Amongst species with fewer than 100 recoveries available to calculate an index, Red Grouse is notable in that it has an index of 36.84 based on a total of 38 recoveries, the highest index of any of the species listed in Table 3. Red Grouse are relatively unmanoeuvrable in flight and it might be expected that they would be at risk from collisions with overhead lines and with other obstacles such as fences. They are not normally ringed by British ringers, and the data on file relate to a brief period of ringing for a specific study. These limited data must be interpreted with caution as they may not be representative. Black Grouse and Grey Partridge have similarly high indices, but these are based on even fewer recoveries (Table 4).

The hit wire indices of most landbirds are low, suggesting that collisions with overhead lines are not an important mortality factor for these species. Although we have no data to demonstrate the point, it is likely that the high hit wire indices for Swifts, hirundines and Jackdaws will mostly be due to collisions with lines supplying power to individual buildings and to telephone lines rather than to high voltage national grid lines.

3.1.6 Specially protected species

Twenty-four of the 132 species with "hit wire" recoveries (Tables 3 and 4) are specially protected under Schedule 1 of the Wildlife and Countryside Act. Eight of these are raptors and have already been discussed. The remaining species are Bittern, Bewick's Swan, Whooper Swan, Greylag Goose (specially protected in Outer Hebrides, Caithness, Sutherland and Western Ross only), Stone Curlew, Little Ringed Plover, Dotterel, Greenshank, Roseate Tern, Barn Owl, Kingfisher, Bluethroat, Redwing, Chough, Brambling and Snow Bunting.

The Bittern is now is now a very endangered species in Britain for which any additional mortality may be serious. The high hit wire index (20.00) is based on only five recoveries so it is a very imprecise estimate. However, because the index for Grey Heron (a related species) is also high it is possible that Bitterns may suffer significant mortality from collisions with overhead lines. Whooper Swan and Bewick's Swan both have very high hit wire indices similar to that obtained from the much larger sample of Mute Swan recoveries. This again suggests that the indices for these species provide a true indication of mortality from overhead lines. Greylag Goose has a high hit wire index (13.33) but which is somewhat lower than that for the larger Canada Goose (20.95). Much of the ringing data relate to the Icelandic population of Greylag Geese which winters in Scotland and northern England. The special protection for Greylag Geese is aimed at the native British breeding population in north-west Scotland. There is also a feral population of Greylag Geese in England, and these birds frequently associate with Canada Goose flocks. Birds from this feral population may be at high risk of collisions with overhead lines, as are Canada Geese, but the feral population is not of special conservation importance.

The four specially protected wader species with "hit wire" recoveries are Stone-curlew, Little Ringed Plover, Dotterel and Greenshank. The first two are lowland breeders while the second two breed in upland areas. All have relatively high hit wire indices, but these are imprecise estimates as they are based on very few recoveries. Little Ringed Plover populations have increased in recent decades due to the increased areas of breeding habitat produced by gravel workings. The other three species all have very limited populations in Britain, principally due to their specialised habitat requirements. These small populations may be vulnerable to increased mortality from such factors as overhead lines.

Roseate Tern does not have a high hit wire index (2.70) and neither does Kingfisher (1.92). Barn Owl has an index (4.34) which is based on a good sample of recoveries (576) and which is similar to the index for Tawny Owl (5.58). This high vulnerability to collisions with overhead lines compared with other landbirds (Section 3.1.5) is probably associated with the species' hunting behaviour.

The five specially protected passerines with "hit wire" recoveries are Bluethroat, Redwing, Chough, Brambling and Snow Bunting. The protection of these species is aimed principally at the very small breeding populations. However, for Bluethroat, Redwing, Brambling and Snow Bunting nearly all of the ringing recovery data relate to passage or wintering birds which breed outside Britain. Hit wire indices for Bluethroat and Snow Bunting are high, but they are very imprecise being based on only one and eleven recoveries respectively. The recovery data do not suggest that mortality from overhead lines is a problem for any of these passerines.

## 3.2 Variation between species in other collision indices

### 3.2.1 General comparison between the four collision mortalities

To make a general assessment of avian mortality resulting from collisions which could be compared with the data on mortality from collisions with overhead lines, we calculated cause of death indices for four other causes of death. These were "hit building", "hit window", road deaths and rail deaths. These cause of death indices were calculated in the same way as the hit wire index (see Methods), but substituting the appropriate set of recoveries for the "hit wire" ones. These indices for different causes of death cannot be compared directly because reporting probabilities differ between different causes of death (see Methods). However, careful interpretation does allow comparison of the patterns of interspecific variation in the individual cause of death indices. Where trends are contrary to those expected from the reporting probabilities, some qualitative comparisons between cause of death indices within a species may also be possible.

Cause of death indices for collisions with buildings and windows and for road and rail deaths were calculated for all species for which hit wire indices were calculated (Tables 3 and 4). The discussion presented here is limited to the 89 species for which a hit wire index could be calculated on the basis of at least 100 recoveries (above). Because in all these causes of death the number of "found dead" recoveries is generally greater than that for the specific cause, all the indices were based on an adequate sample of recoveries.

Deaths from collisions with buildings and windows would be expected to have a high reporting rate as they occur in very close proximity to man. Collisions with buildings appear to be relatively rare, with a mean hit building index of only 0.4. The highest hit building indices were for Sparrowhawk (3.33) and Peregrine (2.68), illustrating again the risks of these birds colliding with stationary objects while hunting. The hit window index was higher than the hit building index, with an overall mean of 4.3. The highest values recorded were for Siskin (28.67) and Sparrowhawk (26.29). However, no "hit window" recoveries were recorded for 39 of the 89 species under consideration.

Road deaths and rail deaths would be expected to have a lower reporting probability than collisions with buildings and windows, with the reporting probability for road deaths probably being greater than that for rail deaths. Road deaths might also be expected to be more common than rail deaths due to the greater extent of roads and road vehicles and public access to them. The mean road death index was 13.1, the two species with the highest indices being Whitethroat (47.84) and Tawny Owl (39.47). The mean rail death index was considerably lower (1.4), with Tawny Owl (15.68), Barn Owl (13.09) and Little Owl (11.17) being the three species with the highest values.

As might be expected, the data indicate that birds are more likely to die from collisions with transparent windows than from collisions with other parts of buildings. Road deaths are a much more important source of mortality than either of the previous two types of collisions. It is more difficult to assess the relative importance of rail deaths due to a lack of information on reporting probabilities. They are certainly a more important cause of death than collisions with buildings, but are probably less important than road deaths.

### 3.2.2 Collisions with buildings

There was no significant correlation between body weight and the hit building index ($r_s$=-0.20, 0.05<P<0.1). Raptors had the highest hit buildings index (mean=1.3, n=6) followed by landbirds (mean=0.5, n=47), and waterfowl (mean=0.3, n=10). Indices for all waders, gulls and seabirds were extremely low. Amongst the raptors, Kestrel had a low index presumably due to its method of hunting, while no "hit building" recoveries were recorded for Buzzard or Hen Harrier, probably due to habitat choice. Mute Swan (index=1.54) was the only one of the waterfowl with an index greater than 0.5. The six landbirds with the highest hit building indices were Sedge Warbler (2.48), Kingfisher (2.39), Swift (2.10), Swallow (1.64), Dipper (1.50) and Collared Dove (1.38). The Swift, Swallow and Collared Dove are readily explained through their habit of nesting in or around buildings. Kingfisher and Dipper deaths are presumably caused by collisions with bridges. The reason why Sedge Warbler should have a high index is less clear, but may be due to the way that nocturnal migrants can be attracted to lights in overcast conditions.

### 3.2.3 Collisions with windows

Small birds were more likely than large ones to be involved in collisions with windows, and over all species there was a negative correlation between body weight and hit window index

($r_s$=-0.73, $P<0.001$). This relationship is mainly due to the preferred habitats of most of the groups containing birds with large body size being away from buildings, hence removing the possibility of collisions with windows. Hit window indices for all waterfowl, waders, gulls and seabirds were negligible. However, even within the landbirds there was a highly significant negative correlation between body weight and hit window index ($r_s$=-0.60, $P<0.001$). This was due mainly to low indices for crows, pigeons and owls, most of which are reluctant to approach buildings closely.

3.2.4 Road deaths

Small birds were also more likely to be killed on the roads than large ones, and over all species there was a highly significant correlation between body weight and road death index ($r_s$=-0.67, $P<0.001$). Again, part of this relationship was due to many species from groups with a larger mean body size occupying habitats away from roads or flying at heights that did not make them vulnerable to collisions with road vehicles. Seabirds all had very low road death indices (mean=0.3, n=10), although there were only three species (Kittiwake, Guillemot and Puffin) for which no road deaths were recorded. Waterfowl had the next lowest road death index (mean=4.9, n=10). Within this group, Moorhen (17.41) and Coot (10.58) had the highest indices, presumably due to their habit of walking or flying low across roads. Waders and gulls had a similar road death index to waterfowl (mean=5.4, n=16), species with unusually high indices being Common Gull (15.72) and Lapwing (12.96). This is consistent with the more markedly inland habitat preferences of these two species relative to other members of the group.

Much higher road death indices were recorded for raptors (mean=15.3, n=6) and landbirds (mean=20.0, n=47). There was a negative correlation between body weight and road death index in both raptors ($r_s$=-0.66, NS) and landbirds ($r_s$=-0.41, $P<0.01$), although the former was not significant, probably due to the very small sample size. Amongst the raptors, Kestrel had the highest road death index (21.20), presumably due to its frequent habit of hunting over roadside verges. Seven landbirds had road death indices greater than 30: Whitethroat (47.84), Tawny Owl (39.47), Goldfinch (39.15), Barn Owl (38.30), Yellowhammer (37.24), Sedge Warbler (36.22) and Blackcap (32.95). The two owls are likely to be particularly susceptible to being hit by vehicles while hunting at night. The other five species are small passerines which occur commonly in hedgerows, including roadside ones. This habitat choice must render them vulnerable to collisions with vehicles.

### 3.2.5 Rail deaths

Rail death indices were generally much lower than the road death equivalents, and over all species there was no correlation between body weight and rail death index. Rail death indices for seabirds (mean=0.09, n=10) and for waders and gulls (mean=0.5, n=16) were very low. The only species within the latter group with an index greater than 1.0 was Snipe (2.52), this being a more inland species than many of the others in the group. Waterfowl also had fairly low rail death indices (mean=0.9, n=10). The rail death index for Moorhen (3.56) was considerably higher than those for other species in the group, as was the case with road deaths. As with the latter, this presumably reflects the walking and low flying habits of this species.

The highest rail death indices were recorded for raptors (mean=2.3, n=6) and landbirds (mean=2.0, n=47). Within each of these groups there was no significant correlation between body weight and rail death index. Kestrel had the highest value amongst the raptors (5.21), presumably because (as with road verges) railway embankments provide attractive foraging areas. Amongst the landbirds, by far the highest indices were for Tawny Owl (15.68), Barn Owl (13.09) and Little Owl (11.17). These owls had indices that were more than twice those of any other landbirds or raptors; the high vulnerability of owls is likely to be associated with their nocturnal hunting behaviour.

### 3.2.6 Relationships between the four collision indices

Viewed across all 89 species, those which were vulnerable to one type of collision were in general also vulnerable to others. There was significant similarity in the way in which the four collision indices (hit building, hit window, road deaths and rail deaths) ranked species according to their vulnerability to collisions (Kendall's Coefficient of Concordance, $W=0.59$, $P<0.001$). This relationship might have been due to the very low collision indices of seabirds and shorebirds, simply reflecting the lack of buildings, roads and railways in and around their usual habitats. We therefore repeated the analysis for landbirds, waterfowl and raptors only, and still obtained highly significant agreement in the ranking of species by the four collision indices ($W=0.46$, $n=63$, $P<0.001$). There was also significant agreement within both landbirds ($W=0.39$, $n=47$, $P<0.05$) and waterfowl ($W=0.63$, $n=10$, $P<0.05$) and even the very small sample of raptors gave a high coefficient of concordance which was almost significant ($W=0.55$, $n=6$, $P<0.1$). This agreement still left a considerable amount of unexplained variation between the rankings, which is likely to have been due to species-specific factors such as those discussed under the individual cause of death indices (above). If agreement had been perfect the coefficient of concordance would have had a value of 1.00.

We examined further the relationships between the individual cause of death indices by calculating Spearman correlation coefficients between individual pairs of cause of death indices. We did this using data for landbirds, raptors and

waterfowl. The resulting matrix of correlation coefficients was as follows:

| | Hit window index | Road death index | Rail Death index |
|---|---|---|---|
| Hit building index | 0.33 P<0.01 | 0.15 NS | 0.25 P<0.05 |
| Hit window index | 1.00 | 0.55 P<0.001 | 0.00 NS |
| Road death index | - | 1.00 | 0.42 P<0.001 |

The strongest relationships were between the ranking of species by the road death and rail death indices, and by the hit window and road death indices. There was no significant relationship between indices for hit building and road death nor between hit window index and rail death index. These correlation coefficients further indicate that there are important differences in the susceptibility of particular species to different types of collisions.

### 3.3 Comparison of the hit wire index with other collision indices

There was little evidence that species which were susceptible to collisions with overhead lines were also susceptible to other collision mortalities. Considering all 89 species with hit wire indices based on over 100 recoveries, there was no correlation between the ranking of species by the hit wire index and hit building index, nor between the hit wire and road death indices. There was a negative correlation between the hit wire index and hit window index ($r_s$=-0.31, P<0.01), probably because of the trend for large birds to have high hit wire values and for small birds to have high hit window values (above). There was a weak positive correlation between the hit wire index and the rail death index ($r_s$=0.27, P<0.01).

Because seabirds and shorebirds generally have very low collision indices, we followed the procedure used in the previous section of repeating the analysis using data for landbirds, raptors and waterbirds only. This showed negative correlations between the hit wire index and both the hit window index ($r_s$=-0.51, P<0.001) and the road death index ($r_s$=-0.35, P<0.01), again presumably mediated through the effects of body size. There was no significant correlation between the hit wire index and either the hit building index ($r_s$=0.17, NS) or the rail death index ($r_s$=0.20, NS).

Comparisons of values of the hit wire index for individual species or groups with the other four collision indices must be made with extreme caution due to the lack of data on reporting rates for the different causes of death (see Methods). It is reasonable to assume that the reporting probability for birds hitting buildings or windows will be considerably higher than that for birds hitting overhead lines. We suspect that the reporting probability for road deaths will be higher than that for "hit wire" recoveries. We are less certain what relationship to expect for the reporting rates of rail deaths and "hit wire" recoveries. Perhaps rail deaths would have a higher reporting probability, as most accidents will at least be seen by a driver, even though frequently they may be unable to stop to investigate them. Because "hit wire" recoveries generally have a lower reporting probability than other causes of collisions, these data cannot be used to provide quantitative evidence that mortality from overhead lines is less important than that from other causes.

On the basis of the above assumptions a few general conclusions can be reached. For all groups mortality from overhead lines appears to be more important than collisions with buildings, but for nearly all species such collisions must be a very unimportant mortality factor. Similarly, for all groups except landbirds collisions with windows are a less important mortality factor than collisions with overhead lines. Landbirds have a mean hit window index of 7.2 compared with a mean hit wire index of 1.9. Collisions with windows are almost certainly a more important mortality factor than collisions with overhead lines for a number of landbirds. There were 15 species for which the hit window index was more than ten times the value of the hit wire index. These were all small passerines with the exception of Kingfisher and Great Spotted Woodpecker.

The mean road death indices for shorebirds, landbirds and raptors were considerably higher that the equivalent hit wire indices, probably at least partly due to a higher reporting rate for road casualties. However, for landbirds the difference between the mean hit wire index (1.9) and the mean road death index (20.0) was so great that it seems reasonable to suggest that roads may be the greater source of mortality. Twenty-seven landbird species had road death indices more than ten times their "hit wire" equivalents. They comprised 23 small passerines, Little Owl, Kingfisher, Great Spotted Woodpecker and Jay. The mean road death index for waterfowl (4.9) was only slightly more than half their mean hit wire index. Thus for this group mortality from overhead lines is considerably more important than road deaths. Five species of waterfowl - Pink-footed Goose, Mute Swan, Grey Heron, Teal and Canada Goose - had hit wire indices more than five times their road death value.

Mean rail death indices for shorebirds, raptors and waterfowl were considerably less than the equivalent hit wire indices, while for landbirds the mean rail death index (2.0) and hit wire index (1.9) were similar. Out of the 89 species with hit wire indices based on at least 100 recoveries, only Yellowhammer had a rail death index more than five times its hit wire index. In contrast, there were 40 species with hit wire indices more than five times their rail death equivalents and for 24 of these the hit wire index was more than ten times the rail death index. Quantitative comparisons between deaths from overhead wires and rail accidents are impossible due to the lack of data on reporting rates. For raptors and waterfowl, however, collisions with overhead lines do appear to be a more important cause of mortality than railways. Three out of six raptors (Peregrine, Merlin and Hen Harrier) had hit wire indices more than five times their rail death index. The proportion of waterfowl falling into this category was even greater, with seven out of ten species having a hit wire index more than five times the rail death index. These were Coot, Pink-footed Goose, Mute Swan, Grey Heron, Teal, Canada Goose and Tufted Duck.

### 3.4 Regional variation in the hit wire index

Hit wire indices were calculated for six regions of the British Isles (Figure 1) for the 46 species having 10 or more "hit wire" recoveries (Table 5). Detailed maps showing the distributions of "hit wire" and "found dead" recoveries for these species are presented in Appendix 2. Sample sizes were sufficient to allow chi-square tests for differences in the hit wire index between regions for 23 species, and of these 16 showed significant regional variation (Table 5).

We used Kendall's Coefficient of Concordance to determine whether different species ranked the six regions similarly with respect to the incidence of mortality from overhead lines. The analysis was carried out for 27 species which had a total of at least 20 recoveries in each region. There was significant but very weak agreement in the rankings given by the different species ($W=0.15$, $P<0.001$). We repeated this analysis for the 12 of these species for which a chi-square test showed significant differences between regions, and obtained a similar result ($W=0.19$, $P<0.05$). Totals of the ranks assigned to the regions by the different species suggest that in general the hit wire index was highest in Scotland and

Table 5. Regional variation in the hit wire index for species with 10 or more recoveries attributable to overhead lines.

$$\text{Hit wire index} = \frac{\text{'Hit Wire' recoveries}}{\text{Total}} \times 100$$

Total = 'Hit wire' recoveries + 'Found dead' recoveries

Indices based on totals of less than 20 recoveries are shown in parenthesis.
Regions are shown in Figure 1. Detailed maps of the recovery distribution are presented in Appendix 2.

Column headed Sig. gives the results of an overall 2 x n chi-square test for differences in the hit wire index between regions:

** P<0.01 * P<0.05 NS not significant NA not applicable due to small sample sizes.

Where the overall chi-square test was significant, the row labelled Dev. gives the results of a Haberman test for the significance of deviations by individual cells (see methods):

+ index significantly high - index significantly low NS not significant
NA not applicable due to small sample size
Lines indicate where data from adjacent regions have been combined for testing.

| Species | | Ireland | Scotland | NW England | NE England | SW England | SE England | Sig |
|---|---|---|---|---|---|---|---|---|
| Manx | Index | 0.72 | 0.0 | 1.74 | (20.00) | 0.77 | (25.00) | NA |
| Shearwater | Total | 138 | 60 | 230 | 10 | 908 | 4 | |
| Cormorant | Index | 2.19 | 1.13 | 2.13 | 2.75 | 3.73 | 4.08 | * |
| | Total | 457 | 885 | 375 | 109 | 295 | 196 | |
| | Dev | NS | - | NS | NS | + | NS | |
| Grey Heron | Index | 4.88 | 12.43 | 16.74 | 13.22 | 9.68 | 6.60 | * |
| | Total | 82 | 346 | 272 | 295 | 124 | 318 | |
| | Dev | NS | NS | NS | NS | NS | - | |

| Species | | Ireland | Scotland | NW England | NE England | SW England | SE England | Sig |
|---|---|---|---|---|---|---|---|---|
| Mute Swan | Index | 20.73 | 33.11 | 36.09 | 33.29 | 22.84 | 25.46 | ** |
| | Total | 82 | 737 | 1380 | 895 | 2272 | 2985 | |
| | Dev | NS | + | + | + | - | - | |
| Pink-footed Goose | Index | 0 | 4.69 | 1.85 | 1.22 | 0 | (0.0) | NA |
| | Total | 0 | 277 | 108 | 82 | 0 | 3 | |
| Canada Goose | Index | 0 | 13.56 | 20.40 | 26.40 | 13.82 | 18.27 | ** |
| | Total | 0 | 59 | 706 | 447 | 152 | 197 | |
| | Dev | NA | NS | NS | + | - | NS | |
| Teal | Index | 3.45 | 9.10 | 7.32 | 4.23 | 1.67 | 6.67 | NA |
| | Total | 30 | 22 | 41 | 71 | 60 | 135 | |
| Mallard | Index | 0.00 | 5.41 | 8.01 | 10.51 | 1.06 | 3.14 | ** |
| | Total | 67 | 37 | 87 | 547 | 377 | 605 | |
| | Dev | NA | NS | NS | + | - | - | |
| Tufted Duck | Index | (0.00) | 0.00 | (14.29) | 5.41 | (7.14) | 8.51 | NA |
| | Total | 12 | 24 | 14 | 37 | 14 | 141 | |
| Hen Harrier | Index | (0.0) | 13.86 | (0.0) | (50.00) | 0 | 0 | |
| | Total | 7 | 101 | 8 | 4 | 0 | 0 | NA |
| Sparrowhawk | Index | 7.41 | 9.74 | 5.96 | 8.51 | 4.30 | 5.19 | NA |
| | Total | 54 | 267 | 235 | 47 | 93 | 270 | |
| Buzzard | Index | (0.0) | 16.83 | 6.67 | (0.0) | 2.08 | (0.0) | |
| | Total | 5 | 101 | 60 | 1 | 48 | 3 | ** |
| | Dev | NA | + | NS | | - | | |

| Species | | Ireland | Scotland | NW England | NE England | SW England | SE England | Sig |
|---|---|---|---|---|---|---|---|---|
| Kestrel | Index | 3.23 | 11.02 | 7.37 | 3.06 | 5.73 | 4.68 | |
| | Total | 31 | 236 | 434 | 294 | 157 | 342 | ** |
| | Dev | NS | + | NS | - | NS | NS | |
| Merlin | Index | (0.0) | 14.52 | 15.25 | 5.00 | (9.09) | (0.0) | NA |
| | Total | 4 | 62 | 59 | 20 | 11 | 3 | |
| Peregrine | Index | (11.76) | 6.56 | 15.00 | 0 | (0.0) | 0 | NA |
| | Total | 17 | 61 | 40 | 0 | 3 | 0 | |
| Red Grouse | Index | 0 | 37.84 | (0.0) | 0 | 0 | 0 | NA |
| | Total | 0 | 37 | 1 | 0 | 0 | 0 | |
| Moorhen | Index | 1.27 | 1.96 | 4.88 | 3.61 | 0.0 | 1.43 | NA |
| | Total | 79 | 51 | 82 | 83 | 38 | 140 | |
| Coot | Index | (0.00) | 10.00 | 8.57 | 7.81 | 0.0 | 3.05 | NA |
| | Total | 6 | 20 | 35 | 64 | 32 | 197 | |
| Oystercatcher | Index | 1.56 | 5.62 | 2.07 | 1.74 | 1.79 | 4.00 | ** |
| | Total | 64 | 872 | 724 | 287 | 224 | 25 | |
| | Dev | NS | + | - | NS | NS | NS | |
| Lapwing | Index | 2.78 | 6.37 | 10.95 | 6.67 | 3.95 | 4.50 | * |
| | Total | 108 | 361 | 475 | 75 | 76 | 111 | |
| | Dev | - | NS | + | NS | NS | NS | |
| Dunlin | Index | (10.00) | (7.14) | 2.82 | 5.66 | 0.0 | 2.38 | NA |
| | Total | 10 | 14 | 71 | 159 | 30 | 84 | |
| Curlew | Index | 4.55 | 8.79 | 7.09 | 3.92 | 2.32 | 11.11 | NS |
| | Total | 44 | 91 | 141 | 51 | 43 | 27 | |

| Species | | Ireland | Scotland | NW England | NE England | SW England | SE England | Sig |
|---|---|---|---|---|---|---|---|---|
| Redshank | Index | 4.76 | 3.74 | 2.73 | 0.48 | 00.0 | 4.31 | NA |
| | Total | 21 | 214 | 183 | 209 | 34 | 116 | |
| Black-headed Gull | Index | 3.94 | 6.40 | 5.42 | 7.54 | 4.87 | 4.09 | |
| | Total | 507 | 860 | 1475 | 491 | 308 | 1493 | * |
| | Dev | NS | NS | NS | + | NS | - | |
| Common Gull | Index | 4.00 | 4.23 | (0.0) | (10.53) | (0.0) | 5.13 | NA |
| | Total | 75 | 331 | 12 | 19 | 6 | 39 | |
| Lesser Black-backed Gull | Index | 2.22 | 3.69 | 4.23 | 8.75 | 3.60 | 3.23 | NS |
| | Total | 90 | 407 | 1325 | 80 | 333 | 93 | |
| Herring Gull | Index | 3.64 | 2.54 | 3.45 | 5.42 | 2.19 | 1.85 | |
| | Total | 577 | 2758 | 2001 | 277 | 960 | 162 | * |
| | Dev. | NS | NS | NS | + | NS | NS | |
| Great Black-backed Gull | Index | 1.49 | 2.06 | 5.33 | 7.41 | 0.51 | 5.26 | ** |
| | Total | 134 | 389 | 169 | 27 | 197 | 19 | |
| | Dev | NA | NS | + | | NS | | |
| Barn Owl | Index | (0.0) | 4.00 | 4.72 | 5.81 | 4.55 | 2.75 | NS |
| | Total | 3 | 100 | 212 | 86 | 66 | 109 | |
| Tawny Owl | Index | 0 | 3.57 | 5.00 | 7.14 | 3.51 | 9.20 | NS |
| | Total | 0 | 84 | 200 | 56 | 57 | 87 | |
| Swift | Index | (33.33) | (0.00) | 7.80 | 8.02 | 3.70 | 3.14 | * |
| | Total | 3 | 14 | 295 | 212 | 54 | 509 | |
| | Dev | NA | NS | + | NS | NS | - | |
| Sand Martin | Index | (0.00) | 17.24 | 0.00 | 5.56 | 8.57 | 5.22 | NA |
| | Total | 6 | 29 | 51 | 90 | 35 | 134 | |

| Species | | Ireland | Scotland | NW England | NE England | SW England | SE England | Sig |
|---|---|---|---|---|---|---|---|---|
| Swallow | Index | 5.71 | 6.80 | 4.91 | 3.66 | 4.49 | 4.75 | NS |
| | Total | 35 | 147 | 468 | 246 | 156 | 337 | |
| House Martin | Index | (25.00) | 7.69 | 1.04 | 3.45 | 1.89 | 3.05 | NA |
| | Total | 4 | 39 | 96 | 87 | 53 | 164 | |
| Pied Wagtail | Index | (0.00) | 2.13 | 2.78 | 0.80 | 2.22 | 0.79 | NA |
| | Total | 10 | 94 | 180 | 125 | 225 | 633 | |
| Robin | Index | 1.85 | 0.93 | 0.59 | 0.50 | 0.28 | 0.40 | NA |
| | Total | 54 | 214 | 506 | 404 | 363 | 1239 | |
| Song Thrush | Index | 3.74 | 2.99 | 2.87 | 1.72 | 2.37 | 1.02 | ** |
| | Total | 187 | 401 | 871 | 754 | 464 | 2163 | |
| | Dev | NS | NS | + | NS | NS | - | |
| Mistle Thrush | Index | (0.00) | 0.00 | 3.61 | 6.12 | 6.52 | 1.44 | NA |
| | Total | 27 | 24 | 166 | 98 | 46 | 278 | |
| Blackbird | Index | 2.31 | 2.17 | 1.37 | 1.18 | 1.01 | 0.61 | ** |
| | Total | 520 | 1983 | 3879 | 3807 | 1686 | 8198 | |
| | Dev | + | + | NS | NS | NS | - | |
| Blue Tit | Index | 0.00 | 0.68 | 0.43 | 0.26 | 0.71 | 0.22 | NA |
| | Total | 45 | 295 | 927 | 765 | 842 | 2755 | |
| Great Tit | Index | 0.00 | 2.70 | 0.54 | 0.40 | 0.31 | 0.55 | NA |
| | Total | 29 | 111 | 367 | 247 | 321 | 1100 | |
| Jackdaw | Index | 3.16 | 4.60 | 2.04 | 0.00 | 7.48 | 1.14 | NS |
| | Total | 95 | 87 | 147 | 43 | 107 | 175 | |

| Species | | Ireland | Scotland | NW England | NE England | SW England | SE England | Sig |
|---|---|---|---|---|---|---|---|---|
| Rook | Index | 3.90 | 1.18 | 3.70 | 1.11 | 2.44 | 2.04 | NA |
| | Total | 77 | 170 | 108 | 90 | 41 | 196 | |
| Starling | Index | 2.99 | 2.08 | 1.15 | 0.93 | 1.42 | 0.70 | ** |
| | Total | 435 | 1348 | 3231 | 3017 | 1409 | 6302 | |
| | Dev | + | + | NS | NS | NS | - | |
| Chaffinch | Index | 4.76 | 1.65 | 0.92 | 1.27 | 0.36 | 0.49 | NA |
| | Total | 63 | 182 | 327 | 158 | 277 | 610 | |
| Greenfinch | Index | 1.02 | 0.87 | 1.32 | 1.10 | 0.64 | 0.55 | NS |
| | Total | 98 | 229 | 1134 | 1174 | 777 | 3974 | |

North-west England and lowest in southern England and Ireland. However there was obviously considerable variation between species, much of it related to the ecology of individual species and to their distribution relative to the distribution of overhead lines. Only limited interpretation of these differences is possible because we did not have detailed information on the regional distribution of overhead lines.

Cormorant has a significantly low hit wire index for Scotland and a significantly high hit wire index for South-east England and exhibits a trend of increasing hit wire indices from north to south. Cormorants breed and winter on the coast in the north but in the south they occur principally inland in winter. They are unlikely to encounter overhead lines in coastal habitats but are much more likely to do so around inland habitats such as reservoirs and gravel pits. Thus regional variation in the hit wire index is related to regional variation in habitat occupancy.

Four species of waterbirds showed significant regional variation in the hit wire index: Grey Heron, Mute Swan, Canada Goose and Mallard. Indices for South-west and South-east England were significantly low for three species, while North-east England had three species with significantly high indices. Mute Swans also showed significantly high indices in Scotland and North-west England (Table 5). The five waterfowl species with indices for each region based on at least 20 recoveries showed highly significant agreement in the ranking of the regions according to the incidence of recoveries from overhead lines (Kendall's coefficient of concordance, $W=0.83$, $P<0.001$). The rankings suggest that mortality from overhead lines was high in Scotland and northern England, and low in southern England and Ireland.

Two raptors showed significant regional variation in the hit wire index (Table 5). The index for Buzzards was high in Scotland and low in southern England where the species is restricted to relatively remote areas. The index for Kestrels was also high in Scotland, but within Scotland there was no relationship between the distributions of "hit wire" recoveries for Buzzards and Kestrels (Appendix 2).

Oystercatchers had a much higher hit wire index in Scotland than in any other regions, presumably because they are a widespread inland breeding species there, while in other regions they are more restricted to coastal areas, and are thus less likely to encounter overhead lines. The recently developed habit of rooftop nesting by Oystercatchers may have increased further the susceptibility of a small proportion of the population to collisions with overhead lines during the breeding season. Lapwing is the only other wader showing significant regional variation in the hit wire index, with a significantly low index in Ireland and a significantly high one in North-west England.

Three gulls (Black-headed Gull, Herring Gull and Great Black-backed Gull) all have significantly high hit wire indices for North-east England, and the limited data for Common Gull and Lesser Black-backed Gull suggest a similar pattern (Table 5). Herring Gull and Great Black-backed Gull show concentrations of recoveries on the coast around the Tyne and Tees estuaries (Appendix 2) but for the other species the pattern is less clear. An extensive programme of marking gulls was carried out on rubbish tips in these areas in the 1970s and 1980s and may have produced a sample of ringed birds which were particularly likely to be involved in collisions with overhead lines.

Three medium-sized passerines with very large samples of recoveries (Song Thrush, Blackbird and Starling) all show significant regional variation in the hit wire index. Blackbird and Starling show the same pattern, with significantly high indices in Scotland and Ireland and a significantly low index in South-east England. A similar general pattern was shown by the 12 species of landbirds for which it was possible to calculate a hit wire index for each region based on at least 20 recoveries. The degree of agreement in the regional rankings given by these species was weak though significant (Kendall's coefficient of concordance, W=0.25, P<0.05). This pattern suggests that, for passerines, hit wire indices tended to be highest in regions with low population density. This might come about if the increase in reporting probability in urban and suburban areas as compared with rural ones was greater for "found dead" recoveries than for "hit wire" recoveries. Unfortunately we were not able to test this idea, but it might be possible through a much more detailed examination of the distributions of "hit wire" and "found dead" recoveries in relation to human population density. Interpretation of these regional patterns for small passerines is complex, because there are declines in the hit wire index with time period despite increased ringing in Scotland and Ireland over the last decade (below). However, even now in the 1980s passerine recoveries from Scotland and Ireland represent a fairly small proportion of the national sample.

## 3.5 Seasonal variation in the hit wire index

Monthly hit wire indices were calculated for the 46 species with 10 or more "hit wire" recoveries (Table 6). A chi-square test for differences in the hit wire index between months was possible for 12 species. One of these, the Swallow, was a summer migrant so could only be analysed for the months of April to October. Ten of the twelve species showed significant variation between months, the exceptions being Swallow and Kestrel. These ten species showed only very weak agreement of their ranking of months according to the magnitude of the hit wire index (Kendall's coefficient of concordance, W=0.27, P<0.01), with a tendency for indices to be lowest during the breeding season and summer, and higher in autumn and winter. Detailed patterns were best explained in terms of the behaviour of individual species.

Table 6. Monthly variation in the hit wire index.

$$\text{Hit wire index} = \frac{\text{'Hit Wire' recoveries}}{\text{Total}} \times 100$$

Total = 'Hit wire' recoveries + 'Found dead' recoveries

Indices based on totals of less than 20 recoveries are shown in parenthesis.

Column headed Sig. gives the results of an overall 2 x n chi-square test for differences in the hit wire index between months:

** P<0.01    * P<0.05    NS not significant    NA not applicable due to small sample sizes.

Where the overall chi-square test was significant, the row labelled Dev. gives the results of a Haberman test for the significance of deviations by individual cells (see methods):

+ index significantly high    - index significantly low    NS not significant
NA not applicable due to small sample size
Lines indicate where data from adjacent months have been combined for testing.

| Species | | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manx | Index | (0.00) | (0.00) | 0.00 | 0.65 | 0.47 | 0.00 | 0.39 | 1.28 | 3.25 | 0.00 | (0.00) | (0.00) | NA |
| Shearwater | Total | 2 | 3 | 21 | 153 | 215 | 179 | 256 | 234 | 246 | 27 | 12 | 2 | |
| Cormorant | Index | 0.75 | 2.94 | 1.60 | 2.31 | 2.55 | 1.41 | 0.00 | 3.31 | 2.71 | 3.17 | 2.90 | 1.83 | NS |
| | Total | 265 | 238 | 188 | 216 | 157 | 142 | 125 | 181 | 258 | 189 | 138 | 218 | |
| Grey Heron | Index | 8.16 | 8.97 | 9.20 | 3.97 | 9.01 | 16.90 | 7.32 | 12.5 | 14.43 | 12.24 | 22.11 | 15.03 | ** |
| | Total | 196 | 156 | 163 | 151 | 111 | 71 | 82 | 88 | 97 | 98 | 95 | 128 | |
| | Dev | NS | NS | NS | - | NS | NS | NS | NS | NS | NS | + | NS | |
| Mute Swan | Index | 26.65 | 29.00 | 30.40 | 30.03 | 30.58 | 21.75 | 12.88 | 11.36 | 24.36 | 33.73 | 33.43 | 28.65 | ** |
| | Total | 968 | 969 | 1067 | 979 | 618 | 377 | 295 | 352 | 550 | 750 | 676 | 712 | |
| | Dev | NS | NS | NS | NS | NS | - | - | - | NS | + | + | NS | |

| Species | | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pink-footed Goose | Index | 2.70 | 4.48 | 2.27 | 1.69 | 0.00 | (0.00) | (0.00) | (0.00) | (0.00) | 4.17 | 8.16 | 4.92 | NS |
| | Total | 111 | 67 | 44 | 59 | 29 | 14 | 6 | 3 | 3 | 24 | 49 | 61 | |
| Canada Goose | Index | 19.16 | 29.41 | 30.83 | 21.28 | 16.35 | 17.10 | 1.20 | 19.30 | 14.38 | 14.68 | 26.61 | 19.80 | ** |
| | Total | 167 | 102 | 133 | 188 | 159 | 76 | 83 | 114 | 160 | 154 | 124 | 101 | |
| | Dev | NS | + | + | NS | NS | NS | - | NS | - | NS | NS | NS | |
| Teal | Index | 7.58 | 6.06 | 6.98 | (12.5) | (0.00) | (12.5) | (0.00) | (0.00) | 5.00 | 4.00 | 0.00 | 3.64 | NA |
| | Total | 66 | 66 | 43 | 16 | 9 | 8 | 8 | 5 | 20 | 25 | 38 | 55 | |
| Mallard | Index | 3.64 | 1.81 | 6.56 | 10.82 | 9.18 | 4.69 | 0.00 | 2.17 | 0.95 | 1.90 | 3.13 | 1.40 | ** |
| | Total | 165 | 166 | 183 | 26 | 207 | 64 | 62 | 92 | 105 | 105 | 160 | 143 | |
| | Dev | NS | NS | NS | + | + | NS | NS | NS | NS | NS | NS | - | |
| Tufted Duck | Index | 9.76 | 3.23 | 11.11 | (6.67) | 15.00 | (18.18) | (0.00) | (0.00) | (5.56) | (0.00) | (5.26) | 4.00 | NA |
| | Total | 41 | 31 | 27 | 15 | 20 | 11 | 10 | 8 | 18 | 17 | 19 | 25 | |
| Hen Harrier | Index | (11.76) | (25.00) | (15.38) | (28.57) | (11.11) | (50.00) | (0.00) | (8.33) | (18.75) | (0.00) | (0.00) | (33.33) | NA |
| | Total | 17 | 8 | 13 | 7 | 9 | 2 | 14 | 12 | 16 | 7 | 9 | 6 | |
| Sparrowhawk | Index | 8.22 | 4.62 | 8.55 | 5.22 | 3.33 | 11.76 | 4.44 | 9.16 | 5.68 | 4.92 | 12.28 | 5.68 | NS |
| | Total | 73 | 65 | 117 | 134 | 90 | 34 | 45 | 131 | 88 | 61 | 57 | 71 | |
| Buzzard | Index | 23.81 | 14.29 | 4.35 | 6.90 | (6.67) | (0.00) | (0.00) | (10.53) | (11.76) | 10.00 | (12.50) | (5.99) | NS |
| | Total | 21 | 28 | 23 | 29 | 14 | 7 | 6 | 19 | 17 | 20 | 16 | 17 | |
| Kestrel | Index | 5.22 | 8.72 | 2.83 | 5.13 | 5.33 | 6.38 | 8.33 | 5.38 | 10.48 | 6.45 | 457 | 5.41 | NS |
| | Total | 134 | 149 | 106 | 117 | 75 | 47 | 120 | 186 | 124 | 155 | 133 | 148 | |
| Merlin | Index | (0.00) | (22.22) | (22.22) | (5.26) | (7.14) | (0.00) | (16.67) | 9.09 | (5.88) | 28.57 | (16.67) | (10.00) | NA |
| | Total | 9 | 9 | 9 | 19 | 14 | 5 | 6 | 22 | 17 | 21 | 18 | 10 | |
| Peregrine | Index | (0.00) | (33.33) | (10.00) | (5.88) | (0.00) | (0.00) | (0.00) | (0.00) | (11.11) | (18.78) | (20.00) | (16.67) | NA |
| | Total | 8 | 10 | 10 | 17 | 14 | 2 | 4 | 14 | 9 | 11 | 10 | 12 | |
| Red Grouse | Index | (100.00) | (100.00) | (16.67) | (0.00) | (50.00) | (100.00) | 0 | (0.00) | (0.00) | (100.00) | (100.00) | (60.00) | NA |
| | Total | 2 | 1 | 6 | 11 | 6 | 1 | 0 | 1 | 2 | 2 | 1 | 5 | |

| Species | | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moorhen | Index | 0.00 | 5.41 | 3.33 | 4.00 | 0.00 | 0.00 | 7.69 | 0.00 | 0.00 | 0.00 | (5.26) | 0.00 | NA |
| | Total | 47 | 37 | 60 | 75 | 50 | 36 | 39 | 35 | 23 | 28 | 19 | 22 | |
| Coot | Index | 3.70 | 4.00 | 4.55 | 8.06 | 0.00 | 4.17 | (0.00) | (0.00) | (8.33) | (14.29) | 5.00 | 0.00 | NA |
| | Total | 54 | 50 | 44 | 62 | 27 | 24 | 11 | 10 | 12 | 14 | 20 | 26 | |
| Oyster-catcher | Index | 1.86 | 2.70 | 5.77 | 5.61 | 6.44 | 4.12 | 3.24 | 1.92 | 1.27 | 0.00 | 2.15 | 2.94 | * |
| | Total | 215 | 222 | 260 | 196 | 202 | 170 | 216 | 208 | 158 | 120 | 93 | 136 | |
| | Dev | NS | NS | + | NS | + | NS | NS | NS | NS | - | NS | NS | |
| Lapwing | Index | 7.37 | 0.00 | 9.21 | 10.14 | 7.14 | 6.49 | 6.45 | 6.61 | 8.70 | 14.29 | 10.00 | 6.67 | NS |
| | Total | 95 | 54 | 76 | 138 | 154 | 185 | 155 | 121 | 69 | 49 | 50 | 60 | |
| Dunlin | Index | 3.51 | 4.65 | 2.50 | 0.00 | 9.52 | (0.00) | (7.69) | 6.00 | 0.00 | 8.70 | 4.35 | 2.86 | NA |
| | Total | 57 | 43 | 40 | 26 | 21 | 6 | 13 | 50 | 31 | 23 | 23 | 35 | |
| Curlew | Index | 0.00 | 6.67 | 3.33 | 9.52 | 0.00 | 0.00 | 10.26 | 17.39 | 4.17 | 0.00 | 4.35 | 15.38 | NS |
| | Total | 32 | 30 | 30 | 42 | 29 | 23 | 39 | 46 | 48 | 29 | 23 | 26 | |
| Redshank | Index | 0.00 | 0.80 | 2.60 | 3.61 | 12.50 | 2.78 | 8.82 | 0.00 | 7.69 | 0.00 | 2.44 | 2.60 | NA |
| | Total | 176 | 125 | 77 | 83 | 40 | 36 | 34 | 34 | 26 | 28 | 41 | 77 | |
| Black-headed Gull | Index | 4.05 | 3.45 | 6.95 | 7.64 | 7.16 | 3.33 | 3.98 | 5.30 | 4.78 | 6.06 | 8.15 | 5.61 | * |
| | Total | 370 | 406 | 331 | 301 | 377 | 450 | 830 | 811 | 418 | 297 | 258 | 285 | |
| | Dev | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | + | NS | |
| Common Gull | Index | 3.45 | 6.67 | 3.23 | 0.00 | 3.85 | 10.00 | 2.53 | 3.48 | 3.92 | 4.00 | 8.00 | (11.11) | NA |
| | Total | 29 | 30 | 31 | 23 | 26 | 30 | 79 | 115 | 57 | 25 | 25 | 18 | |
| Lesser Black-backed Gull | Index | 8.11 | 0.00 | 9.30 | 9.68 | 5.68 | 5.21 | 1.41 | 2.86 | 4.89 | 4.55 | 1.39 | 7.5 | NS |
| | Total | 37 | 32 | 43 | 93 | 229 | 288 | 425 | 525 | 368 | 176 | 72 | 40 | |
| Herring Gull | Index | 3.03 | 3.42 | 2.84 | 4.24 | 2.96 | 2.10 | 1.75 | 2.28 | 3.18 | 4.16 | 4.85 | 5.81 | ** |
| | Total | 297 | 292 | 282 | 401 | 540 | 619 | 1026 | 1406 | 848 | 457 | 309 | 258 | |
| | Dev | NS | NS | NS | NS | NS | NS | 0.00 | NS | NS | NS | + | + | |
| Great Black backed Gull | Index | 5.77 | 6.67 | 1.37 | 2.44 | 3.85 | 0.00 | 0.00 | 1.85 | 1.87 | 3.39 | 5.88 | 3.13 | NA |
| | Total | 52 | 45 | 73 | 82 | 78 | 72 | 122 | 162 | 107 | 59 | 51 | 32 | |

| Species | | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barn Owl | Index | 3.57 | 1.43 | 5.17 | 2.04 | 0.00 | (0.00) | 5.00 | 6.45 | 5.48 | 6.36 | 5.45 | 6.25 | NS |
| | Total | 56 | 70 | 58 | 49 | 24 | 13 | 20 | 31 | 73 | 63 | 55 | 64 | |
| Tawny Owl | Index | 6.45 | 14.81 | 0.00 | 0.00 | 6.25 | 0.00 | 6.82 | 13.16 | 10.71 | 5.56 | 0.00 | 8.33 | NS |
| | Total | 31 | 27 | 52 | 57 | 48 | 41 | 44 | 38 | 56 | 36 | 30 | 24 | |
| Swift | Index | 0 | 0 | 0 | (0.00) | 441 | 5.40 | 7.75 | 5.56 | (0.00) | (0.00) | 0 | 0 | NS |
| | Total | 0 | 0 | 0 | 12 | 363 | 315 | 271 | 90 | 16 | 9 | 0 | 0 | |
| Sand Martin | Index | 0 | 0 | 0 | 4.35 | 2.41 | 7.81 | 3.26 | 14.00 | 6.45 | (0.00) | 0 | 0 | * |
| | Total | 0 | 0 | 0 | 23 | 83 | 64 | 92 | 50 | 31 | 2 | 0 | 0 | |
| | Dev | | NA | | | | - | | | + | | NA | | |
| Swallow | Index | 0 | 0 | (0.00) | 8.90 | 3.87 | 4.76 | 4.08 | 5.00 | 8.62 | 0.00 | (0.00) | 0 | NS |
| | Total | 0 | 0 | 1 | 29 | 336 | 294 | 294 | 220 | 174 | 31 | 9 | 0 | |
| House Martin | Index | 0 | 0 | (0.00) | (0.00) | 8.06 | 0.00 | 2.04 | 6.74 | 0.00 | 2.94 | 0 | 0 | NA |
| | Total | 0 | 0 | 1 | 4 | 62 | 83 | 98 | 89 | 67 | 34 | 0 | 0 | |
| Pied Wagtail | Index | 0.00 | 3.36 | 4.29 | 1.70 | 1.65 | 1.72 | 0.00 | 1.28 | 5.00 | 0.00 | 0.00 | 0.00 | NA |
| | Total | 193 | 147 | 140 | 176 | 121 | 116 | 93 | 78 | 40 | 33 | 33 | 97 | |
| Robin | Index | 0.00 | 0.64 | 0.33 | 0.75 | 0.33 | 0.91 | 0.00 | 0.60 | 0.00 | 1.30 | 0.55 | 0.85 | NA |
| | Total | 306 | 313 | 301 | 265 | 303 | 219 | 151 | 167 | 179 | 154 | 182 | 240 | |
| Song Thrush | Index | 2.82 | 1.55 | 1.58 | 1.15 | 1.01 | 1.78 | 1.20 | 2.24 | 2.59 | 3.68 | 8.53 | 1.22 | ** |
| | Total | 355 | 388 | 568 | 521 | 692 | 731 | 585 | 312 | 232 | 163 | 129 | 164 | |
| | Dev | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | + | NS | |
| Mistle Thrush | Index | 3.45 | 2.08 | 5.45 | 4.40 | 0.71 | 1.80 | 1.85 | 5.88 | (5.88) | 8.70 | (5.88) | (0.00) | NA |
| | Total | 29 | 48 | 55 | 91 | 141 | 111 | 54 | 34 | 17 | 23 | 17 | 19 | |
| Blackbird | Index | 0.99 | 1.40 | 1.11 | 1.04 | 0.84 | 0.82 | 1.06 | 0.54 | 1.20 | 1.79 | 1.63 | 2.29 | * |
| | Total | 1411 | 1859 | 2617 | 2703 | 2856 | 2689 | 1895 | 1109 | 753 | 615 | 737 | 829 | |
| | Dev | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | + | |

| Species | | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue Tit | Index | 0.35 | 0.15 | 0.68 | 0.33 | 0.31 | 0.23 | 0.50 | 0.00 | 0.00 | 0.00 | 0.91 | 0.26 | NA |
| | Total | 570 | 656 | 882 | 903 | 643 | 434 | 201 | 153 | 201 | 275 | 329 | 382 | |
| Great Tit | Index | 0.00 | 0.48 | 0.00 | 0.62 | 1.49 | 0.89 | 0.00 | 1.18 | 0.00 | 0.00 | 0.82 | 0.81 | NA |
| | Total | 176 | 208 | 257 | 322 | 335 | 224 | 131 | 85 | 92 | 99 | 122 | 124 | |
| Jackdaw | Index | 4.76 | 0.00 | 1.64 | 4.71 | 1.04 | 4.84 | 2.00 | 0.00 | 0.00 | 5.71 | (33.33) | 0.00 | NA |
| | Total | 21 | 41 | 61 | 85 | 96 | 124 | 100 | 35 | 29 | 35 | 9 | 18 | |
| Rook | Index | 0.00 | 0.00 | 5.17 | 0.98 | 0.00 | 6.36 | 1.08 | 2.70 | 0.00 | 5.88 | 0.00 | 0.00 | NA |
| | Total | 28 | 42 | 58 | 102 | 99 | 110 | 93 | 37 | 27 | 34 | 24 | 28 | |
| Starling | Index | 1.21 | 0.97 | 1.11 | 0.93 | 1.13 | 0.68 | 0.53 | 0.78 | 2.11 | 1.80 | 1.60 | 1.64 | * |
| | Total | 1238 | 1441 | 1714 | 2143 | 2923 | 1919 | 1130 | 773 | 616 | 612 | 561 | 672 | |
| | Dev | NS | NS | NS | NS | NS | NS | NS | NS | + | NS | NS | NS | |
| Chaffinch | Index | 0.00 | 0.59 | 1.98 | 0.30 | 1.15 | 1.19 | 0.00 | 2.44 | 0.00 | 0.00 | 0.00 | 3.23 | NA |
| | Total | 131 | 170 | 253 | 333 | 261 | 168 | 84 | 41 | 29 | 42 | 43 | 62 | |
| Greenfinch | Index | 0.33 | 0.51 | 0.49 | 1.30 | 0.54 | 1.20 | 0.86 | 1.66 | 0.00 | 0.98 | 2.88 | 0.00 | NS |
| | Total | 602 | 785 | 1233 | 1454 | 1115 | 752 | 584 | 302 | 120 | 102 | 139 | 198 | |

Chi-square was used to test for seasonal variation in a further twelve species by combining the data into three month periods (starting in November). Only one of these species, Sand Martin, showed significant seasonal variation, with a significantly higher index during the late summer and autumn dispersal and migration periods (August and September) than during the breeding season (May to July) (Table 6). Lack of significance for these species should not be taken as evidence that there is no seasonal variation, as sample sizes were small.

The low monthly indices in the summer coincide with the breeding season and moult. In the breeding season most birds are sedentary on their breeding areas and few undertake long distance movements. They also spend a large amount of time stationary at the nest. Wildfowl become flightless during moult so are precluded from "hit wire" mortality. Other birds suffer from impaired flight while moulting, so undergo only essential movements. In spring and autumn many birds undertake long movements between breeding and wintering grounds, and in autumn juveniles of many species disperse together with some adults. Birds tend to fly higher than normal during long distance movements and may visit unfamiliar areas. The altitude of long distance migration is usually well above the height of any overhead lines, but birds may be at risk from collisions with overhead lines when descending into unfamiliar stopping-off areas or when bad weather forces them to fly at low levels.

Grey Herons have a very low hit wire index in April, perhaps as a result of reduced movement at the start of the nesting season and during incubation. Indices tend to be high from August through to December, and there is a particularly high index in November (Table 6). These autumn figures reflect the high vulnerability of young Herons to collisions with overhead lines (below), first year birds comprising 71% of the sample of Heron recoveries.

Mute Swans have low indices in June, July and August reflecting low flying activity during brood rearing and moult. High indices in October and November correspond with the dispersal of juveniles which are particularly vulnerable to collisions with overhead lines. The very low July index for Canada Geese is again a result of their moult period. A significantly low index in September and significantly high indices in February and March (Table 6) are less easily explained, but are presumably related to seasonal variation in the location of suitable feeding areas relative to the water bodies which are used for roosting. The high February and March figures may also reflect movements associated with the establishment of breeding territories. Mallard have very high hit wire indices in April and May which are almost certainly associated with courtship activities. At this time of year groups of males pursue unmated females, often flying at a height that would render them vulnerable to collisions with overhead lines. No "hit wire" recoveries were recorded for Mallard during the July moult period. The significantly low December index may reflect less long distance movements during the mid-winter period.

High hit wire indices for Oystercatchers in March, April and May are associated with the timing of aerial courtship behaviour. This takes the form of a twisting and turning aerial display performed by males. Breeding often takes place inland, and even on the roofs of buildings, hence increasing further the probability of collisions with overhead lines. The low autumn indices for Oystercatchers probably reflect their predominantly coastal distribution at this time of year, with most feeding restricted to the shore. Later in the winter, feeding on coastal pastures is common in some areas.

Black-headed Gulls have a significantly high hit wire index in November, while Herring Gull shows a similar pattern with high indices in November and December (Table 6). This may reflect increased movement inland at this time of year together with the arrival of wintering birds in areas with which they are unfamiliar.

Song Thrush, Blackbird and Starling all have low breeding season indices and higher winter ones. The high winter indices may be associated with winter roosting movements, which are often completed in poor light, and with the presence of many winter visitors in unfamiliar areas. Song Thrush has a significantly high index in November while Blackbird shows a similar pattern but with a significantly high index in December (Table 6). Starlings have their highest index in September, with a gradual decline through to the spring. This pattern may result from high vulnerability of inexperienced juveniles to collisions with overhead lines (Section 3.7.1).

## 3.6 Long-term trends in the hit wire index

Five periods were used for analyses of long-term trends in the hit wire index: 1909-1954, 1955-1964, 1965-1974, 1975-1984 and 1985-1987 (see Methods). Hit wire indices were calculated for each of these periods for all 46 species with 10 or more "hit wire" recoveries (Table 7). Particular care must be taken when interpreting the figures from the period 1909-1954, because it is a long period with very limited numbers of recoveries. There may also have been differences in the composition of the ringed sample compared with more recent periods, due to changes in catching techniques. Chi-square tests for variation between time periods were possible for 42 species, and of these only 11 showed significant temporal variation (Table 7). There was no significant agreement between these species in the pattern of variation of hit wire indices with time (Kendall's coefficient of concordance, W=0.04, NS). There was no overall tendency for the hit wire index to either increase or decrease with time. A number of species with high hit wire indices or with large samples of recoveries did not show any significant variation in the hit wire index with time period, including Cormorant, Mute Swan,

Table 7. Variation in the hit wire index with time period.

$$\text{Hit wire index} = \frac{\text{'Hit Wire' recoveries}}{\text{Total}} \times 100$$

Total = 'Hit wire' recoveries + 'Found dead' recoveries

Indices based on totals of less than 20 recoveries are shown in parenthesis.

Column headed Sig. gives the results of an overall 2 x n chi-square test for differences in the hit wire index between time periods:

** P<0.01 * P<0.05 NS not significant
NA not applicable due to small sample sizes.

Where the overall chi-square test was significant, the row labelled D gives the results of a Haberman test for the significance of deviations by individual cells (see methods):

+ index significantly high - index significantly low
NS not significant NA not applicable due to small sample size

Lines indicate where data from adjacent time periods have been combined for testing.

| | | Pre-1954 | 1955-1964 | 1965-1974 | 1975-1984 | 1985-1987 | Sig |
|---|---|---|---|---|---|---|---|
| Manx Shearwater | I | 0.96 | 0.91 | 2.01 | 0.00 | 2.08 | NS |
| | T | 209 | 551 | 348 | 194 | 48 | |
| Cormorant | I | 2.26 | 0.62 | 1.99 | 2.64 | 3.28 | NS |
| | T | 177 | 323 | 854 | 719 | 244 | |
| Grey Heron | I | 4.33 | 10.55 | 13.11 | 13.83 | 9.46 | ** |
| | T | 254 | 256 | 366 | 412 | 148 | |
| | D | - | NS | NS | + | NS | |
| Mute Swan | I | 0 | 28.56 | 27.88 | 28.16 | 26.48 | NS |
| | T | 0 | 11446 | 3113 | 2880 | 876 | |
| Pink-footed Goose | I | 3.88 | 3.62 | 0.00 | (7.14) | (50.00) | NA |
| | T | 103 | 304 | 48 | 14 | 2 | |
| Canada Goose | I | (0.00) | 14.71 | 24.22 | 20.86 | 17.6 | NS |
| | T | 1 | 34 | 322 | 954 | 250 | |
| Teal | I | 10.00 | 4.90 | 2.90 | 0.00 | (0.00) | * |
| | T | 100 | 143 | 69 | 36 | 11 | |
| | D | + | NS | | - | | |
| Mallard | I | 1.74 | 3.36 | 6.36 | 7.38 | 1.90 | ** |
| | T | 172 | 536 | 582 | 325 | 105 | |
| | D | - | - | + | + | NS | |

| | | Pre-1954 | 1955-1964 | 1965-1974 | 1975-1984 | 1985-1987 | Sig |
|---|---|---|---|---|---|---|---|
| Tufted Duck | I | 12.00 | 4.76 | 6.90 | 6.12 | 7.50 | |
| | T | 25 | 21 | 58 | 98 | 40 | NS |
| Hen Harrier | I | 0 | 11.54 | 20.00 | 9.30 | (0.00) | NS |
| | T | 0 | 26 | 45 | 43 | 6 | |
| Sparrowhawk | I | 13.79 | 10.00 | 7.94 | 6.11 | 5.82 | NS |
| | T | 58 | 20 | 126 | 573 | 189 | |
| Buzzard | I | (0.00) | (16.67) | 3.85 | 15.45 | 2.94 | NS |
| | T | 10 | 12 | 52 | 110 | 34 | |
| Kestrel | I | 4.76 | 9.35 | 7.16 | 5.33 | 5.50 | NS |
| | T | 84 | 139 | 433 | 638 | 200 | |
| Merlin | I | 10.71 | (6.25) | 12.50 | 9.68 | 24.14 | NS |
| | T | 28 | 16 | 24 | 62 | 29 | |
| Peregrine | I | (0.00) | (0.00) | (0.00) | 12.33 | 8.57 | NA |
| | T | 5 | 3 | 5 | 73 | 35 | |
| Red Grouse | I | 0 | 36.84 | 0 | 0 | 0 | NA |
| | T | 0 | 38 | 0 | 0 | 0 | |
| Moorhen | I | 0.00 | 2.74 | 2.03 | 3.57 | 0.00 | NA |
| | T | 40 | 146 | 148 | 112 | 25 | |
| Coot | I | (0.00) | 1.14 | 6.76 | 5.71 | 5.88 | NS |
| | T | 18 | 88 | 74 | 140 | 34 | |
| Oystercatcher | I | 0.00 | 2.15 | 2.91 | 4.34 | 4.74 | NS |
| | T | 97 | 279 | 757 | 852 | 211 | |
| Lapwing | I | 7.19 | 9.16 | 10.22 | 5.91 | 5.00 | NS |
| | T | 501 | 251 | 137 | 237 | 80 | |
| Dunlin | I | (100.00) | 3.57 | 4.03 | 3.07 | 8.33 | NS |
| | T | 1 | 56 | 124 | 163 | 24 | |
| Curlew | I | 4.41 | 9.52 | 6.19 | 6.78 | 5.88 | NS |
| | T | 68 | 63 | 97 | 118 | 51 | |
| Redshank | I | 7.14 | 5.83 | 3.05 | 0.51 | 5.13 | ** |
| | T | 42 | 103 | 164 | 390 | 78 | |
| | D | | + | | − | NS | |
| Black-headed Gull | I | 4.14 | 5.08 | 6.94 | 4.79 | 3.28 | ** |
| | T | 724 | 1338 | 1383 | 1231 | 458 | |
| | D | NS | NS | + | NS | − | |
| Common Gull | I | 1.22 | 2.78 | 4.35 | 5.23 | 5.48 | NS |
| | T | 82 | 36 | 92 | 199 | 73 | |
| Lesser Black- | I | 2.55 | 4.88 | 6.09 | 2.89 | 2.73 | * |
| backed Gull | T | 196 | 389 | 657 | 866 | 220 | |
| | D | NS | NS | + | − | NS | |

| | | Pre-1954 | 1955-1964 | 1965-1974 | 1975-1984 | 1985-1987 | Sig |
|---|---|---|---|---|---|---|---|
| Herring Gull | I | 2.53 | 2.61 | 3.93 | 2.47 | 2.59 | * |
| | T | 395 | 1071 | 2059 | 2630 | 580 | |
| | D | NS | NS | + | NS | NS | |
| Great Black-backed Gull | I | 0.00 | 1.69 | 3.09 | 1.82 | 5.88 | NS |
| | T | 29 | 178 | 259 | 384 | 85 | |
| Barn Owl | I | 6.94 | 5.77 | 5.48 | 3.51 | 1.28 | NS |
| | T | 72 | 52 | 146 | 228 | 78 | |
| Tawny Owl | I | 3.08 | 4.76 | 9.38 | 4.65 | 5.68 | NS |
| | T | 65 | 63 | 96 | 172 | 88 | |
| Swift | I | 7.14 | 5.86 | 5.37 | 5.85 | 1.47 | NS |
| | T | 28 | 222 | 410 | 359 | 68 | |
| Sand Martin | I | (0.00) | 7.07 | 5.49 | 5.56 | (0.00) | NS |
| | T | 6 | 99 | 182 | 54 | 4 | |
| Swallow | I | 7.07 | 3.94 | 3.96 | 3.95 | 5.13 | NS |
| | T | 184 | 254 | 544 | 329 | 78 | |
| House Martin | I | 2.08 | 5.32 | 0.79 | 3.39 | 5.36 | NS |
| | T | 48 | 94 | 127 | 118 | 56 | |
| Pied Wagtail | I | 6.90 | 2.69 | 0.30 | 1.17 | 0.00 | NS |
| | T | 58 | 260 | 332 | 515 | 102 | |
| Robin | I | 0.62 | 0.58 | 0.68 | 0.30 | 0.00 | NS |
| | T | 487 | 693 | 736 | 673 | 191 | |
| Song Thrush | I | 4.55 | 1.63 | 1.25 | 0.82 | 0.00 | ** |
| | T | 945 | 1286 | 1436 | 972 | 201 | |
| | D | + | NS | - | - | - | |
| Mistle Thrush | I | 7.00 | 3.53 | 1.89 | 1.28 | 1.85 | * |
| | T | 100 | 170 | 159 | 156 | 54 | |
| | D | + | NS | | NS | | |
| Blackbird | I | 1.75 | 1.33 | 1.11 | 0.86 | 0.42 | ** |
| | T | 1828 | 4134 | 7104 | 5577 | 1430 | |
| | D | + | NS | NS | - | - | |
| Blue Tit | I | 0.35 | 0.17 | 0.40 | 0.47 | 0.19 | NS |
| | T | 572 | 11455 | 1486 | 1902 | 514 | |
| Great Tit | I | 0.38 | 0.72 | 0.85 | 0.45 | 0.41 | NS |
| | T | 266 | 414 | 587 | 666 | 242 | |
| Jackdaw | I | 4.46 | 2.16 | 0.74 | 4.62 | 2.04 | NS |
| | T | 157 | 139 | 136 | 173 | 49 | |
| Rook | I | 2.70 | 2.92 | 1.80 | 2.29 | 0.00 | NS |
| | T | 111 | 171 | 222 | 131 | 47 | |

| | | Pre-1954 | 1955-1964 | 1965-1974 | 1975-1984 | 1985-1987 | Sig |
|---|---|---|---|---|---|---|---|
| Starling | I | 1.42 | 1.14 | 0.99 | 0.98 | 0.58 | NS |
| | T | 2536 | 5254 | 3953 | 2970 | 1029 | |
| Chaffinch | I | 1.27 | 0.85 | 1.07 | 0.74 | 0.60 | NS |
| | T | 314 | 355 | 375 | 405 | 168 | |
| Greenfinch | I | 2.60 | 1.70 | 0.58 | 0.42 | 0.17 | ** |
| | T | 308 | 1353 | 2742 | 2380 | 603 | |
| | D | + | + | NS | – | | |

Canada Goose, Sparrowhawk, Kestrel, Lapwing, Swallow and Starling.

Grey Heron and Mallard both show a pattern of change with time which might be expected, with increases in the hit wire index broadly related to the increase in the abundance of overhead lines which has taken place since the earlier part of this century. For the other nine species showing significant variation in the hit wire index with time period, changes are more likely to be related to changes in the pattern of ringing. Most ringing of Teal has taken place at a few sites operated by the Wildfowl Trust, and long-term changes in ringing activity at particular sites may have affected the hit wire index according to variation in the abundance of wires in the catchment areas of particular trapping stations. Before 1954 most ringing of Redshanks was of chicks from the British breeding population, which would be more likely to encounter overhead lines because many of the birds breed inland. In contrast the significantly low index for 1975-1984 corresponds with extensive ringing of Redshanks on Scottish estuaries where the chances of collisions with overhead lines are likely to be small.

Black-headed Gull, Lesser Black-backed Gull and Herring Gull all have significantly high hit wire indices during the period 1965 to 1974, while Black-headed Gull has a significantly low index in 1985-1987 and Lesser Black-backed Gull has a significantly low index in 1975-1984. Before the early 1970s most gull ringing was of chicks, while after that date many wintering birds were caught for ringing using cannon-nets. This switch will have altered the composition and geographical distribution of the ringed samples which may be responsible for the apparent changes in the hit wire indices.

Four passerines showed significant variation in the hit wire index with time period: Song Thrush, Mistle Thrush, Blackbird and Greenfinch. They had extremely similar patterns of variation (Kendall's coefficient of concordance, $W$=0.96, P<0.01), with a decline in the hit wire index with time period. The most likely explanation for this is that there has been a long-term trend of increased ringing of passerines in rural and more remote areas, where the probability of small passerines colliding with wires is almost certainly lower than in suburban and urban areas. There has been a long-term decline in the recovery reporting rates of small passerines which is also thought to be attributable to this change in the distribution of ringing effort (Baillie and Green 1987).

## 3.7 Variation in the hit wire index with age

### 3.7.1 Differences between first year birds and adults

Thirty-four species had sufficient data for chi-square tests to be carried out between the hit wire indices of first year and older birds. The hit wire index for first year birds was significantly higher than that of adults for seven of these species: Mute Swan, Canada Goose, Peregrine, Curlew, Song Thrush, Blackbird and Starling. There were no species for which the hit wire index for first year birds was significantly lower than that for adults.

The first year survival rates of many bird species are lower than those of adults (Lack 1954, Dobson 1983). This may arise because young birds are less efficient foragers than adults, because they are more prone to accidents or because they are excluded from limiting resources through competitive interactions with adults. The above data suggest that for at least some species first year birds are less able to aviod overhead lines than adults. This may be because they have not yet learnt to avoid such objects so well as adults or because they have not learnt the locations of all overhead lines within their home range. First year birds tend to be more mobile than adults and this may also contribute to their vulnerability to collisions with overhead lines.

### 3.7.2 Variation in the hit wire index with age in years

Sufficient data were available to carry out a more detailed analysis of variation in the hit wire index with age for 24 species (Table 8). Hit wire indices were calculated for birds in their first six months of life, second six months of life and thereafter in one year age classes up to 10 years, with data for all birds over 10 years of age being combined. The first two age categories were from ringing as a nestling to the end of the first calendar year, and from 1 January to 30 June of the second calendar year. Thereafter years were taken as running from 1 July to 30 June. The number of year classes for which hit wire indices could be calculated varied considerably between species, depending on longevity and on the size of the recovery sample. In all cases the final age class contained all birds of the specified year or older when recovered.

Chi-square tests showed significant variation between the above individual age classes for six species: Grey Heron, Mute Swan, Canada Goose, Mallard, Curlew and Song Thrush (Table 8).

The age-related variation in the hit wire indices for Grey Heron, Mallard, Curlew and Song Thrush occurs principally in the first year of life. Mallard has a very low hit wire index in its first six months of life followed by a high hit wire index in the second six months. This corresponds with the seasonal pattern of variation in the hit wire indices of Mallard, with the highest indices occurring in spring (above). In contrast Curlew have a hit wire index for the six months following fledging that is more than twice that of older age classes. This suggests that in this species naive young birds may be particularly vulnerable to collisions with overhead lines. Alternatively recently fledged birds in inland breeding areas may be more likely to encounter overhead lines than they are on coastal wintering areas during their second six months of life.

Table 8. Variation in the hit wire index with age of bird

$$\text{Hit wire index} = \frac{\text{'Hit Wire' recoveries}}{\text{Total}} \times 100$$

Total = 'Hit wire' recoveries + 'Found dead' recoveries

In each case the last age class for which an index is given also includes data for all other age classes. Column headed Sig. gives the results of an overall 2 x n chi-square test for differences in the hit wire index between age classes:

** $P<0.01$     * $P<0.05$     NS not significant

Where the overall chi-square test was significant, the row labelled Dev. gives the results of a Haberman test for the significance of deviations by individual cells (see methods):

\+ index significantly high     - index significantly low     NS not significant

| Species | | 1st six months | 2nd six months | 2nd year | 3rd year | 4th year | 5th year | 6th year | 7th year | 8th year | 9th year | 10th year | >10 | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cormorant | Index | 3.17 | 1.63 | 1.72 | 1.54 | | | | | | | | | NS |
| | Total | 758 | 613 | 290 | 649 | | | | | | | | | |
| Grey Heron | Index | 16.12 | 6.34 | 13.37 | 14.29 | 2.22 | 8.77 | | | | | | | ** |
| | Total | 484 | 536 | 172 | 77 | 45 | 114 | | | | | | | |
| | Dev | + | - | NS | NS | NS | | | | | | | | |
| Mute Swan | Index | 36.13 | 28.70 | 26.62 | 35.54 | 31.94 | 29.81 | 24.27 | 22.08 | 21.55 | 19.35 | 11.29 | 14.29 | ** |
| | Total | 501 | 805 | 1142 | 740 | 454 | 312 | 206 | 154 | 116 | 62 | 62 | 371 | |
| | Dev | + | NS | NS | + | NS | NS | NS | NS | NS | NS | - | - | |
| Canada Goose | Index | 25.55 | 37.08 | 23.08 | 23.53 | 12.50 | 12.82 | 16.98 | 14.74 | | | | | *** |
| | Total | 137 | 89 | 104 | 85 | 64 | 39 | 53 | 251 | | | | | |
| | Dev | NS | + | NS | NS | NS | NS | NS | - | | | | | |

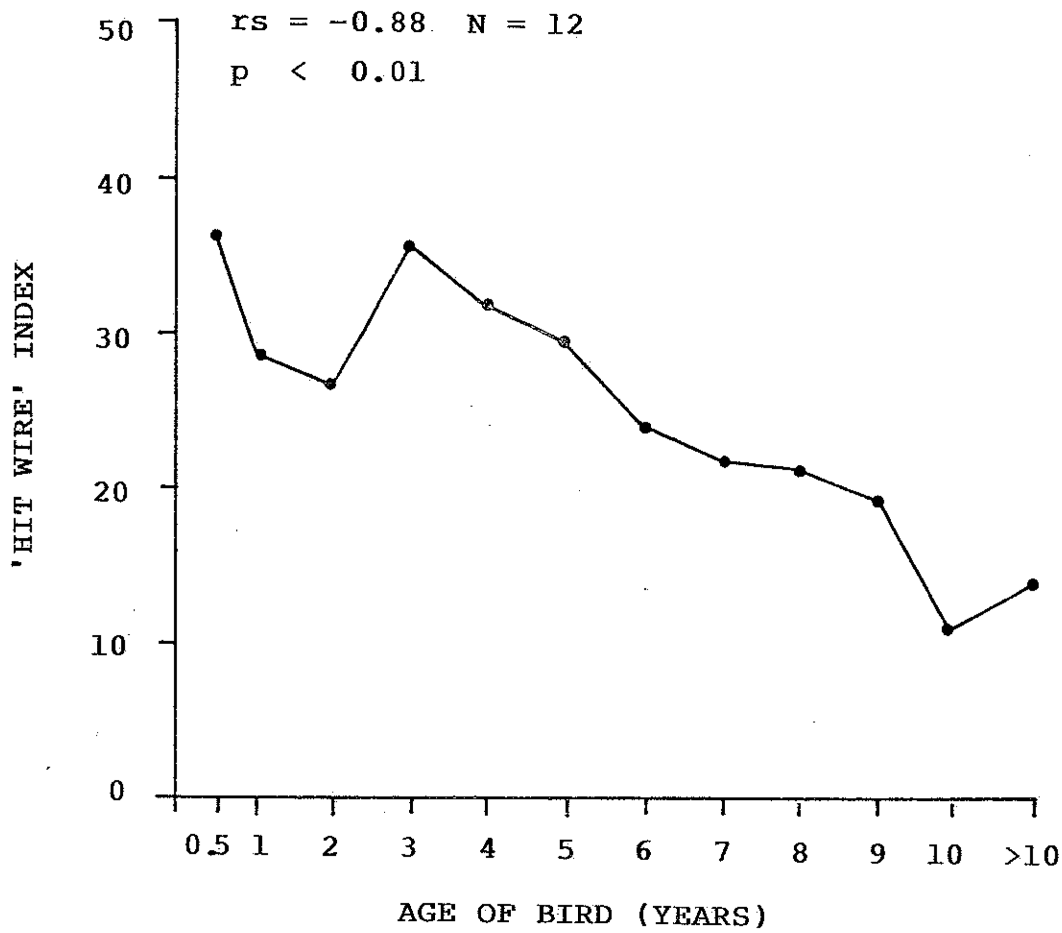
| Species | | 1st six months | 2nd six months | 2nd year | 3rd year | 4th year | 5th year | 6th year | 7th year | 8th year | 9th year | 10th year | >10 | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mallard | Index | 1.03 | 9.21 | 7.19 | 7.29 | 5.52 | | | | | | | | * |
| | Total | 194 | 152 | 153 | 96 | 471 | | | | | | | | |
| | Dev | - | + | NS | NS | NS | | | | | | | | |
| Hen Harrier | Index | 8.11 | 15.38 | 15.79 | | | | | | | | | | NS |
| | Total | 37 | 26 | 57 | | | | | | | | | | |
| Sparrow-hawk | Index | 7.24 | 5.83 | 11.59 | 5.48 | 4.49 | | | | | | | | NS |
| | Total | 304 | 240 | 138 | 73 | 156 | | | | | | | | |
| Buzzard | Index | 12.07 | 10.14 | 8.89 | | | | | | | | | | NS |
| | Total | 58 | 69 | 90 | | | | | | | | | | |
| Kestrel | Index | 5.92 | 5.09 | 7.56 | 8.89 | 7.11 | | | | | | | | NS |
| | Total | 608 | 334 | 172 | 90 | 197 | | | | | | | | |
| Merlin | Index | 14.29 | 14.29 | 11.11 | | | | | | | | | | NS |
| | Total | 56 | 28 | 72 | | | | | | | | | | |
| Oyster-catcher | Index | 2.94 | 2.68 | 4.40 | 4.23 | 3.53 | | | | | | | | NS |
| | Total | 238 | 149 | 91 | 71 | 1248 | | | | | | | | |
| Lapwing | Index | 7.47 | 8.90 | 10.00 | 7.96 | 6.17 | 6.25 | 4.97 | | | | | | NS |
| | Total | 442 | 146 | 160 | 113 | 81 | 64 | 161 | | | | | | |
| Curlew | Index | 12.77 | 6.06 | 4.15 | | | | | | | | | | * |
| | Total | 94 | 33 | 241 | | | | | | | | | | |
| | Dev | + | NS | - | | | | | | | | | | |
| Black-headed Gull | Index | 5.70 | 5.66 | 4.26 | 4.56 | 4.00 | 4.37 | 4.57 | 8.11 | 6.06 | 5.67 | 3.70 | 8.51 | NS |
| | Total | 1456 | 442 | 517 | 351 | 275 | 252 | 175 | 148 | 132 | 141 | 81 | 282 | |
| Lesser Black-backed Gull | Index | 3.36 | 2.67 | 7.41 | 4.58 | 5.13 | 6.12 | 7.92 | 2.99 | 1.45 | 3.95 | 3.85 | 3.42 | NS |
| | Total | 714 | 75 | 162 | 153 | 117 | 98 | 101 | 67 | 69 | 76 | 52 | 409 | |

| Species | | 1st six months | 2nd six months | 2nd year | 3rd year | 4th year | 5th year | 6th year | 7th year | 8th year | 9th year | 10th year | >10 | Sig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Herring Gull | Index | 3.15 | 3.45 | 2.03 | 2.58 | 4.59 | 3.53 | 2.61 | 2.41 | 3.23 | 1.10 | 2.78 | 2.04 | NS |
| | Total | 1778 | 608 | 640 | 388 | 370 | 340 | 307 | 249 | 217 | 182 | 144 | 491 | |
| Great Black-backed Gull | Index | 1.76 | 2.86 | 3.26 | 4.48 | 3.64 | 2.18 | | | | | | | NS |
| | Total | 284 | 140 | 92 | 67 | 55 | 276 | | | | | | | |
| Barn Owl | Index | 6.58 | 0.77 | 2.90 | 4.42 | | | | | | | | | NS |
| | Total | 228 | 130 | 69 | 113 | | | | | | | | | |
| Tawny Owl | Index | 8.33 | 3.88 | 0.00 | 5.43 | | | | | | | | | NS |
| | Total | 156 | 103 | 61 | 129 | | | | | | | | | |
| Swallow | Index | 6.23 | 5.20 | 3.08 | 4.46 | 2.97 | | | | | | | | NS |
| | Total | 321 | 346 | 292 | 112 | 101 | | | | | | | | |
| Song Thrush | Index | 2.53 | 2.34 | 2.04 | 1.09 | | | | | | | | | * |
| | Total | 1145 | 555 | 442 | 1382 | | | | | | | | | |
| | Dev | + | NS | NS | - | | | | | | | | | |
| Blackbird | Index | 1.46 | 0.96 | 1.16 | 1.13 | 0.87 | 1.01 | 1.73 | 0.44 | | | | | NS |
| | Total | 2882 | 2696 | 2154 | 1415 | 916 | 692 | 462 | 1591 | | | | | |
| Starling | Index | 1.89 | 0.93 | 0.91 | 1.13 | 0.82 | 0.88 | | | | | | | NS |
| | Total | 1431 | 1616 | 1320 | 705 | 488 | 2719 | | | | | | | |
| Greenfinch | Index | 0.68 | 0.67 | 0.22 | 0.66 | | | | | | | | | NS |
| | Total | 147 | 1492 | 893 | 2425 | | | | | | | | | |

Grey Herons also have a very high hit wire index for the first six months of life followed by a low index for the second six months. Dispersal is relatively limited in this species and the inexperience of young birds is the most likely explanation of their high hit wire index. The Grey Heron data also suggest that birds which are four or more years old have lower hit wire indices than those in their second and third years, but this difference is not statistically significant ($x^2$=3.83, 0.05<P<0.1). Song Thrushes show a similar pattern to Grey Herons, with a significantly high index in the first six months of life and a significantly low one for birds which are three or more years old. The inexperience of young birds again seems likely to be the cause of this relationship.

Canada Goose and Mute Swan both show a decline in the hit wire index throughout adult life (Table 8). Mute Swans have their highest hit wire indices during the first 6 months of life and then in their third year, decreasing steadily after three years (Figure 4). Young Mute Swans disperse from their natal areas into non-breeding flocks during their first six months of life and may be susceptible to collisions with overhead lines through inexperience. They remain in the non-breeding flocks for two or more years, after which they attempt to establish a breeding territory. The second peak in the hit wire index of Mute Swans at three and four years of age corresponds well to this period of territorial establishment during which they may move around a great deal in search of a territory. Established territorial birds move around much less and consequently the hit wire index declines. The continual decline in "hit wire" mortality throughout life may be explained in these three ways. Swans may take many years to find a breeding territory; therefore the number of birds searching for a territory, and at high risk from overhead line collision, will steadily decrease with age.

Canada Geese have high hit wire indices during their first three years of life and lower ones thereafter (Table 8). There




0.5 years refers to the time from birth to the end of the first calendar year. The 1 year category runs from the end of the first calendar year until July 1st. Thereafter years run from July 1st to June 30th.

Figure 4. The variation in Mute Swan 'hit wire' index with age.

is a marked peak in the hit wire index during the second six months of life which corresponds with the February and March peak in the hit wire index for Canada Geese (above). This presumably is a time when many inexperienced young birds are particularly likely to encounter overhead wires. The lower hit wire indices from the fourth year onwards probably reflect the onset of breeding, which is likely to result in reduced mobility as with Mute Swans. Detailed data on ages of first breeding are not available for British Canada Geese. A study in north America found that about half the population first bred when two years old, the remainder not doing so until they were three or more years of age (Brakhage 1965). However this population may have been exceptional as studies of related species suggest that most Branta geese do not start to breed until they are at least three years old (Owen 1980).

# 4. DISCUSSION

## 4.1 The relative importance of factors affecting mortality caused by overhead lines

Region and month were the two factors out of those investigated which had the strongest influence on the hit wire index. Sixteen of the 23 species which could be tested showed significant regional variation in the index, while 10 out of 12 species showed significant variation in the index between months. Considerable variation exists in the distribution, abundance, type and siting of overhead lines between areas and such factors are likely to cause geographical variation in the frequency of collisions with overhead lines. Bird distribution, mediated by habitat and other factors, will interact with the distribution of overhead lines to give rise to the observed pattern of collisions. Detailed analyses of local mortality patterns were beyond the scope of this study and in most cases the ringing recovery data alone would be insufficient to describe them fully. It does, however, appear to be a combination of such local, species-specific patterns of geographical variation in mortality from overhead lines that gives rise to the regional differences documented by this study. This view is supported by the general lack of agreement between species in patterns of regional variation in the hit wire index.

Birds vary their flight activity between seasons for a variety of reasons. These include regular migration and dispersal, and less predictable movements caused by fluctuating food supplies or severe weather. Movements which take individuals to areas with which they are unfamiliar are likely to make such birds more vulnerable to collisions with overhead lines. Physiological and behavioural variations in flying activity are for some species the most important factors causing seasonal variation in collisions with overhead lines. The most extreme example is the moult period of wildfowl during which they become flightless while, for a few species, aerial breeding displays increase the frequency of collisions with overhead lines.

Very little evidence could be found for long-term changes in the frequency of collisions with overhead lines. Although 11 out of 42 species which could be tested showed significant variation in the hit wire index with time period, in all but two species the variation could be explained by changes in the pattern of ringing. Several species with large samples of recoveries, such as Mute Swan and Canada Goose, showed remarkably little variation in the hit wire index with time period.

Age also appeared to be a relatively unimportant factor, with first year birds being more vulnerable than adults in only seven out of 34 species tested. Clear variation in the hit wire index with age after the first year could only be demonstrated for Mute Swan and Canada Goose. In most of these cases the higher vulnerability of young birds appears to result from inexperience. However, age-specific variation in collisions with overhead lines could also be brought about through differences in the dispersion of juveniles and adults, or through age-related variation in flying activity. The latter appears to be important for Mute Swans.

## 4.2 Species most at risk from collisions with overhead lines

The groups which suffered the highest mortality from overhead lines were large waterbirds and raptors. Of the species with hit wire indices based on over 100 recoveries, seven had indices greater than 10.0. Three of these were waterbirds (Mute Swan, Canada Goose and Grey Heron) and four were raptors (Hen Harrier, Merlin, Peregrine and Buzzard). This conclusion is also supported by the data for species with hit wire indices based on less than 100 recoveries. Species with indices greater than 10.0 include Bittern, Bewick's Swan, Whooper Swan, Greylag Goose, Red Kite, Marsh Harrier, Montagu's Harrier and Golden Eagle. Several other studies have suggested that large waterbirds are particularly vulnerable to collisions with overhead lines (Thompson 1978, Glystorff 1979), while an analysis of Swedish ringing recoveries showed that raptors and large owls are particularly vulnerable to mortality caused by overhead lines (Stolt et al. 1986). It would thus be prudent to assume that all herons, swans, geese and raptors are vulnerable to collisions with overhead lines unless there is clear evidence to the contrary.

A further five species with large data sets (Lapwing, Tufted Duck, Curlew, Sparrowhawk and Kestrel) had indices between six and ten. Collisions with overhead lines may be of some importance for these species.

### 4.3 Species not adequately covered by this study

Hit wire indices base on fewer than 100 recoveries will generally be rather imprecise estimates. Many of the species listed in Table 4 come into this category, plus others with no "hit wire" recoveries or even with no recoveries at all. The majority of such species are very unlikely to be affected seriously by mortality from overhead lines. We attempted to identify those species for which mortality from overhead lines might possibly be important but for which more data are needed before firm conclusions can be drawn.

Amongst the waterbirds Little Grebe, Great Crested Grebe, Bittern, Bewick's Swan and Whooper Swan have few recoveries, as have all geese with the exceptions of Canada Goose and Pink-footed Goose. Hit wire indices for all raptors except Hen Harrier, Merlin, Peregrine, Buzzard, Kestrel and Sparrowhawk are based on very limited data. Game birds appear to be potentially vulnerable to mortality from overhead lines but as a matter of policy they are not caught by general ringers to avoid conflict with sporting interests.

The ringing recovery data suggest that certain species of waders which breed inland may be vulnerable to mortality from overhead lines, with high indices based on small samples being recorded for Stone-curlew, Little Ringed Plover, Dotterel, Golden Plover, Woodcock and Greenshank. Other wader species which occur inland on passage or in winter and have few recoveries include Ruff and Green Sandpiper. It would be desirable to have more information on their vulnerability to collisions with overhead lines.

Further non-passerines where more information is needed to confirm moderately high hit wire indices include Turtle Dove, Cuckoo, and Short-eared Owl. Amongst the passerines, species living in open habitats may be particularly vulnerable to collisions with overhead lines. More data are needed to determine whether the high indices for Tree Pipit and Corn Bunting are reliable and to provide more precise indices for Stonechat and Whinchat. Although the index for Chough appears low and similar to that for other corvids, more information would be desirable in view of the rarity and restricted distribution of this species. Passerine species of conservation importance and for which the recovery data provide no reliable indication of the level of mortality from overhead lines, include shrikes, Marsh Warbler, Dartford Warbler, Crossbill and Hawfinch.

## 4.4 The proportion of total mortality that is attributable to overhead lines

An attempt to model in detail the proportion of total deaths which are attributable to overhead lines was beyond the scope of this study. It is important to emphasise that the hit wire index is not the percentage of all deaths which are attributable to overhead lines. This percentage could be calculated from the following equation:

$$P = \frac{W}{R \times D} \times 100$$

where,

P = percentage of deaths attributable to overhead lines

W = actual number of hit wire recoveries

R = reporting rate for hit wire recoveries

D = number of deaths of birds from the ringed sample

W is known precisely. D can be calculated from the numbers ringed and from estimates of survival rates. These can be obtained from the ringing data themselves or from intensive studies of marked individuals. The difficult parameter to estimate is R, the reporting rate for hit wire recoveries. The overall reporting rate can be estimated from the ringing recovery data. If this estimate were used, P would be near the percentage of hit wire recoveries in the total sample of all dead recoveries. Further information on the value of R might be obtained by considering the likely reporting rates of the main types of recoveries making up the overall sample, or by comparing national reporting rates with those from intensive local studies. Such an approach would be unlikely to give a precise estimate of P, but might well delineate a range of values within which P is likely to occur. A good estimate of the minimum possible value of P can be obtained by setting R equal to 1.0.

In general, recoveries from overhead lines are likely to have a reporting rate similar to "found dead" recoveries, while many other recoveries in the sample (such as birds which were shot) will have a higher reporting rate. Thus the overall reporting rate will usually overestimate the reporting rate for "hit wire" recoveries, and will overestimate it considerably for quarry species and others which have large numbers of recoveries from high reporting rate categories. Thus for non-quarry species "hit wire" recoveries, expressed as a percentage of all dead recoveries, will be a slight underestimate of the percentage of deaths attributable to overhead wires. On this basis it seems unlikely that deaths caused by overhead lines comprise more than about 20% of total mortality for most of the species for which we have adequate data, and it is unlikely that they exceed more than about 30% for Mute Swan. However, in the absence of a more detailed analysis, these conclusions must be regarded as provisional.

Two intensive studies of Mute Swans provide an independent assessment of the proportion of deaths attributable to overhead wires. Seventeen per cent of 94 Mute Swan deaths on and around the River Thames between August 1979 and October 1981 were attributable to overhead lines (Birkhead 1982), and a similar level of deaths has been found in subsequent years (J.Sears pers comm.). In contrast, 41% of 146 Swan deaths recorded in the Uists, Outer Hebrides, in 1978 and 1979 were attributable to collisions with overhead lines (Spray 1981). Different populations may thus be subjected to very different levels of additional mortality. The behaviour and ecology of the Thames population is likely to be more typical of Mute Swans in most of Britain and Ireland.

## 4.5 The demographic importance of mortality from overhead lines

Bird populations in stable environments, and which have not been subjected to excessive anthropogenic mortality, tend to vary only within fairly narrow limits. Density dependent factors cause population growth if numbers are low, and population decline if numbers are high (Lack 1954, 1966; May 1981; Begon et al. 1986). The details of these density dependent mechanisms are not understood for many birds species, but sufficient populations have been studied to give a general indication of the types of mechanisms involved (e.g. McCleery and Perrins 1985, Potts 1986, Newton 1988). An implication of such density dependent limitation is that it is usually possible to remove some individuals from a population without affecting its size. This idea is central to the theoretical basis of harvesting of bird populations (Robertson and Rosenberg 1988). In some situations mortality from hunting or other artificial causes simply replaces mortality which would otherwise have occurred naturally. This is known as compensatory mortality, of which an example is provided by Mallard hunting in the United States (Anderson and Burnham 1976).

Mortality caused by overhead lines may often act in this way, with the populations affected being able to compensate through reduced natural mortality or increased production of young. However, it must be stressed that only a certain level of compensation is possible and this depends on the dynamics of the population involved. All populations can be depressed if the level of "exploitation" is excessive. Declining populations will, in general, have very little capacity to compensate for additional mortality. Because there is a lack of detailed information on the population dynamics of many species, it is useful to look for information that can provide guidance on the level of additional mortality that a population can support. One useful statistic which is available for many species is the annual survival rate. Populations which normally have high annual survival rates will generally have less scope for compensatory mortality than populations with lower survival rates (Patterson 1979). For example a population with a survival rate of 90% has a mortality rate of 10%; hence if 11% of the population were harvested there would be no possibility of compensation. If annual survival were 80% the theoretical maximum amount of harvesting which could be compensated for would be 20%, assuming all natural mortality could be replaced. In practice full compensation would always cease well before these levels were reached. It is less clear how compensation may operate at other stages of the life cycle, but in general species with high survival have low reproductive rates and so their potential for increased reproduction may also be low.

This suggests that populations of species with high adult survival rates and low reproductive rates are usually more likely to be affected by additional mortality caused by overhead lines than are populations with high reproductive rates and low survival. Declining populations are more likely to be affected than stable or increasing ones. Amongst the species most at risk from collisions with overhead lines, swans and geese usually have high survival rates but also have relatively high productivity. Large raptors have high survival rates and relatively low reproductive rates, and may be able to withstand only a small amount of additional mortality.

Young birds generally have lower survival rates than adults and the population may thus be able to compensate directly for a higher level of "harvesting" of young birds than of adults. The lower survival rates of young birds also suggest that they are often less good at avoiding various kinds of accidents. In some species young birds have been shown to be less efficient foragers than adults, and they may also be forced to occupy suboptimal habitats or less good positions within a flock through competition with adults. Survival estimates for the nine species which showed significant age-related variation in the hit wire index are given in Table 9. The hit wire index for first year birds was higher than that for adults in all nine species and, for all species except Starling, first year survival rates were lower than those of adults. The situation in the Starling is complex and requires further investigation. Although there was no difference in the survival rates of first year birds and adults using data from both sexes, other data suggest a marked difference in first year survival rates between males and females (Coulson 1960). This could not be further examined from the ringing data because many of the birds were unsexed.

Table 9. Survival estimates for species showing age-specific variation in the hit wire index.

| Species | Age class | Survival rate | Source |
|---|---|---|---|
| Grey Heron | First year | 44.1% | |
| | Second year | 53.1% | |
| | Adult | 69.7 | Mead, Nutt and Watmough (1979) |
| Mute Swan | First year (9 months) | 67.9% | |
| | Second year | 64.6% | |
| | Third and fourth years | 75.0% | |
| | Breeders over four years | 81.0% | Beer and Ogilvie (1972) |
| Canada Goose | First year | 61.5% | |
| | Second year | 76.3% | |
| | Third year | 74.8% | |
| | Adult | 82.4% | Parkin and White-Robinson (1985) |
| Mallard (North America) | First year males | 48% | |
| | Adult males | 62% | |
| | First year females | 46% | |
| | Adult females | 54% | Anderson (1975) |
| Peregrine | First year Finland | 41% | |
| | Adults Finland | 68% | Lindberg (1977) |
| | Adults Scotland | 89% | Mearns and Newton (1984) |
| Curlew | First year | 47.0% | |
| | Second year | 63.0% | |
| | Adult | 73.6% | Bainbridge and Minton (1978) |
| Blackbird | First year | 48.3% | |
| | Adult | 61.6% | Batten (1973) |
| Song Thrush | First year | 47% | |
| | Adult | 60% | Lack (1946) |
| Starling | First year | 44% | |
| | Adult | 45% | Coulson (1960) |

All estimates for British populations unless otherwise indicated

## 4.6 The status of species which may be at high risk of mortality from overhead lines

Trends in wildfowl populations are well summarised by Owen *et al.* (1986). The national population of Mute Swans has remained relatively stable since 1955 but there have been some very marked regional declines in major lowland river systems such as the Thames, Trent and Warwickshire Avon, attributable to lead poisoning from anglers weights (Goode 1981, Birkhead 1982, Sears 1988). The use of lead weights has now been banned in most areas and it is expected that Mute Swan populations will recover. Whooper and Bewick's Swans have been increasing since the early 1960s. Long-term increases have been documented for Canada Goose, Greylag Goose, Barnacle Goose and Dark-bellied Brent Goose. Bean Goose and Light-bellied Brent Goose have remained stable, while Greenland Whitefront and European Whitefront have declined. However, for the latter subspecies this simply represents a shift in the winter distribution of an increasing population, with more birds wintering in the Netherlands. Overall, all these populations appear healthy and unlikely to be affected by low levels of mortality from overhead lines.

Grey Herons have increased slightly in numbers since the early 1970s. Apart from fluctuations caused by severe winters, numbers of this species have remained remarkably constant since counts started in 1928 (Reynolds 1979, Reynolds and Marquiss 1987). They seem able to withstand current levels of mortality from overhead lines. In contrast Bittern populations are in severe decline, from 78-83 pairs in 1954 to 36-38 pairs in 1983 (Day 1986) and even fewer latterly. The causes of this decline are obscure but it is likely to be exacerbated by any additional mortality.

Most raptor populations are increasing although Kestrel and Hen Harrier appear to be stable and Merlin is declining (Newton 1984, Ratcliffe 1984, Bibby and Nattrass 1986, Taylor

1988). Most of these populations are recovering from depression caused by a combination of persecution and of organochlorine poisoning in the 1950s and 1960s. Kestrel populations are probably at the level which the environment is able to support but Hen Harrier numbers are probably well below this level. The failure of Hen Harrier populations to increase further suggests that they are still being affected adversely by persecution or by other unidentified factors. The causes of the decline in Merlin populations are unclear and may differ between areas (Newton et al. 1982, Newton et al. 1986, Meek 1988). This species has a high hit wire index and, while there is no suggestion that this mortality is the cause of the decline, such additional mortality might make a small contribution towards it.

Amongst the species with large samples of recoveries and moderate hit wire indices, breeding Lapwings have been in slow decline nationally. Numbers in southern cereal growing areas have declined sharply while those in more northerly sheep rearing areas have increased (O'Connor and Shrubb 1986, Shrubb 1988). There are no national data on changes in numbers of wintering Lapwings. Numbers of Curlews wintering on British estuaries have declined slightly since the early 1970s (Prys-Jones and Kirby 1988). Numbers of breeding Tufted Ducks have trebled since the early 1960s while wintering numbers have doubled (Owen et al. 1986).

Population data are not available for many of the less common species that were identified as being at possible risk of mortality from overhead lines. Stone-curlew numbers have declined from 300 to 500 pairs in the early 1970s, to 118 pairs in 1986 (Spencer 1988). Little Ringed Plovers increased by 30% between 1973 and 1984 and now have a population of about 600 pairs (Prater and Parrinder 1987). Dotterel numbers have recently been found to be considerably higher than was previously supposed but this is probably due to improved recording rather than to a population increase (Watson and Rae 1987).

In summary, Merlin is the only species which has a reliable, high hit wire index and is in long-term decline, while Hen Harrier is stable but appears to be held below the level which the environment could support. All other species with reliable, high hit wire indices are either increasing or stable. A few declining populations, such as Bittern and Stone-curlew, might be at risk from overhead line mortality, but the recovery data are insufficient to establish the levels of such mortality that they experience. Although in most cases levels of mortality from overhead lines do not appear to be sufficiently high to affect population sizes, there are many species for which a considerable number of deaths are caused by overhead lines.

The analyses in this report have been made principally on a national basis, with a few referring to large regions. Although mortality from overhead lines appears unlikely to affect many populations at this scale, it could still have severe effects on particular local populations. Such possibilities would need to be investigated through detailed local research rather than through the broad national approach of this study.

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# APPENDIX 1

## The preparation of ringing recoveries

To illustrate the preparation of recoveries, we have selected three "hit wire" examples which were reported in February 1989. Photocopies of the original notification and of the final computer print-out for each are given overleaf. The Cormorant L06212 and Canada Goose 5153257 were reported by letter by members of the public, whilst Mute Swan Z63914 was notified on one of our own reporting forms which we distribute to ringers and to any others who report ringed birds regularly.

BTO basic ringing data are not computerised; hence the relevant details have to be copied by hand from the ringing schedules (submitted by the ringers) on receipt of the recoveries. Ringing and recovery details are cross-checked for compatibility and the co-ordinates of the finding places ascertained from maps and gazetteers, after which the completed recoveries are ready for input into the computer. A second person then checks the input, to eliminate any copying errors. Also, there is a printed message on the back of the recovery slips sent to ringers and finders which asks that we be notified of any undetected mistakes.

All basic details are computer coded, as explained in the Introduction to this Report and in Tables 1 and 2. The following are particularly relevant to the three cases illustrated in this appendix.

Species code: Cormorant = 720; Mute Swan = 1520; Canada Goose = 1660. The code SPV (species verified) aids confidence that the ring number has been reported correctly.

Age code: nestling = 1; full-grown (older than 1st calendar year) = 4.

Dates and Co-ordinates: these are exact in the present examples, so no error codes are employed.

County: GBAN = Anglesey; GBHT = Hertfordshire; GBWK = Warwickshire; GBDB = Derbyshire.

Finding details: in the three-digit code, the first digit relates to condition and the second two to circumstances. Thus 143 is found dead, unknown duration (1), hit wires (43); while 243 is found freshly dead (2), hit wires (43). When this three-digit code is followed by a letter P (as in the Cormorant recovery) this indicates a presumption; reference to the finder's original letter shows that the bird was merely reported as found beneath power lines, whereas in the other two cases the finders stated explicitly that their birds were killed striking wires.

Batch details: the date and initials at the lower right of each recovery slip indicate the filing data of the original documentation plus the initials of the individuals who prepared and checked the recovery.

Recoveries are stored permanently on magnetic tape. There is also a clear-language print-out for the benefit of the ringers and finders.

42 HARKNESS
ROSEDALE
CHESHUNT
HERTS EN7 6JX

9.2.89

Dear Sir,

I recently found a dead cormorant beneath power lines in my local birdwatching patch.

The bird was ringed and was not far from a regularly used winter roost.

SERIAL NO. L06212

DATE 8.2.89

WHERE HOLLYFIELD MARSH
LEA VALLEY
NR CHESHUNT (HERTS)

Yours faithfully,

M. OAKLAND

BTO 2

Species: CORMORANT — GBT L06212 720

Age/Sex: NESTLING — BROOD 2 — SPV 1

Ringing Information:
18 JUNE 88 ± 53 19'N 4 2'W ±
PUFFIN ISLAND
ANGLESEY, WALES — GBAN

Finding Information:
8 FEB 89 ± 51 42'N 0 1'W ±
HOLYFIELD MARSH
NEAR CHESHUNT
HERTFORDSHIRE, ENGLAND — GBHT

Finder:
MR M OAKLAND
42 HARKNESS
ROSEDALE
CHESHUNT
HERTS EN7 6JX

Finding Details:
143P
DEAD
HIT WIRES
FOUND BENEATH POWER LINES

Distance: 326 KM — Direction: 123 DEG — Duration: 235 DAYS

Ringer: SCAN R G

Batch: 9076
150289 CT SPD

Annual Copy. BTO 2.

**BRC.16 RECOVERY REPORTING FORM**

| | |
|---|---|
| Scheme Ring No. | Z63914 |
| Species | MUTE SWAN |
| Age Sex Status (Hab. Act.) | 1 6/6 |
| Ringing Date | 4.9.88 |
| Ringing Place | LEAMINGTON SPA (WAR) |
| Ringing Coord. | 52.17 1.32 W |
| Finding Date | 19.01.89 |
| Finding Place (Hab. Act.) | ATHERSTONE-ON-STOUR WARWICK |
| Finding Coord. | 52° 09'N 2° 42'W |
| Finding Details (Movement) | DEAD HIT 11 KV POWER LINE |
| Finder's Name (Permit No.) Address | MR R. DUDLEY 94 MANOR AVENUE SOUTH KIDDERMINSTER DY11 6DG |
| Ringer | |

RINGING DATA

Additional information on Recapture

| Age Sex | Wing | Weight | Time | Notes |
|---|---|---|---|---|
| | | | | |

Tick if you require another pad

side A

**BTO 2**

GBT 263914
1520

Species: MUTE SWAN SPV
Age/Sex: NESTLING BROOD 6 1

Ringing Information:
4 SEP 88 ± 52 17'N 1 32'W ±
LEAMINGTON SPA
WARWICKSHIRE, ENGLAND GBWK

Finding Information:
19 JAN 89 ± 52 9'N 1 42'W ±
ATHERSTONE-ON-STOUR
WARWICKSHIRE, ENGLAND GBWK

Finder:
MR R DUDLEY
94 MANOR AVENUE SOUTH
KIDDERMINSTER
DY11 6DG

Finding Details:
143
DEAD
HIT WIRES
=11KV POWER LINE

Distance: 19 KM
Direction: 217 DEG
Duration: 137 DAYS

Ringer: C.H. POTTER

Batch: 2286
130289 JAC CT

Annual Copy. BTO 2.

KINGSBURY
WATER
PARK

County Park Manager's Office,
Bodymoor Heath Lane, Bodymoor Heath
Sutton Coldfield, West Midlands B76ODY
Tamworth (0827) 872660

My ref: EAH/CAL    20 January 1989

Ringing & Migration Section
B.T.O.
Beech Grove
TRING
Herts

Dear Sirs,

Please find enclosed ring no. 5153257 taken from a Canada Goose on 19th January 1989 at Kingsbury Water Park at grid ref. SP202971. Killed after colliding with overhead power cables.

Yours faithfully,

Edwin Hopkins
Head Warden

**BTO 2**

Species: CANADA GOOSE    SPV RING VERIFIED    GBT    5153257
1660

Age/Sex: 1 year +    4

Ringing Information:

25 JUN 88 ±    52 46'N    1 39'W ±
DRAKELOW
DERBYSHIRE, ENGLAND    GBDB

Finding Information:

19 JAN 89 ±    52 34'N    1 42'W ±

KINGSBURY WATER PARK
BODYMOOR HEATH    GBWK
WARWICKSHIRE, ENGLAND

Finder:

EDWIN HOPKINS
KINGSBURY WATER PARK
BODYMOOR HEATH LANE
BODYMOOR HEATH
SUTTON COLDFIELD
WEST MIDLANDS B76 ODY

Finding Details:

243-
FRESHLY DEAD
HIT WIRES

Ringer:
MERCIAN RG

Distance: 22 KM    Direction: 189 DEG    Duration: 208 days

Batch: 130289 JAC CT

Annual Copy. BTO 2.

Registered Name.....MERCIAN.RINGING.GROUP...

Permit Number.................. ---

| 51 | 532 | 51 |
|---|---|---|
| *For Official use* | | |

**Species:** Use brackets, at the extreme left of this column, to indicate pulli from the same brood.

**Age & Sex:** ♂ or M = male, ♀ or F = female. Age code as follows:

**P** Pullus: give number ringed over brood size in brackets, e.g. (4/4), (6/7) etc.

**2** Fully-grown – year of hatching quite unknown (current year) not necessarily excluded)

**3** *Definitely* hatched during current calendar year

**4** Hatched before current calendar year — exact year unknown

**5** *Definitely* hatched during last calendar year

**6** Hatched before last calendar year — exact year unknown

**7** *Definitely* hatched two years ago

**8** Hatched three or more years ago

N.B. All birds change year at 0001 hrs on January 1st. Enter a *single* number only for age, except for birds in distinctive juvenile pluma[ge] which should be entered as '3J' and nestlings — P not 1.

**Ref:** For specific reference codes refer to Ringers' Manual or white schedule.

**Act.:** Enter activity code, if applicable, as follows:- **B** Breeding 'adult' **C** FG. at Colony **F** Moult card completed for Filing at Beech Grove (generally and in conjunction with M below) **L** at Lighthouse **M** Moulting wings or tail **P** on Passage **R** at Roost **T** Tape Lured **S** at Sea

**Date:** Give day, month and year in the appropriate columns in arabic numerals.

**Place:** **ALWAYS GIVE COUNTY** and please enter geographical co-ordinates (in brackets if they have not been agreed by the Ringing Office).

| Ring No. | Species | Age & Sex | Ref. | Act. | Date Day | M'th | Y'r | Place of Ringing (with co-ordinates if known) |
|---|---|---|---|---|---|---|---|---|
| 51532 51 | CANADA GOOSE | 4 | | | 25 | 06 | 88 | DRAKELOW, DERBYSHIRE |
| 52 | | | | | | | | 52°46'N 1°39'W |
| 53 | | | | | | | | |
| 54 | | | | | | | | |
| 55 | | | | | | | | |
| 56 | | | | | | | | |
| 57 | | | | | | | | |
| 58 | | | | | | | | |
| 59 | | | | | | | | |
| 60 | | | | | | | | |
| 61 | | | | | | | | |
| 62 | | | | | | | | |
| 63 | | | | | | | | |
| 64 | | | | | | | | |
| 65 | | | | | | | | |
| 66 | | | | | | | | |
| 67 | | | | | | | | |
| 68 | | | | | | | | |
| 69 | | | | | | | | |
| 51532 70 | | | | | | | | |

Example of BTO ringing schedule incorporating age codes

SCHEDULE II BRC

# APPENDIX 2

## Mapped distributions of the recoveries used

| | | | |
|---|---|---|---|
| A2.1-2 | Manx Shearwater | A2.3-5 | Cormorant |
| A2.6-8 | Grey Heron | A2.9-11 | Mute Swan |
| A2.12-13 | Pink-footed Goose | A2.14-16 | Canada Goose |
| A2.17-18 | Teal | A2.19-21 | Mallard |
| A2.22-23 | Tufted Duck | A2.24-25 | Hen Harrier |
| A2.26-28 | Sparrowhawk | A2.29-30 | Buzzard |
| A2.31-33 | Kestrel | A2.34-35 | Merlin |
| A2.36-37 | Peregrine | A2.38-39 | Red Grouse |
| A2.40-41 | Moorhen | A2.42-43 | Coot |
| A2.44-46 | Oystercatcher | A2.47-49 | Lapwing |
| A2.50-51 | Dunlin | A2.52-53 | Curlew |
| A2.54-55 | Redshank | A2.56-58 | Black-headed Gull |
| A2.59-60 | Common Gull | A2.61-63 | Lesser Black-back Gull |
| A2.64-66 | Herring Gull | A2.67a,b | Great Black-back Gull |
| A2.68-69 | Barn Owl | A2.70-71 | Tawny Owl |
| A2.72-74 | Swift | A2.75a,b | Sand Martin |
| A2.76-78 | Swallow | A2.79-80 | House Martin |
| A2.81-82 | Pied Wagtail | A2.83-84 | Robin |
| A2.85-87 | Song Thrush | A2.88-89 | Mistle Thrush |
| A2.90-92 | Blackbird | A2.93-94 | Blue Tit |
| A2.95-96 | Great Tit | A2.97-98 | Jackdaw |
| A2.99-100 | Rook | A2.101-103 | Starling |
| A2.104-105 | Chaffinch | A2.106-108 | Greenfinch |

The main text of this Report includes analyses by geographical regions, the definitions of the regions used being given under Methods. Mapping of recoveries, as an essential preliminary to the regional analyses, was done by using plotting units of 30 minutes of latitude by 15 minutes of longitude.

Copies of these species maps are included as Appendix 2. For each species there is a standard pair of maps, showing (a) the distribution of "hit wire" recoveries, and (b) the distribution of the "found dead" recoveries with which the former were compared in order to produce a hit wires index. There is also a third map for some species. Where sample sizes were adequate, hit wire index values were also calculated per plotting unit (30' x 15'); for reasons of space (on such small-scale maps) these local index values are rounded to the nearest whole number.

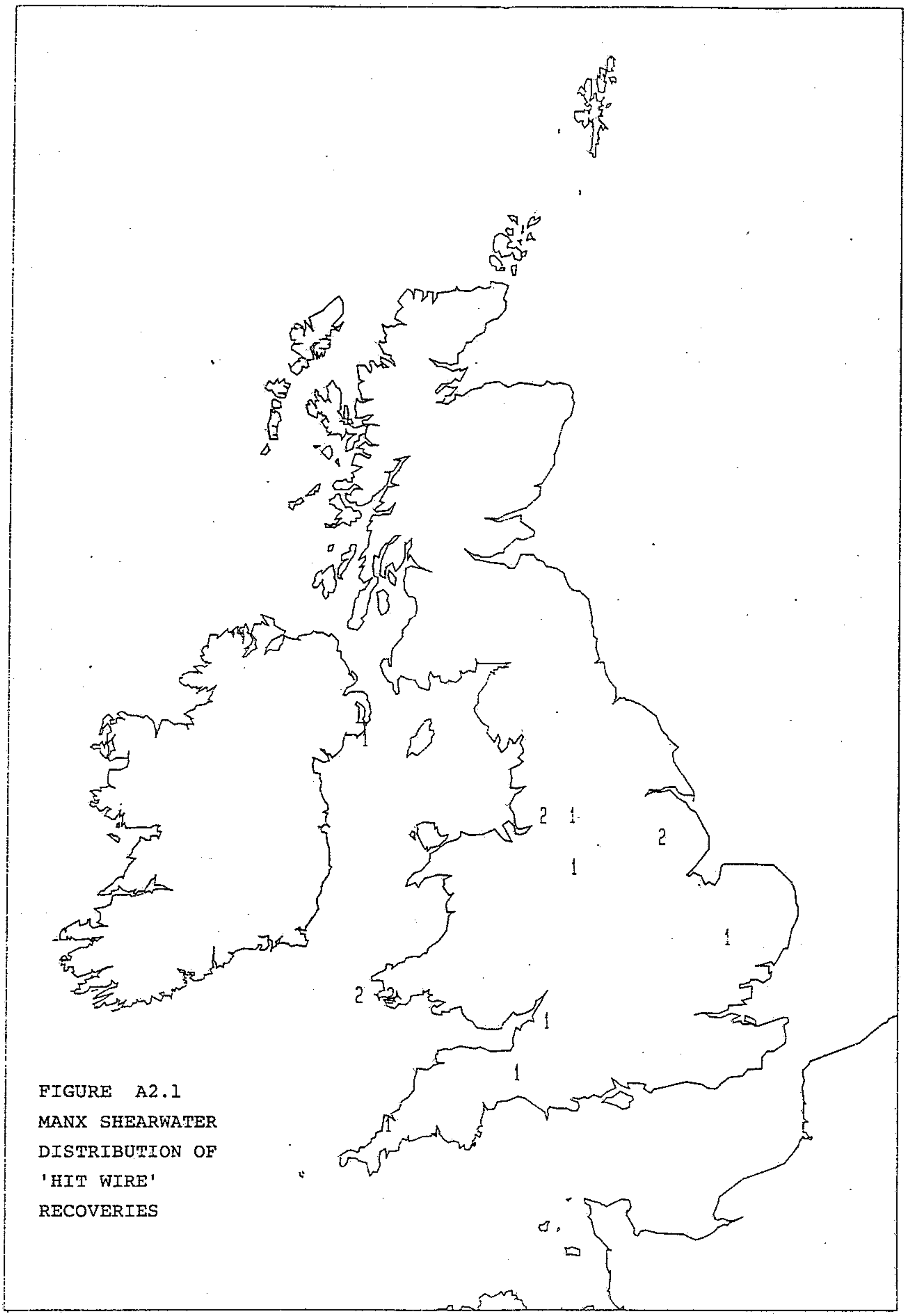


FIGURE A2.1
MANX SHEARWATER
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

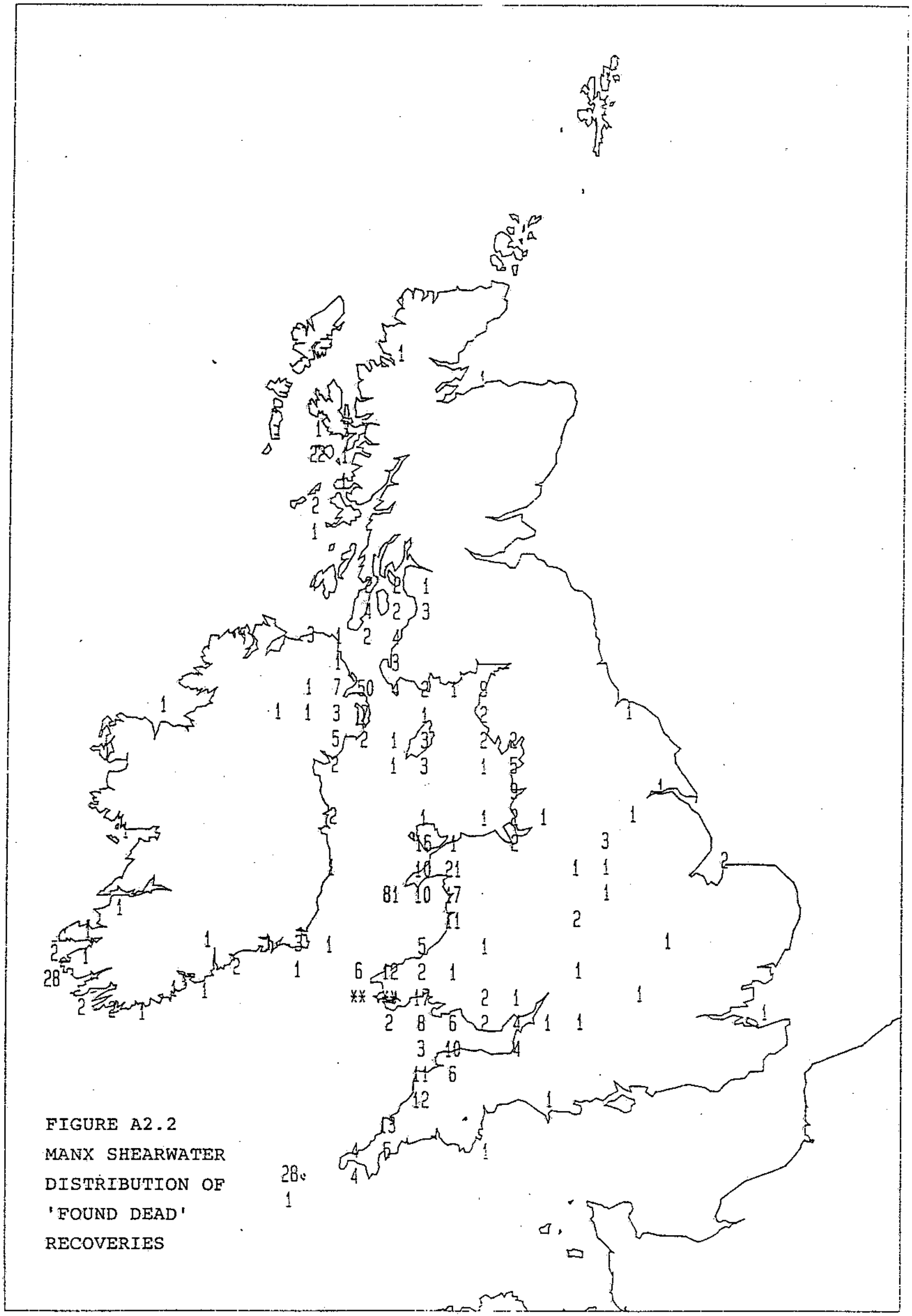

FIGURE A2.2
MANX SHEARWATER
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

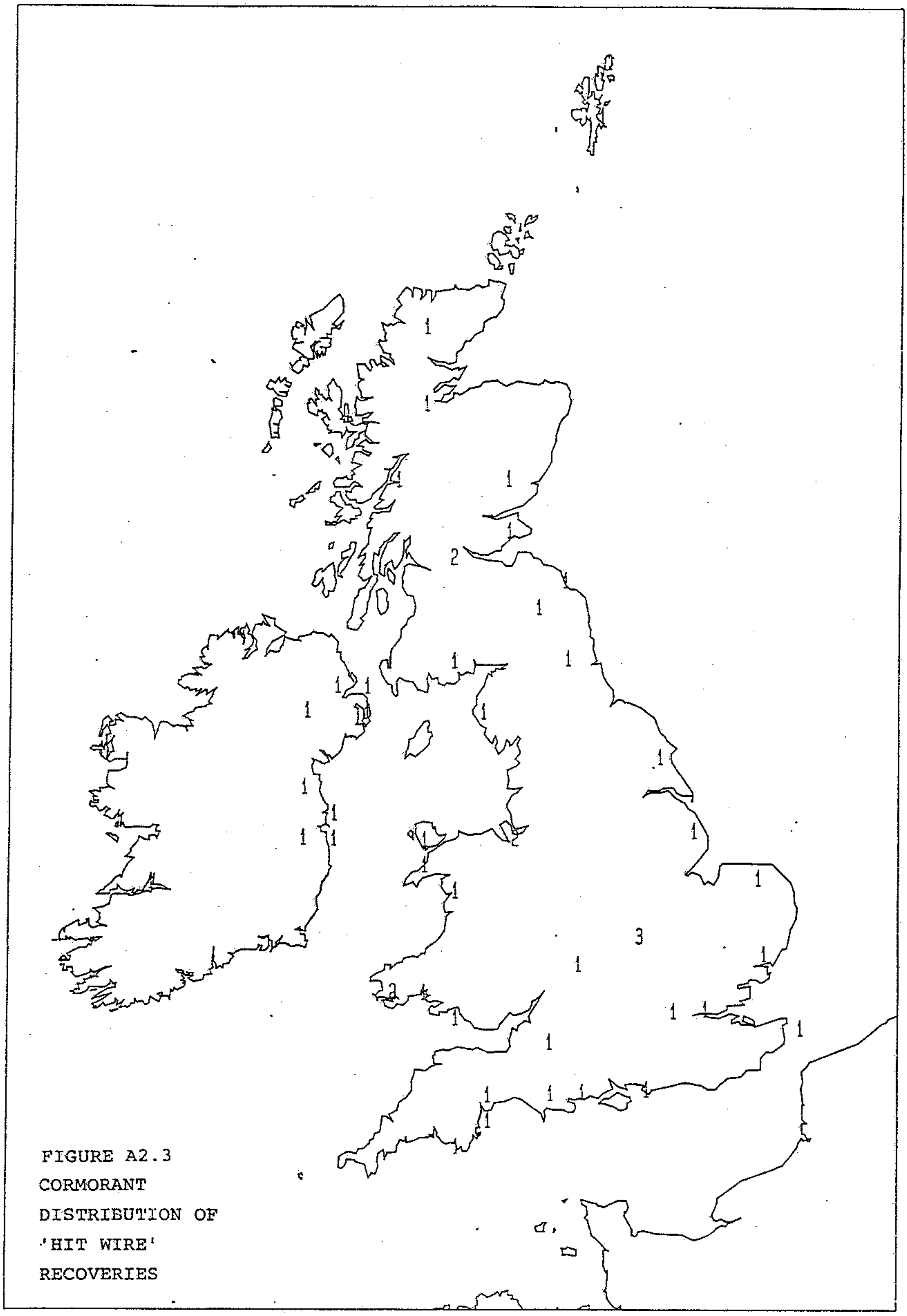

FIGURE A2.3
CORMORANT
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

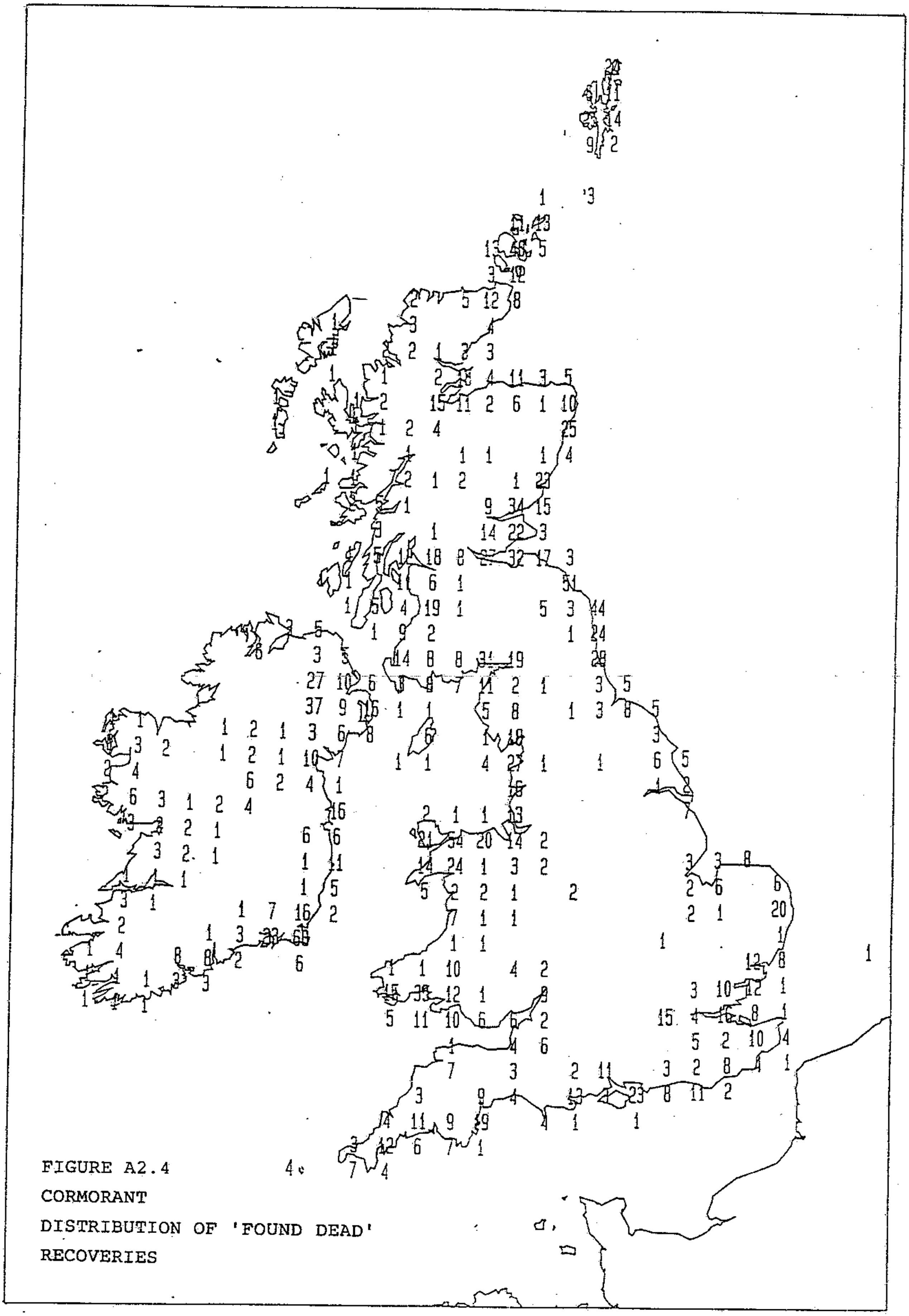

FIGURE A2.4
CORMORANT
DISTRIBUTION OF 'FOUND DEAD'
RECOVERIES

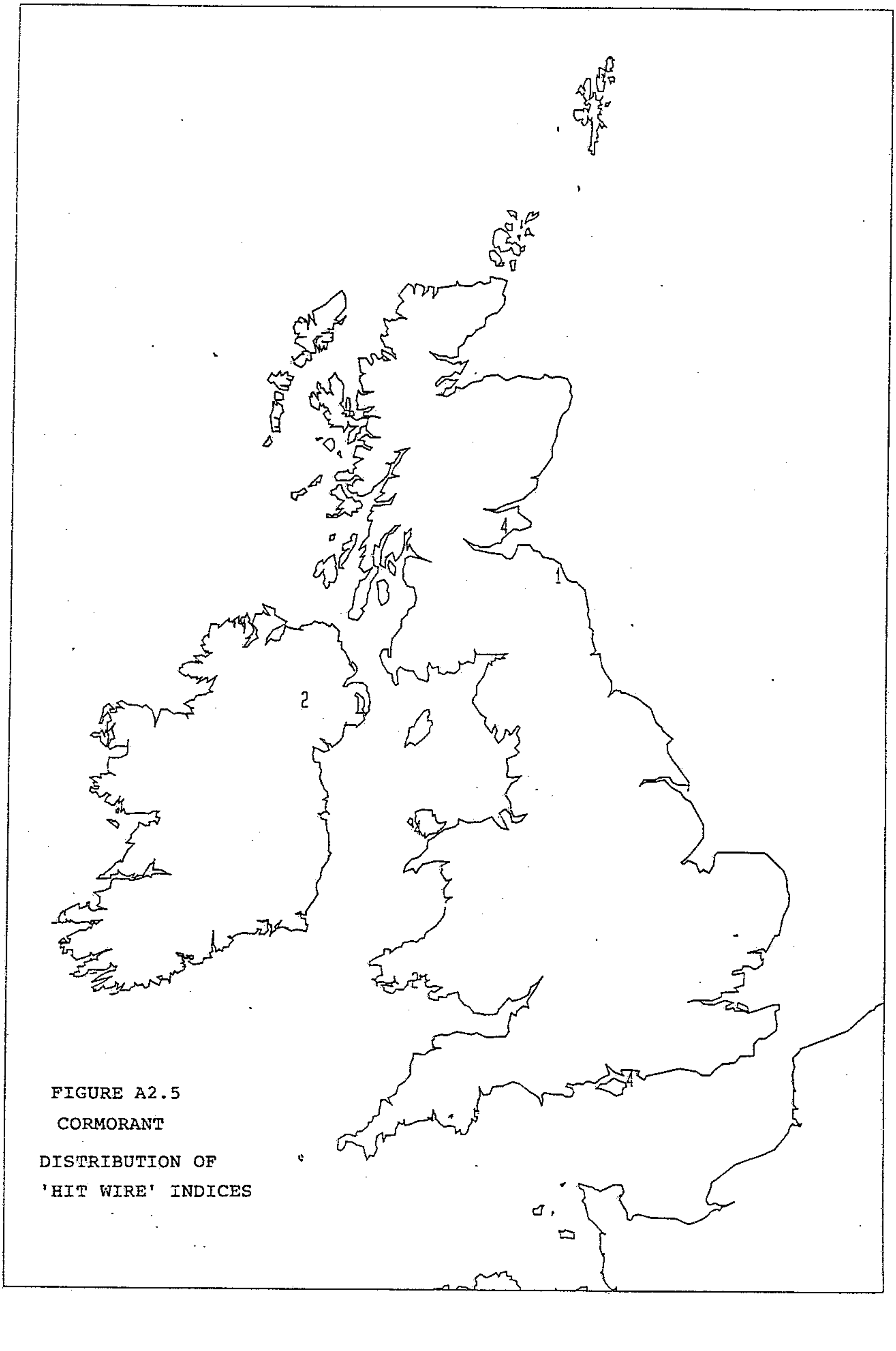


FIGURE A2.5
CORMORANT

DISTRIBUTION OF
'HIT WIRE' INDICES

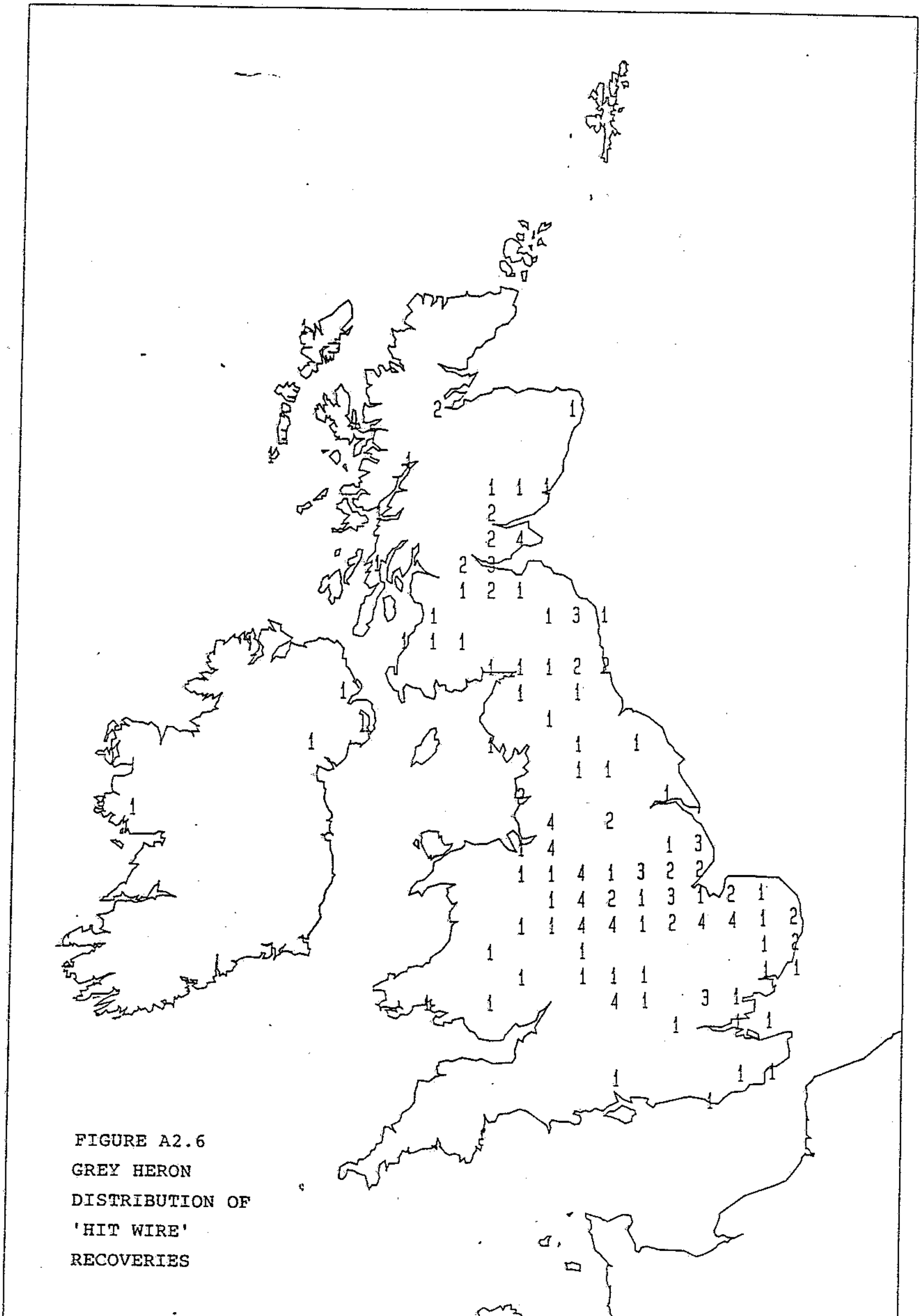

FIGURE A2.6
GREY HERON
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

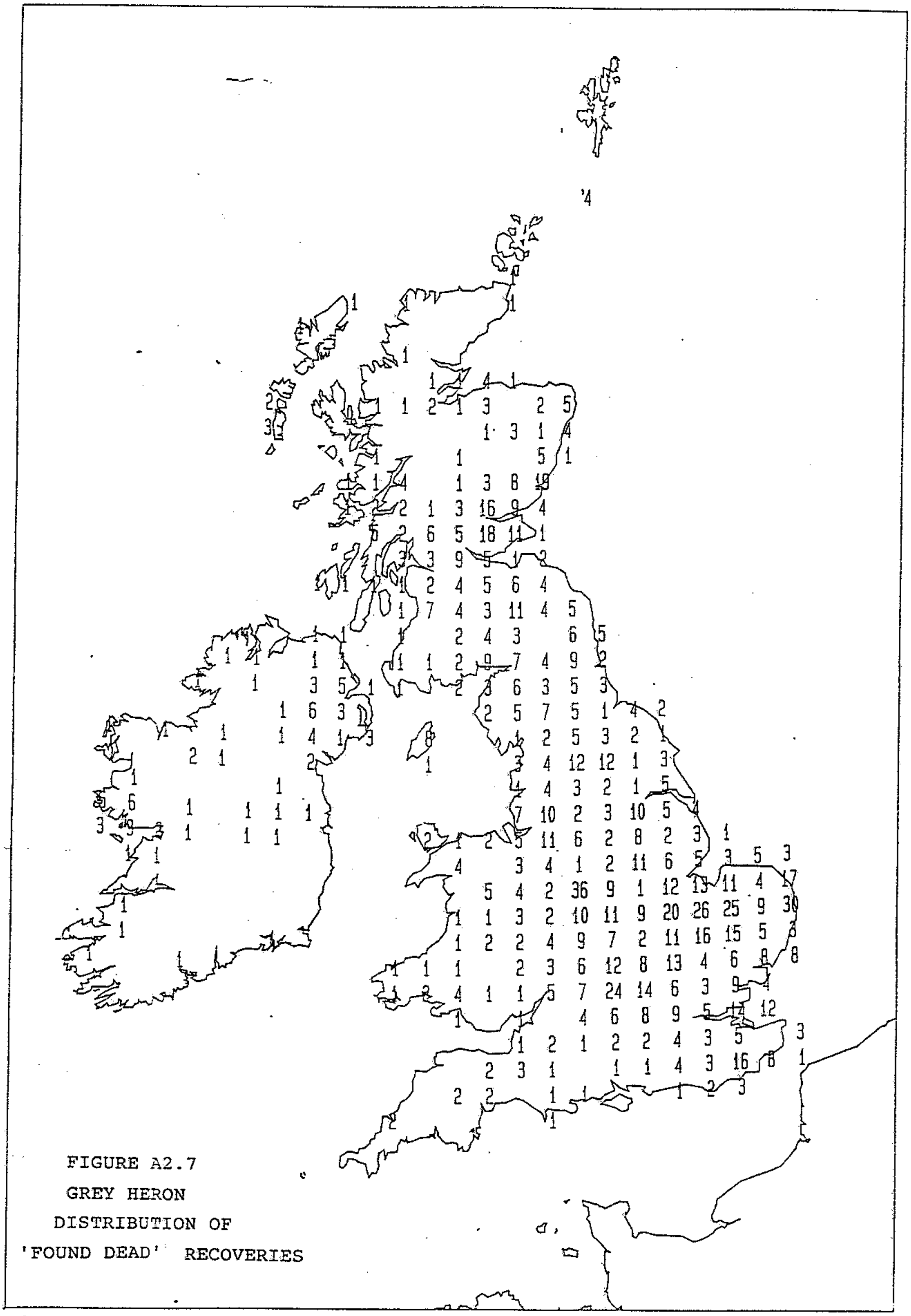

FIGURE A2.7
GREY HERON
DISTRIBUTION OF
'FOUND DEAD' RECOVERIES

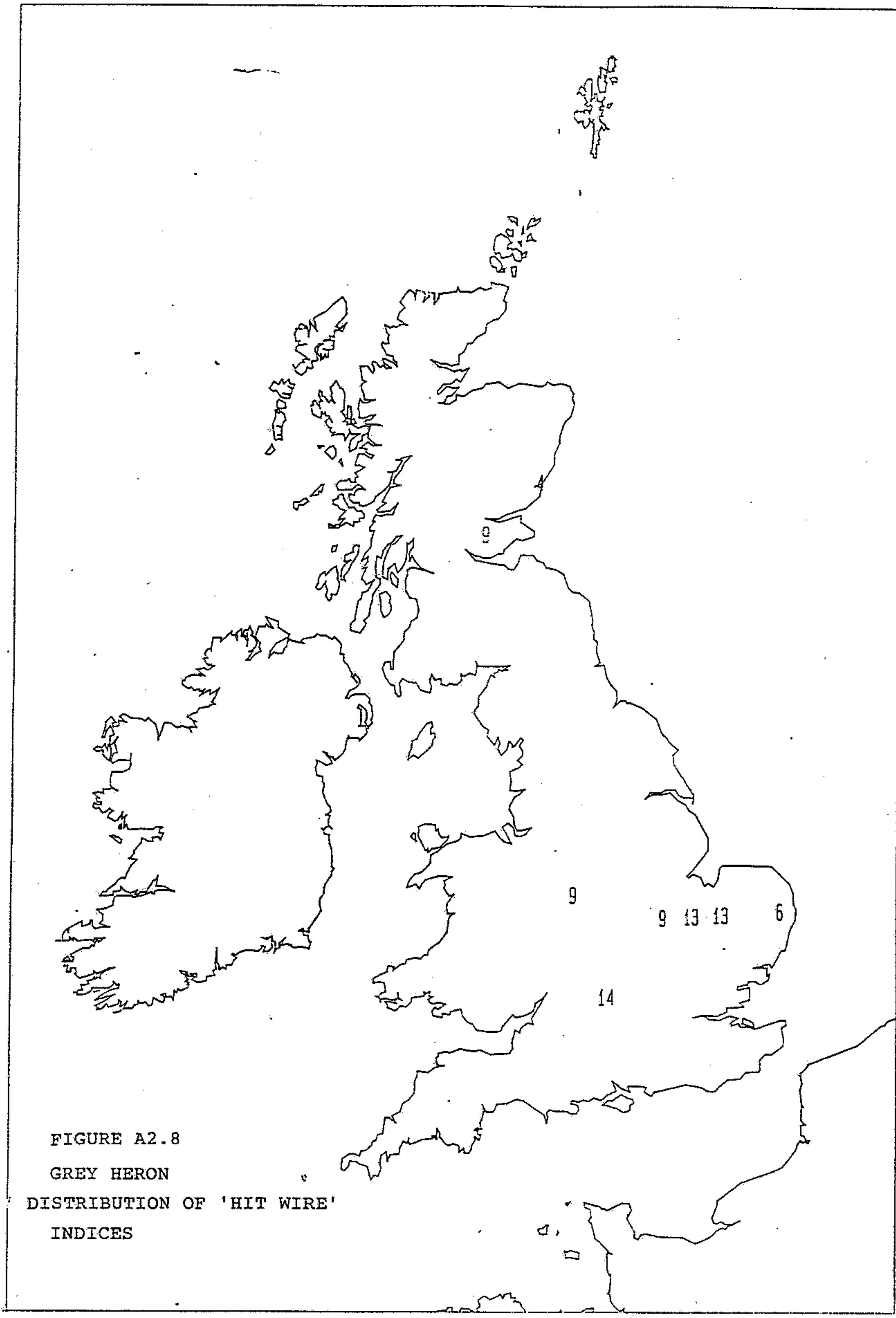


FIGURE A2.8

GREY HERON

DISTRIBUTION OF 'HIT WIRE' INDICES

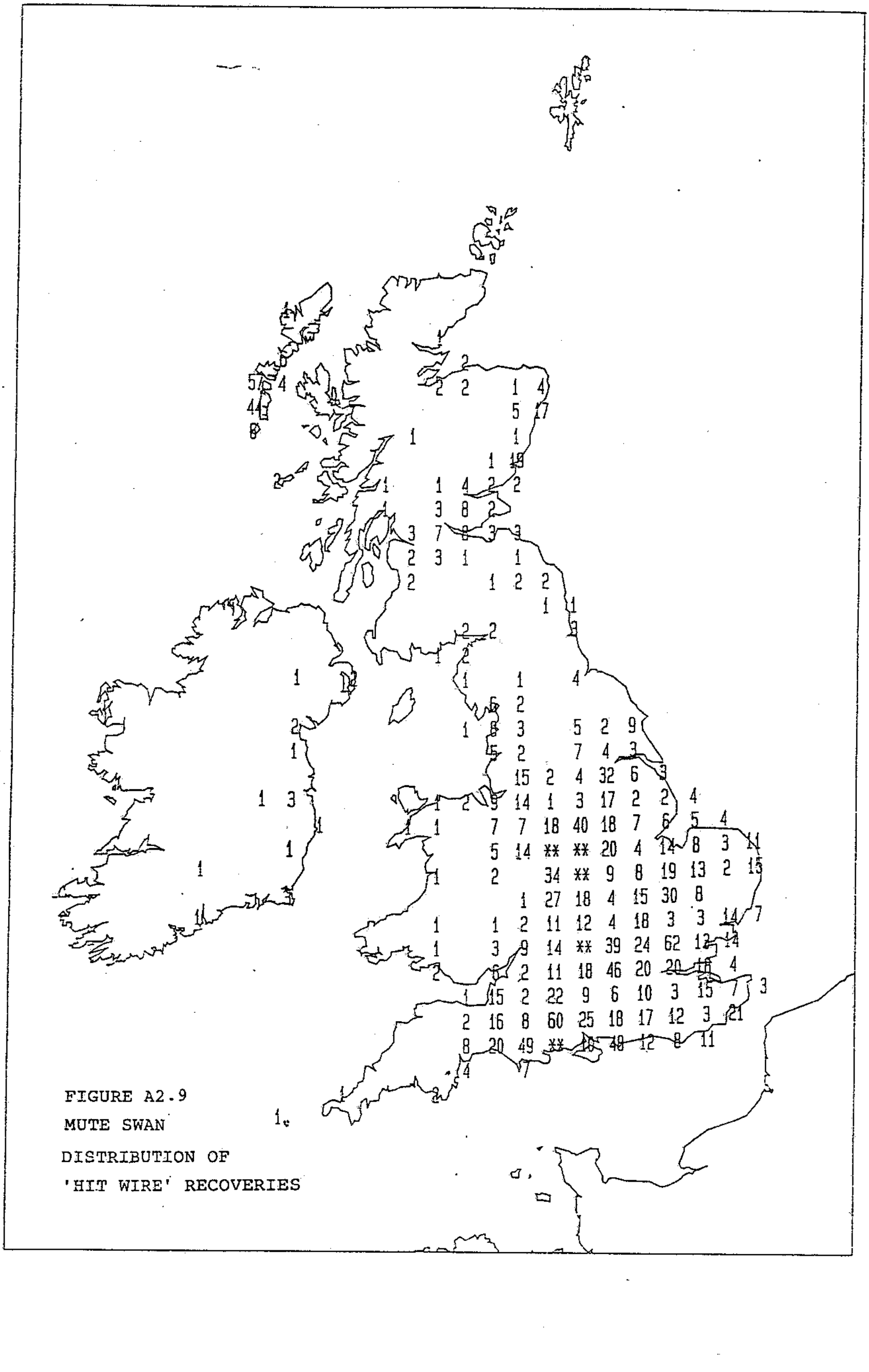

FIGURE A2.9
MUTE SWAN
DISTRIBUTION OF
'HIT WIRE' RECOVERIES

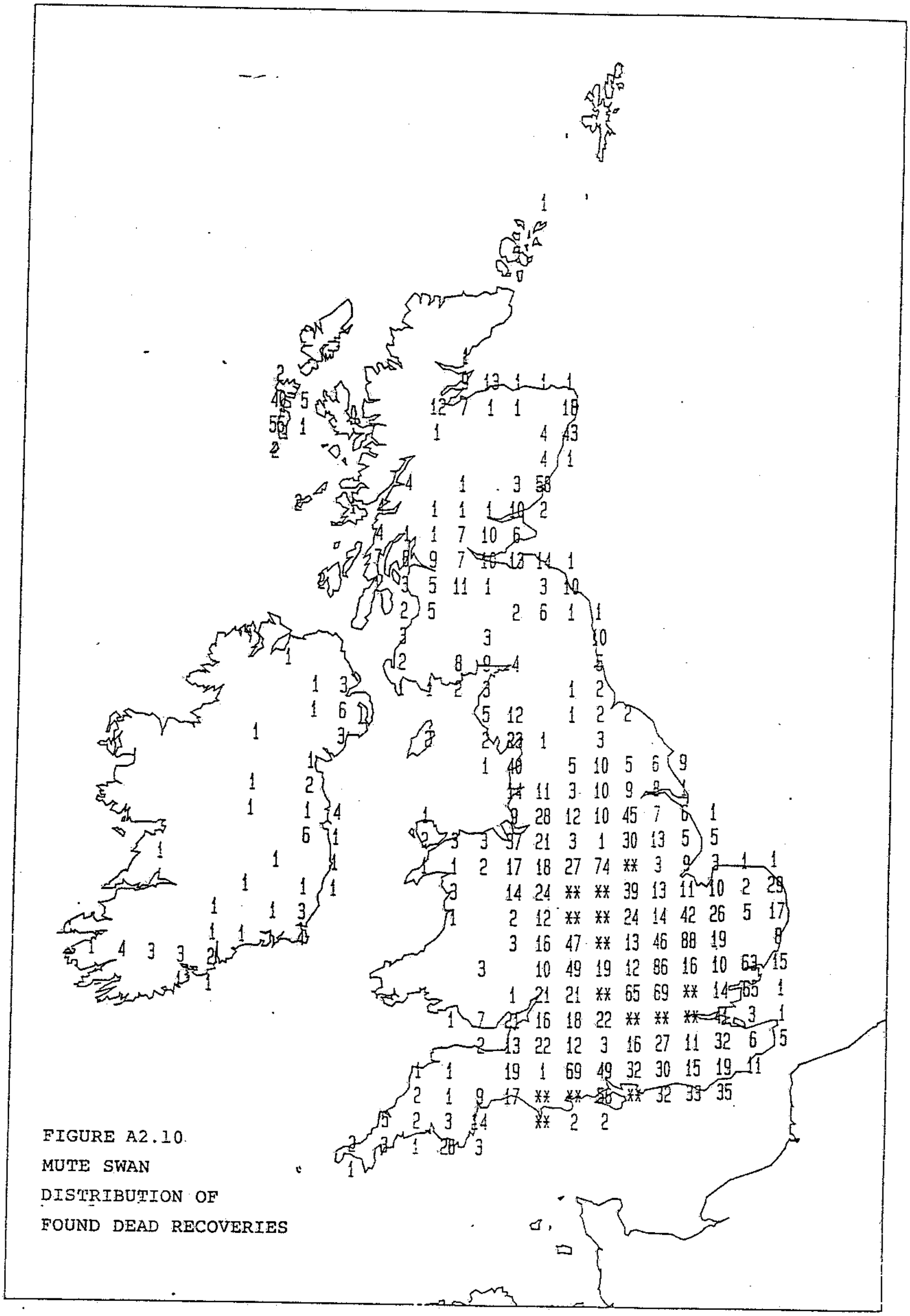

FIGURE A2.10
MUTE SWAN
DISTRIBUTION OF
FOUND DEAD RECOVERIES

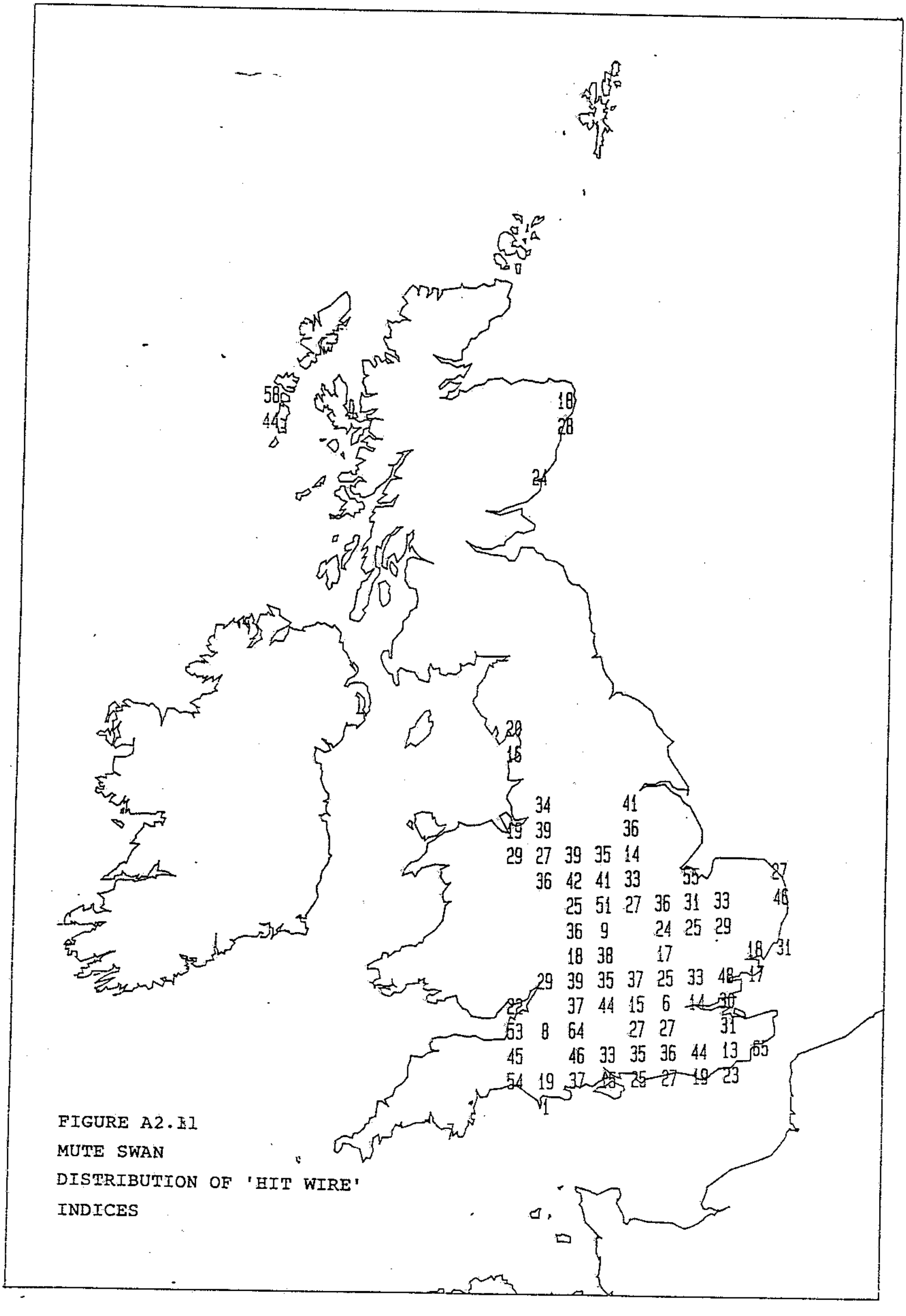


FIGURE A2.11
MUTE SWAN
DISTRIBUTION OF 'HIT WIRE'
INDICES

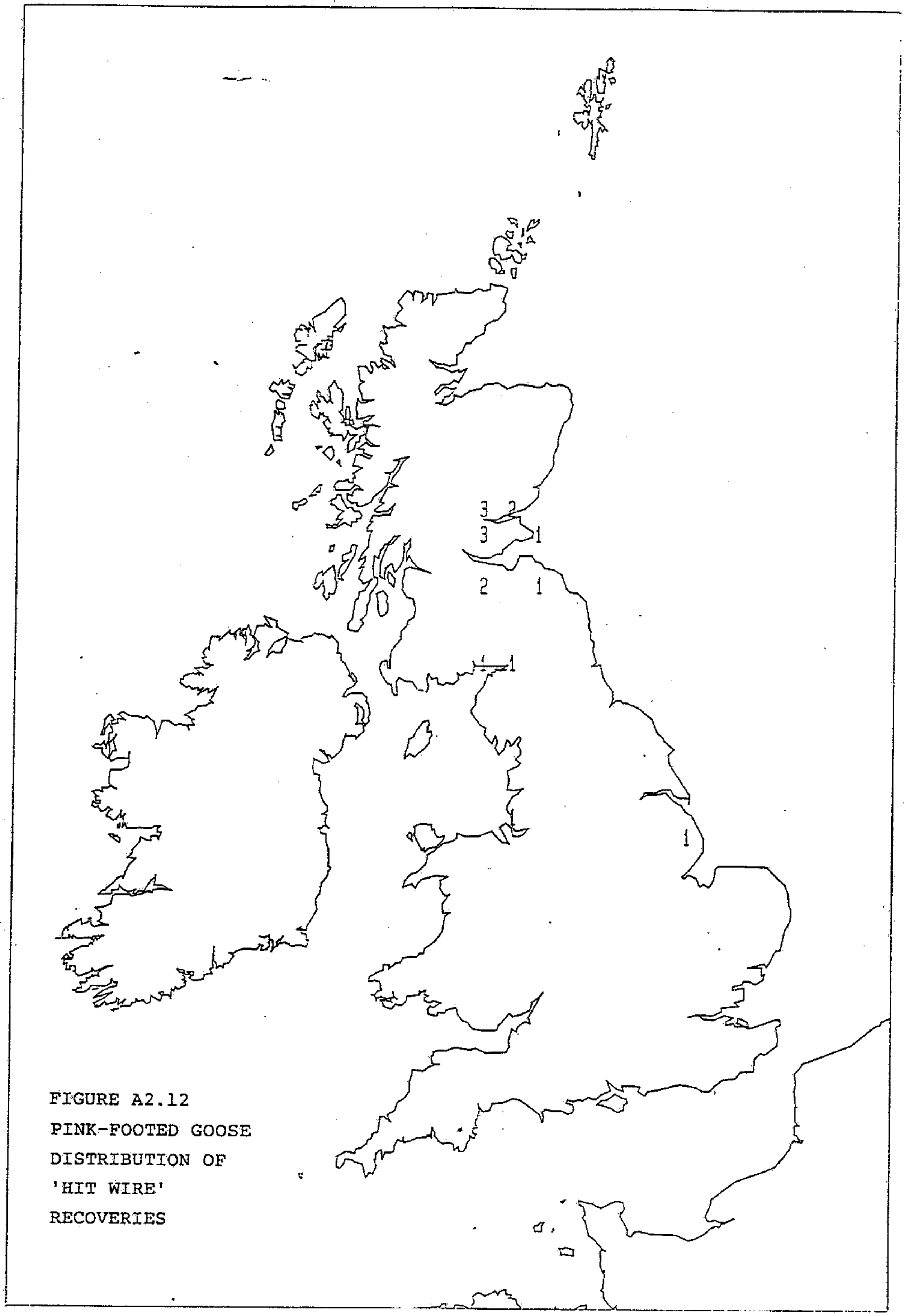


FIGURE A2.12
PINK-FOOTED GOOSE
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

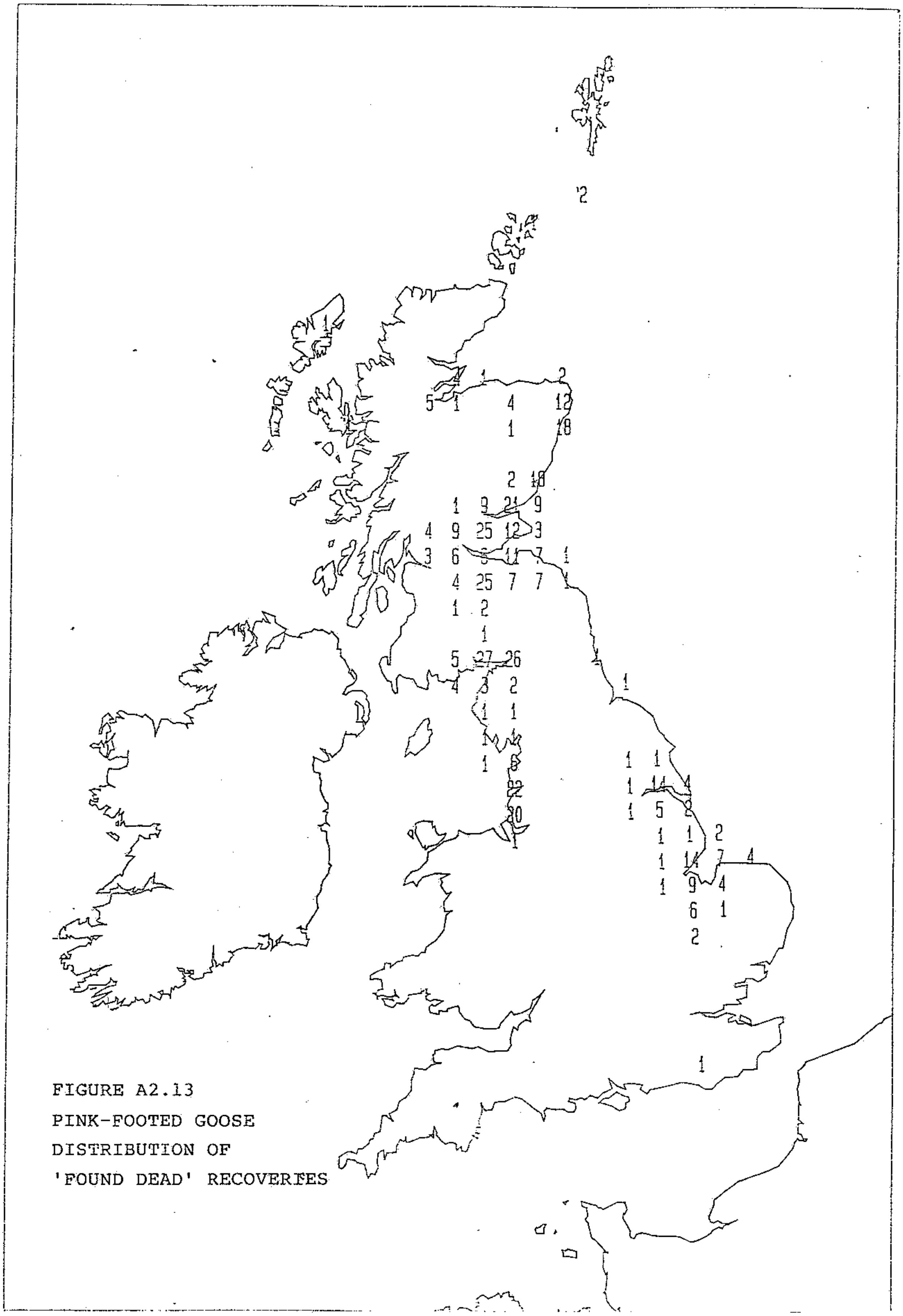

FIGURE A2.13
PINK-FOOTED GOOSE
DISTRIBUTION OF
'FOUND DEAD' RECOVERIES

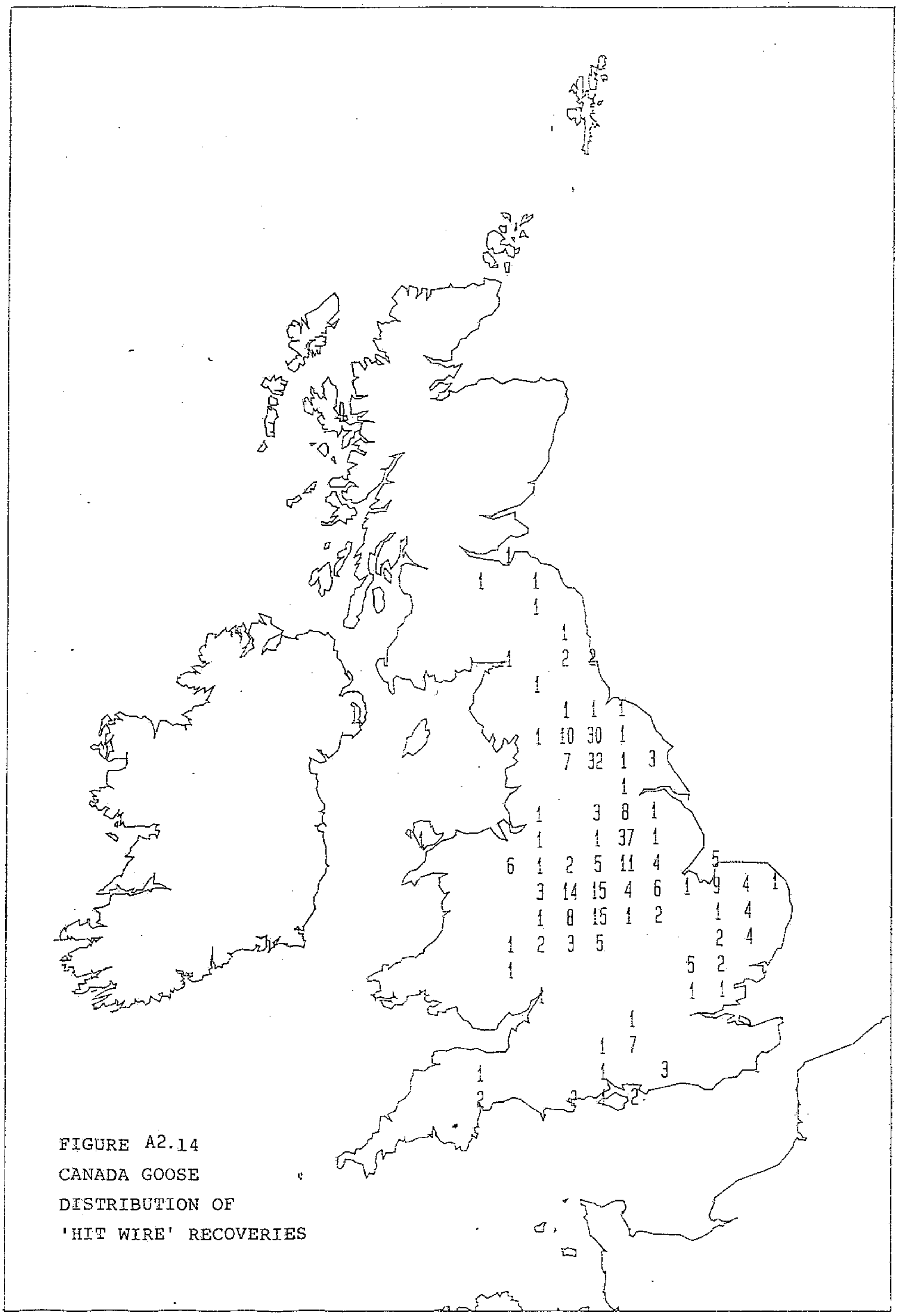

FIGURE A2.14
CANADA GOOSE
DISTRIBUTION OF
'HIT WIRE' RECOVERIES

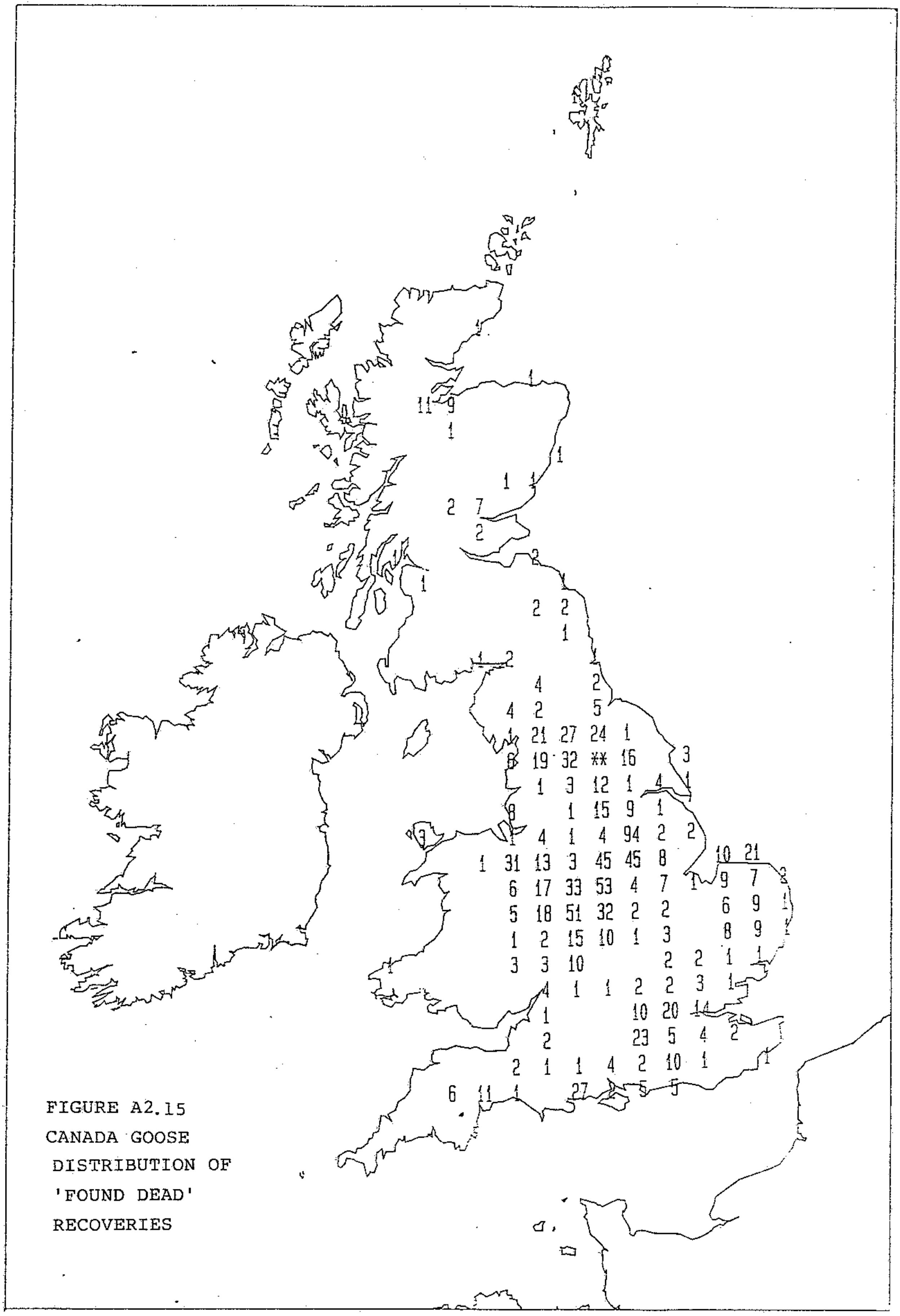

FIGURE A2.15
CANADA GOOSE
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

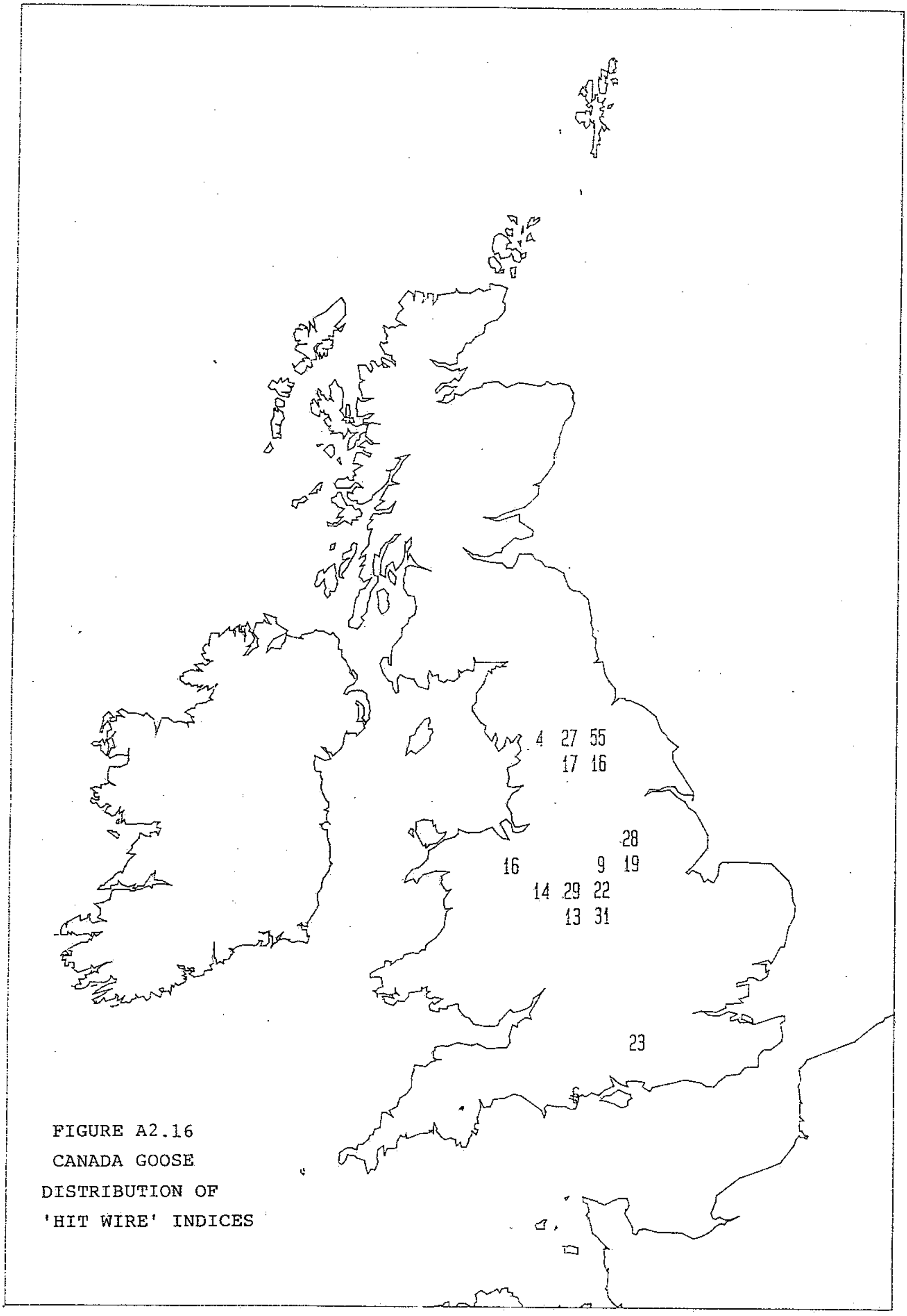


FIGURE A2.16
CANADA GOOSE
DISTRIBUTION OF
'HIT WIRE' INDICES

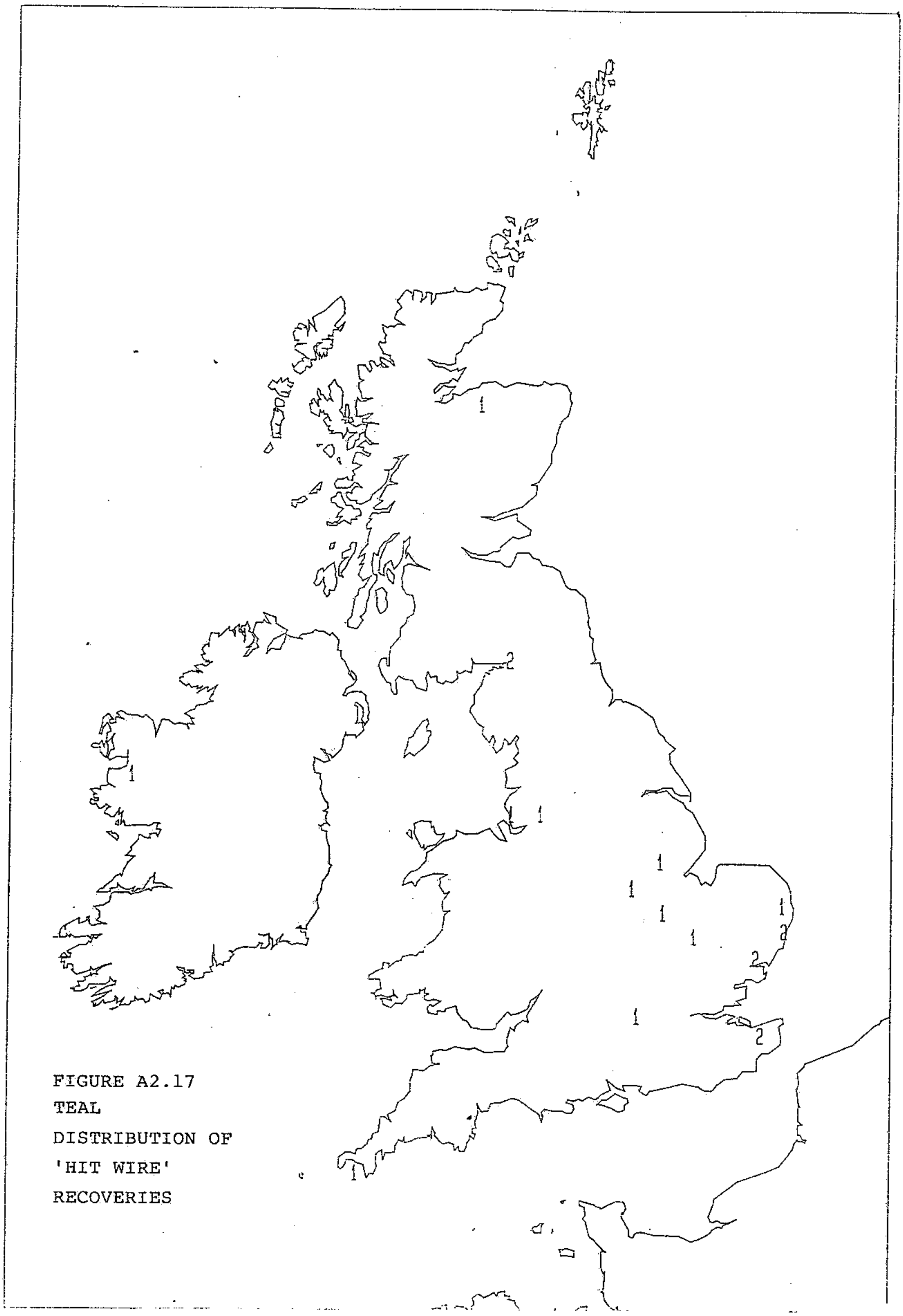


FIGURE A2.17
TEAL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

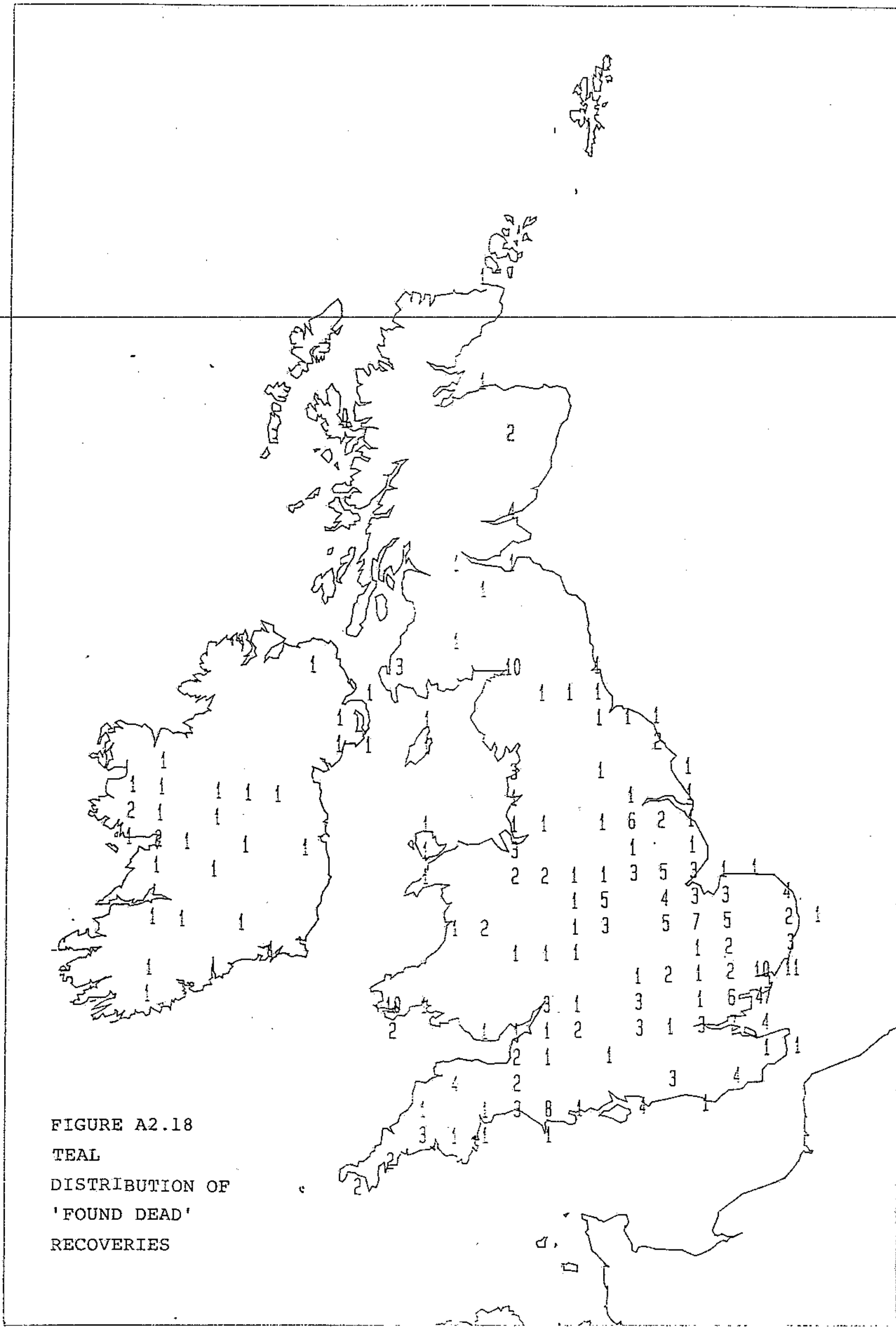

FIGURE A2.18
TEAL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

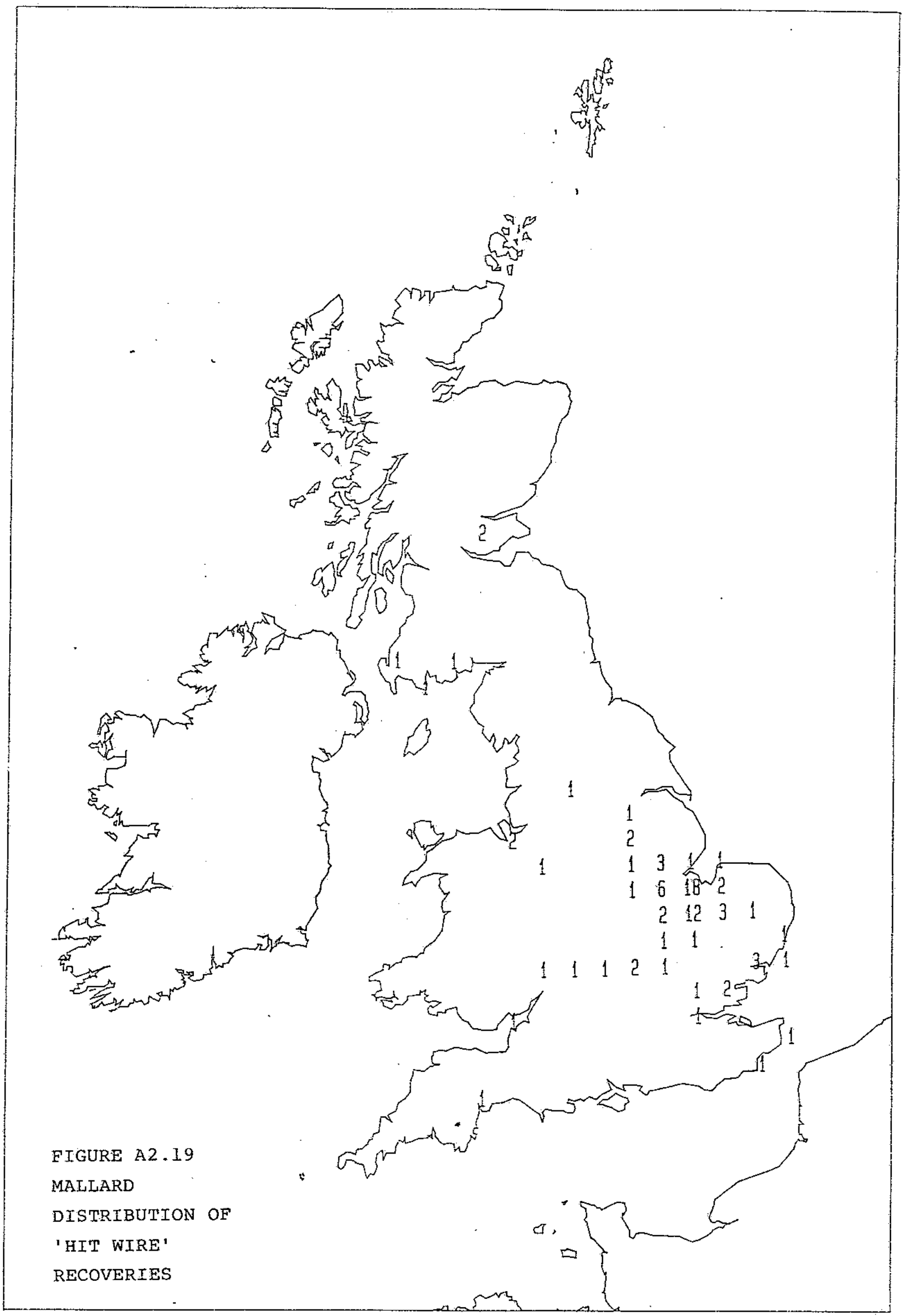

FIGURE A2.19
MALLARD
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

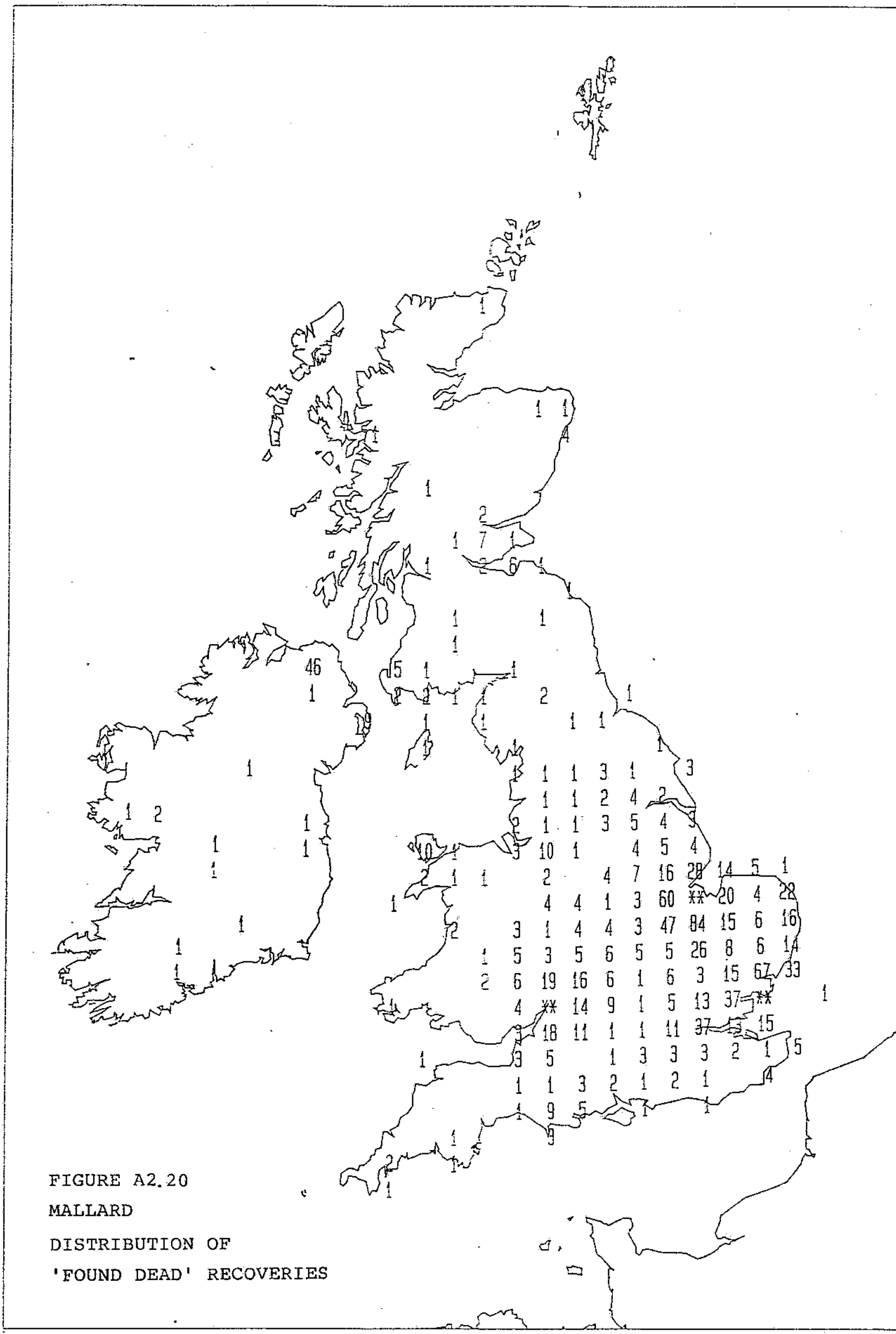

FIGURE A2.20
MALLARD
DISTRIBUTION OF
'FOUND DEAD' RECOVERIES

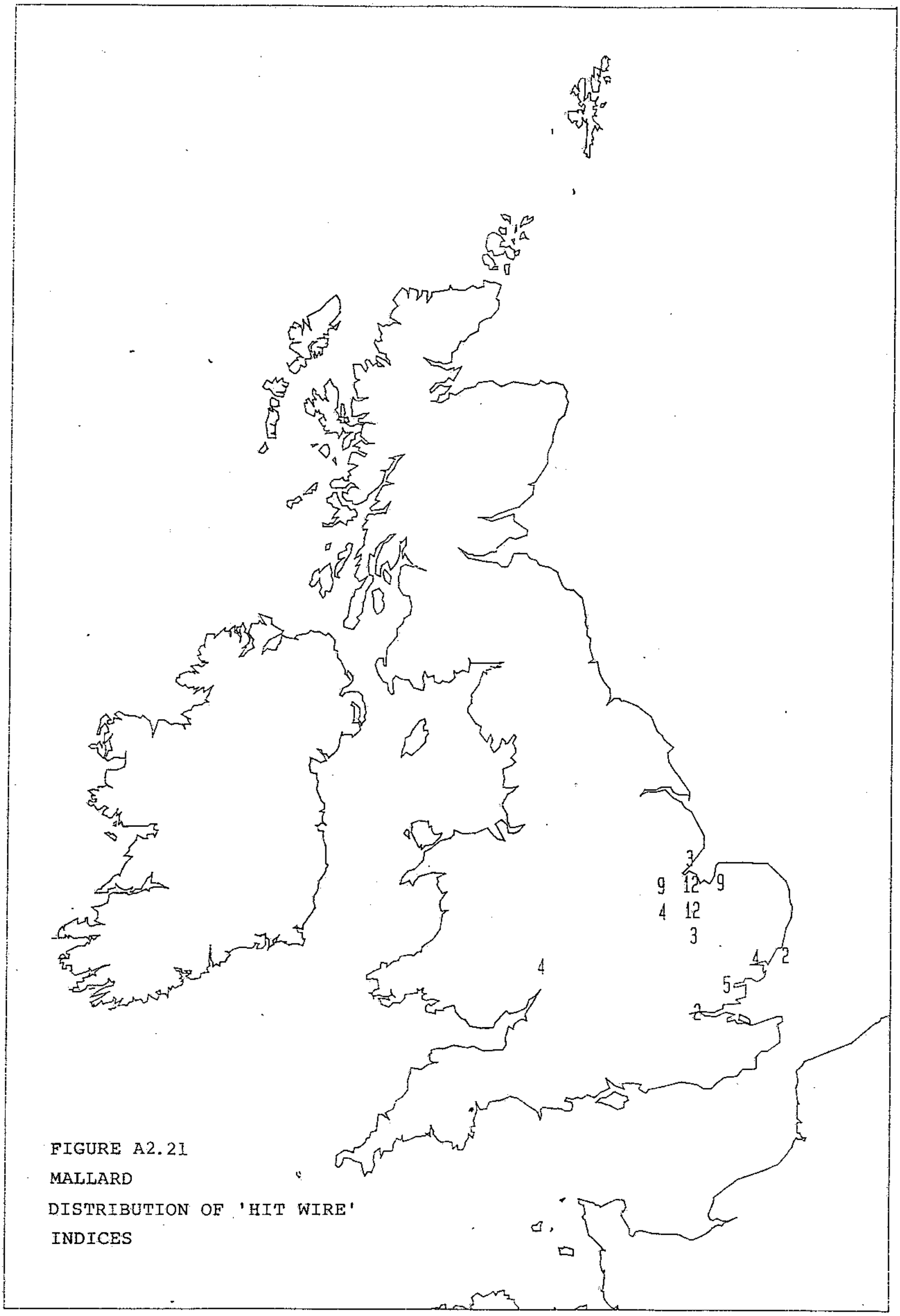


FIGURE A2.21
MALLARD
DISTRIBUTION OF 'HIT WIRE'
INDICES

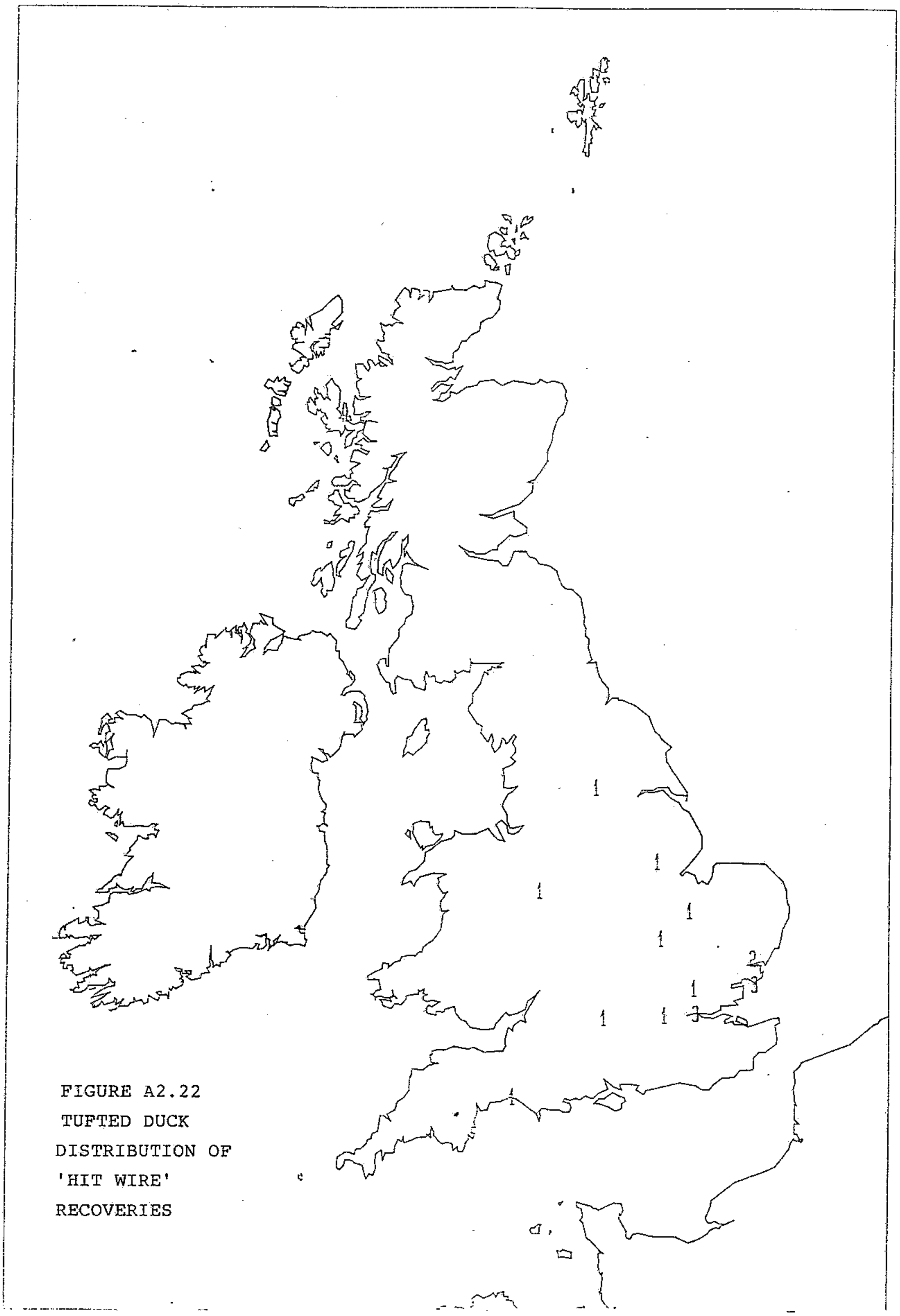


FIGURE A2.22
TUFTED DUCK
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

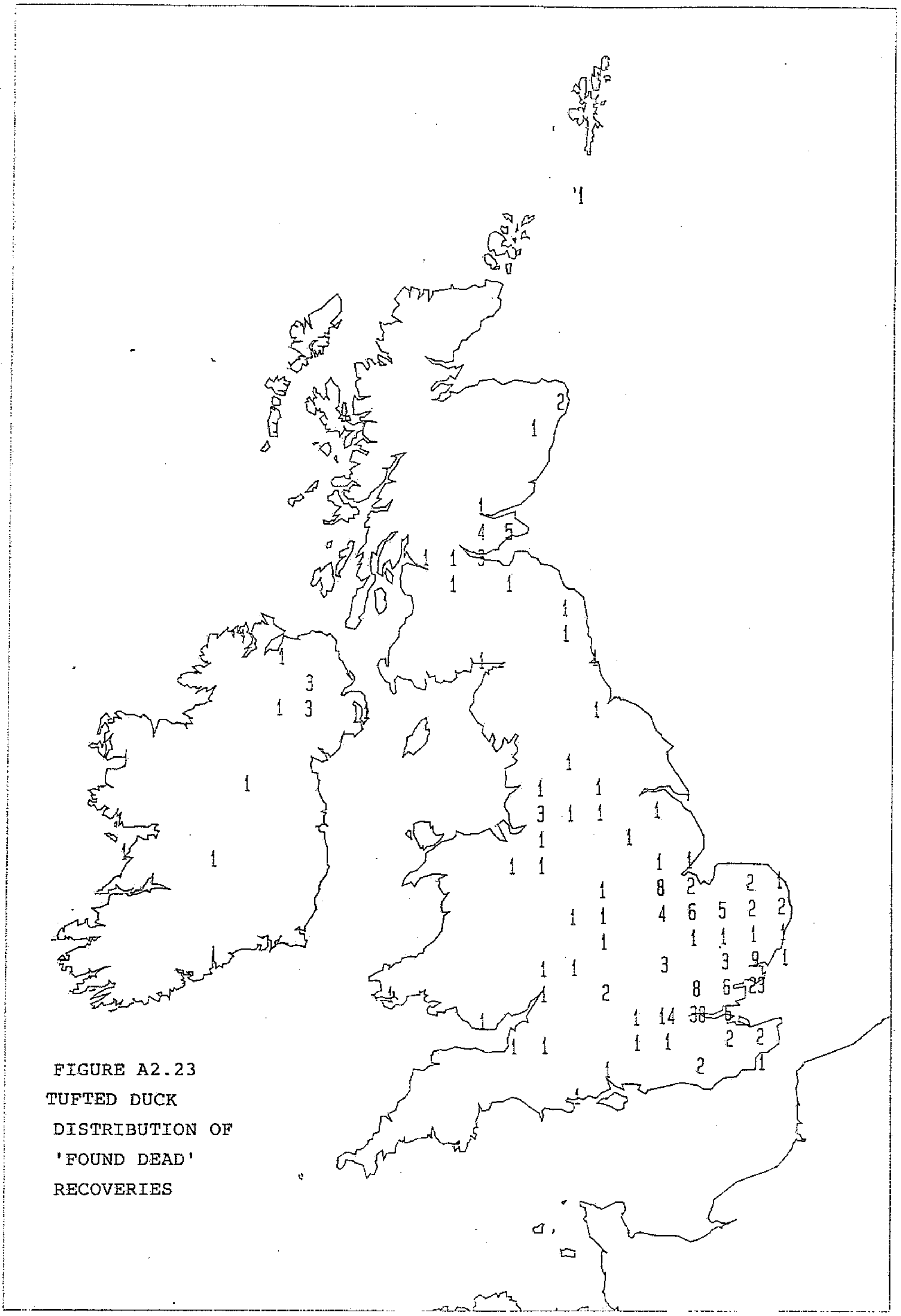

FIGURE A2.23
TUFTED DUCK
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

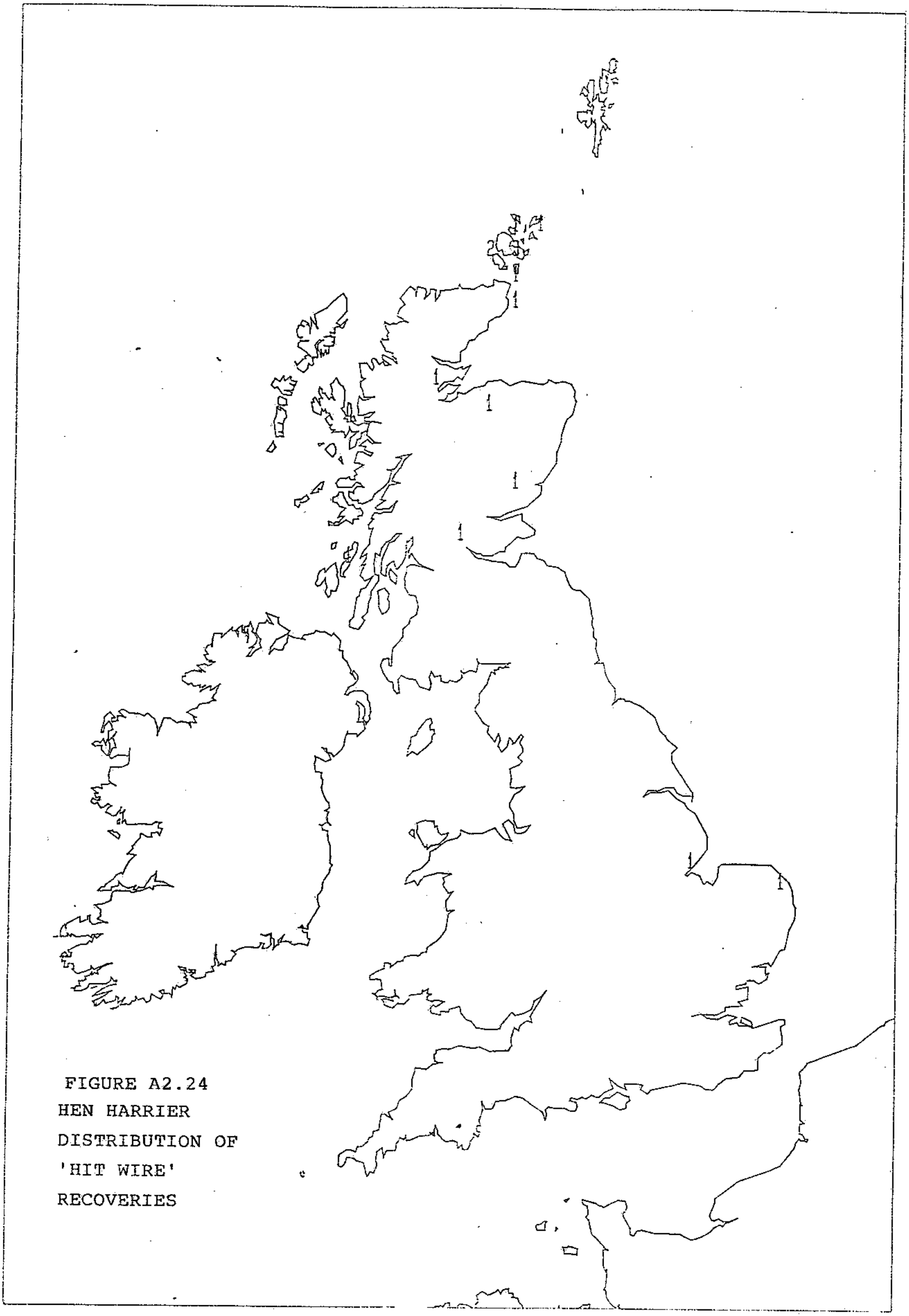

FIGURE A2.24
HEN HARRIER
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

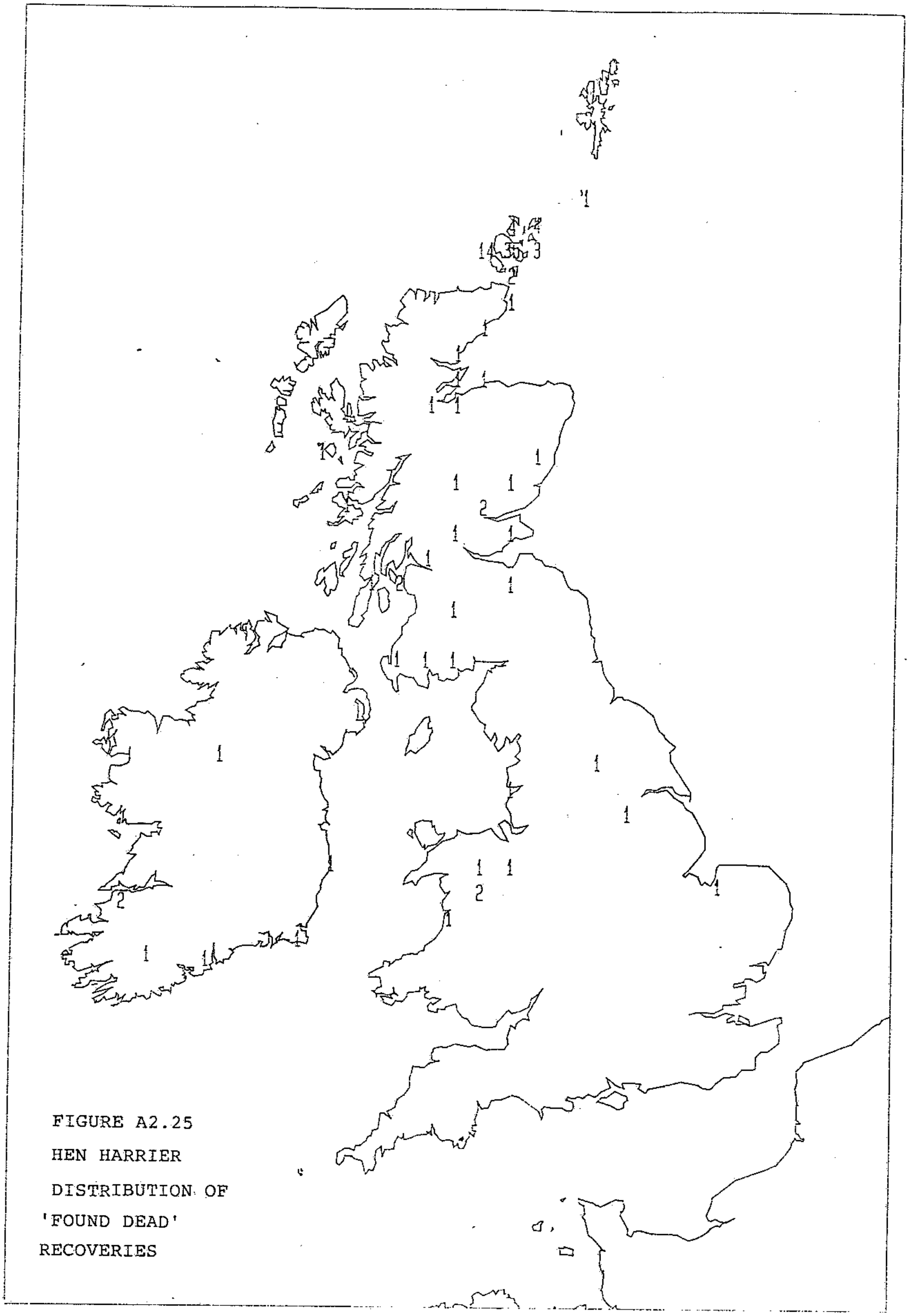

FIGURE A2.25
HEN HARRIER
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

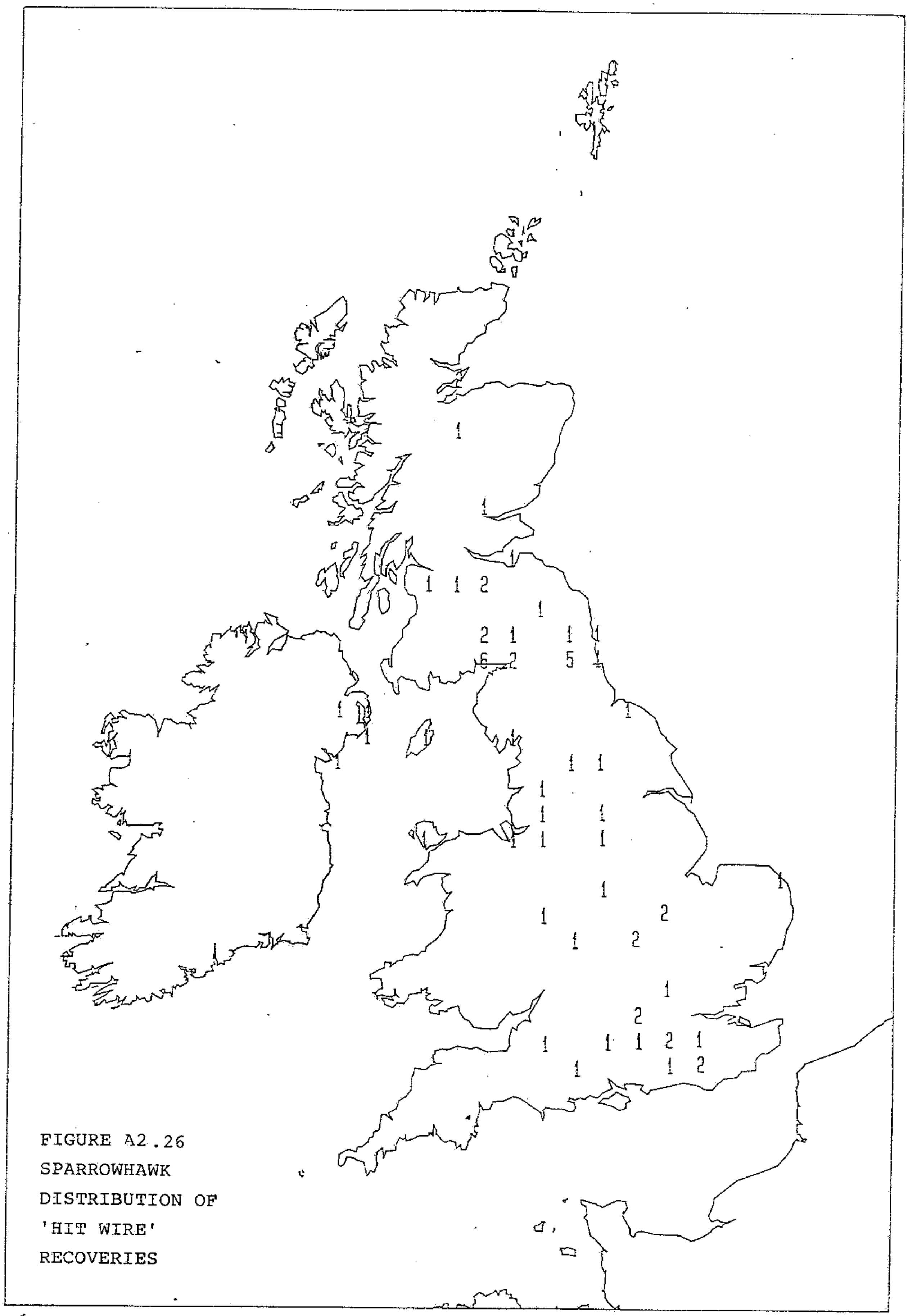

FIGURE A2.26
SPARROWHAWK
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

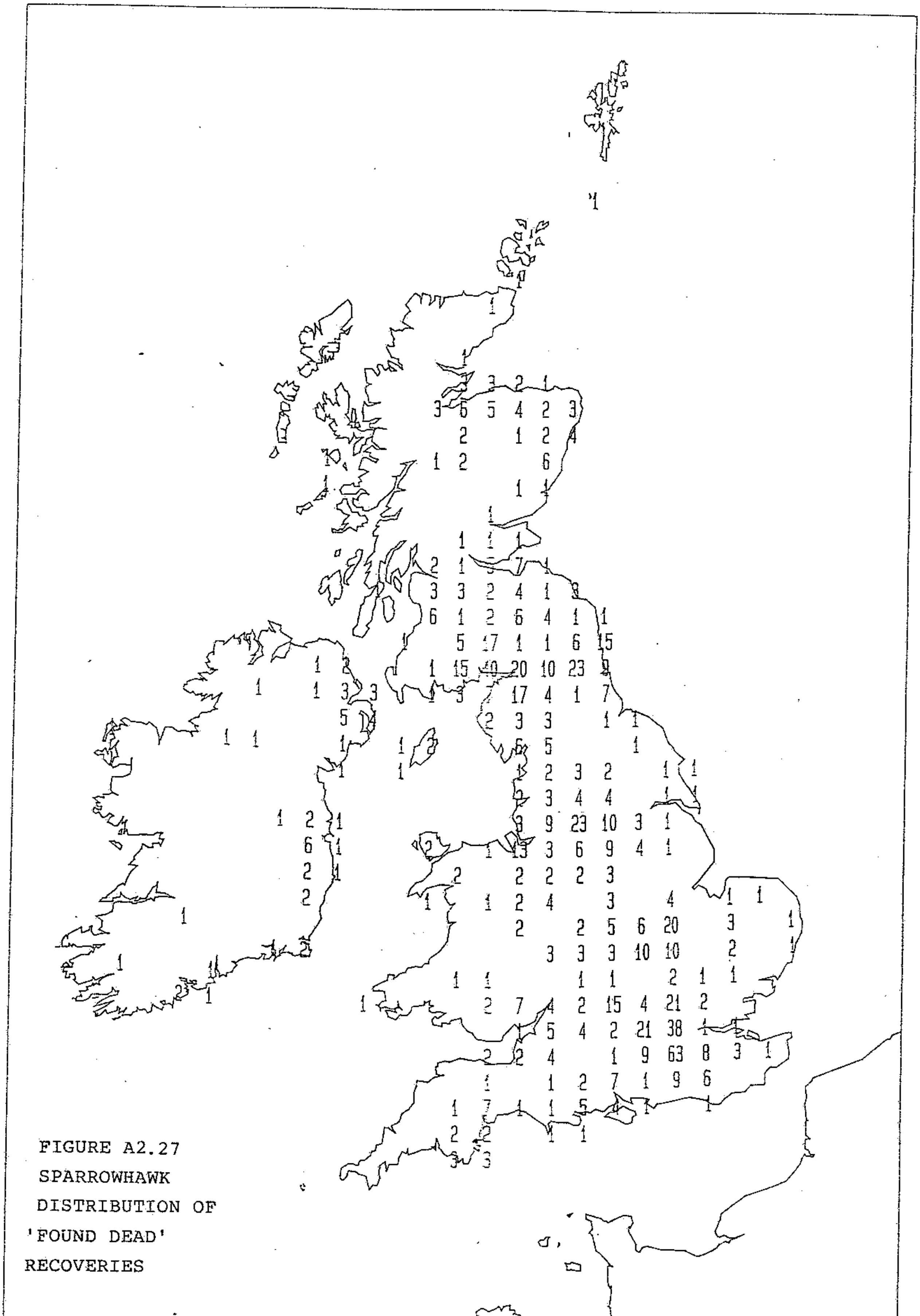

FIGURE A2.27
SPARROWHAWK
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

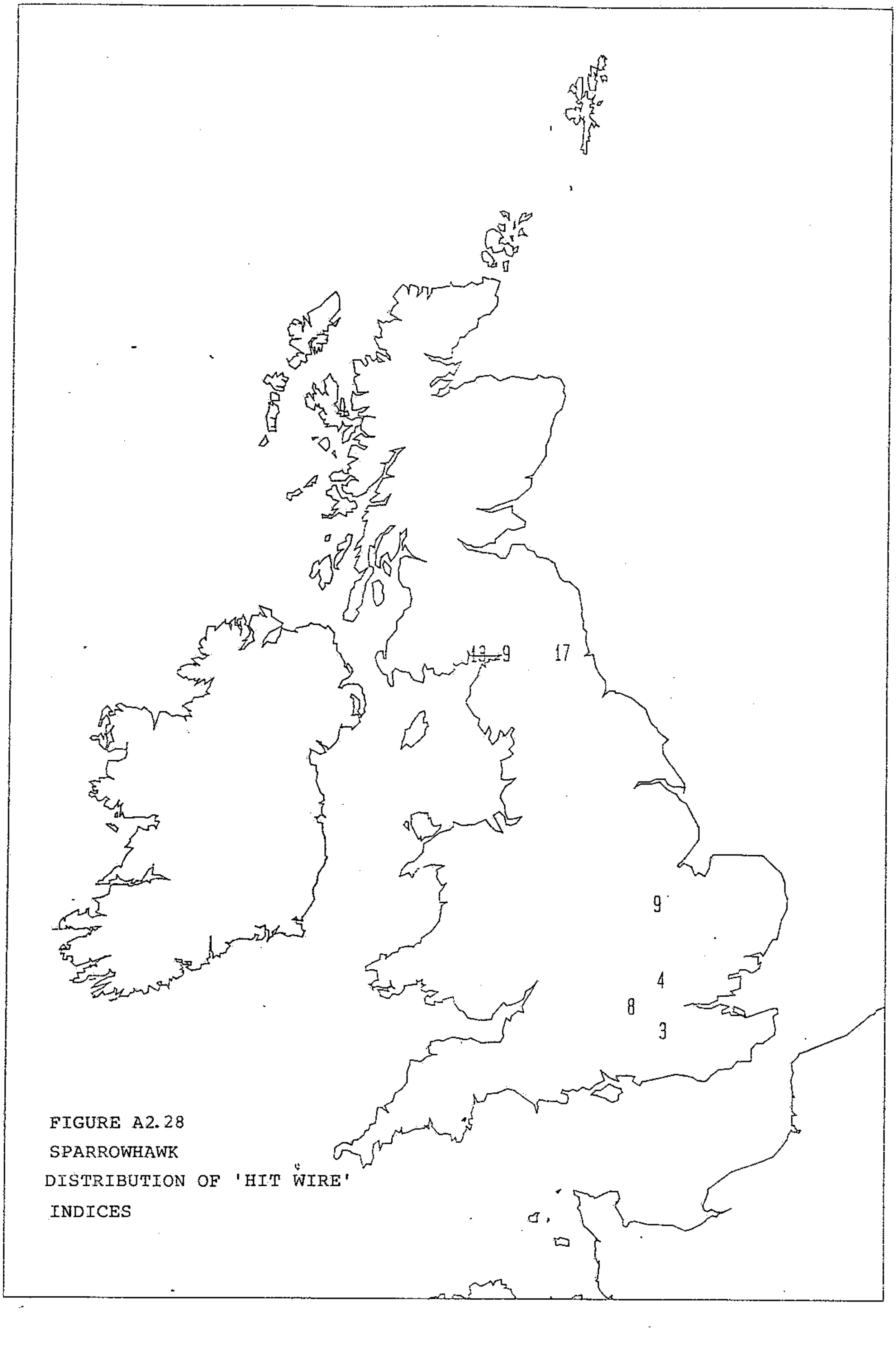


FIGURE A2.28
SPARROWHAWK
DISTRIBUTION OF 'HIT WIRE'
INDICES

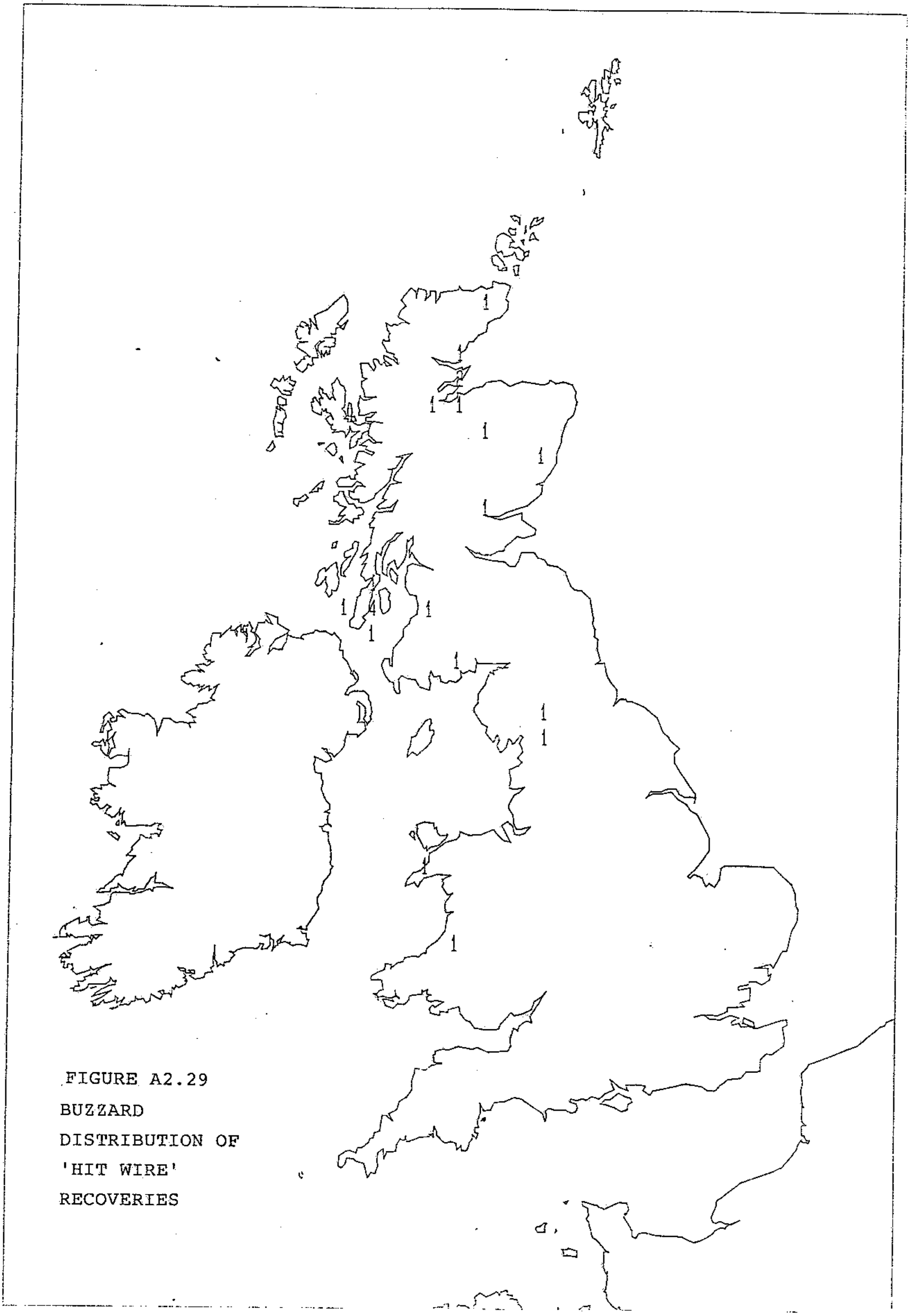

FIGURE A2.29
BUZZARD
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

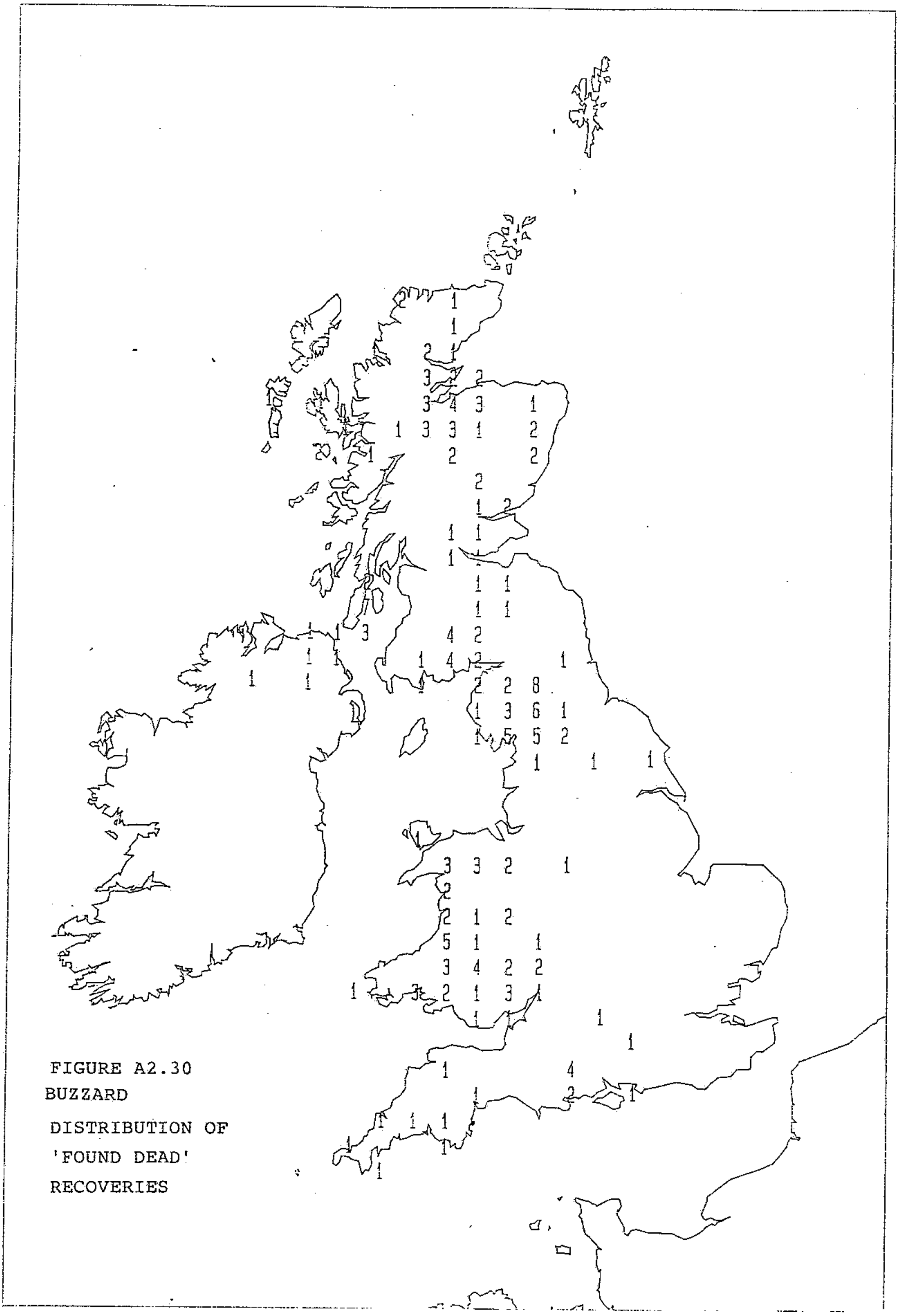

FIGURE A2.30
BUZZARD
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

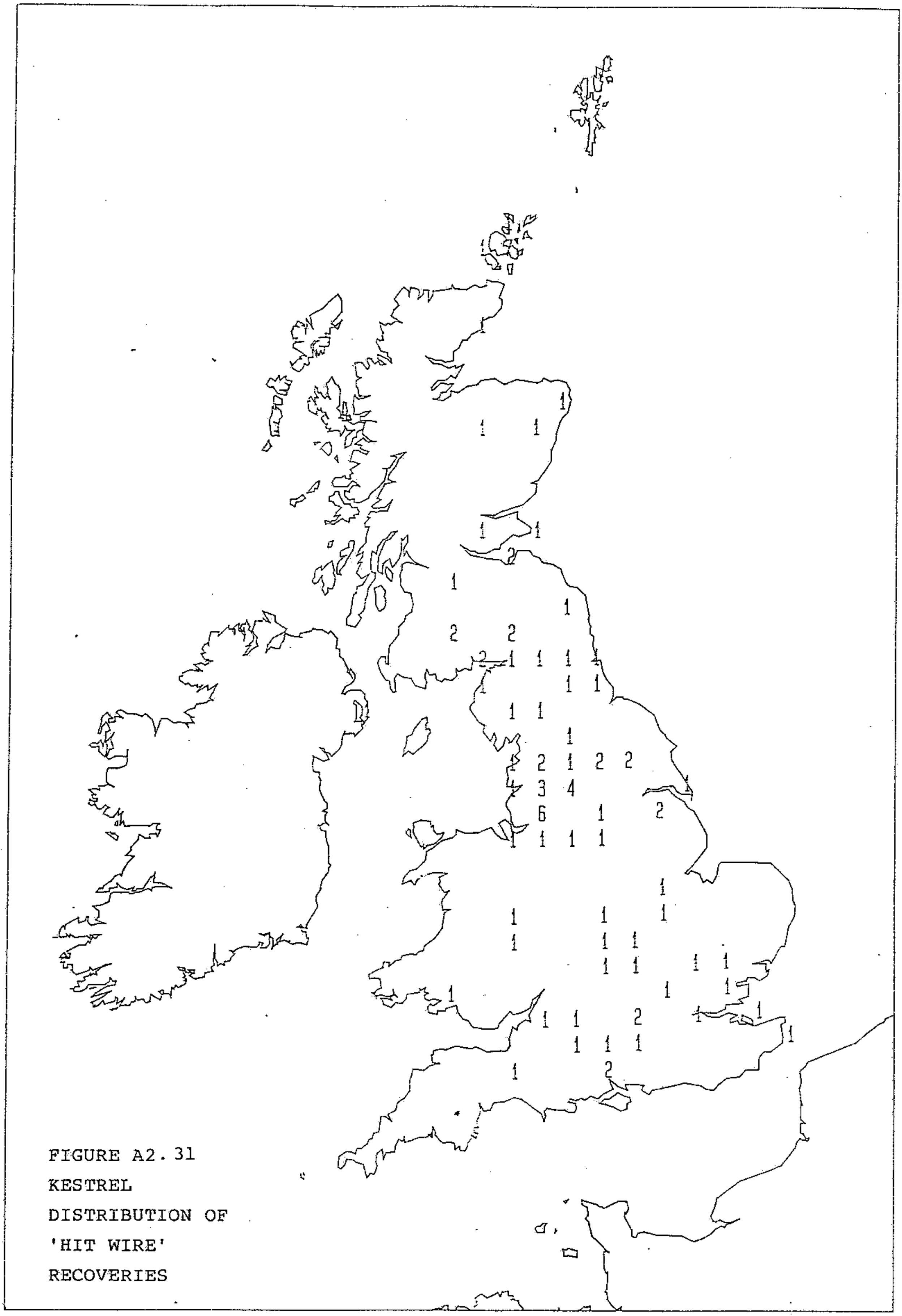

FIGURE A2. 31
KESTREL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

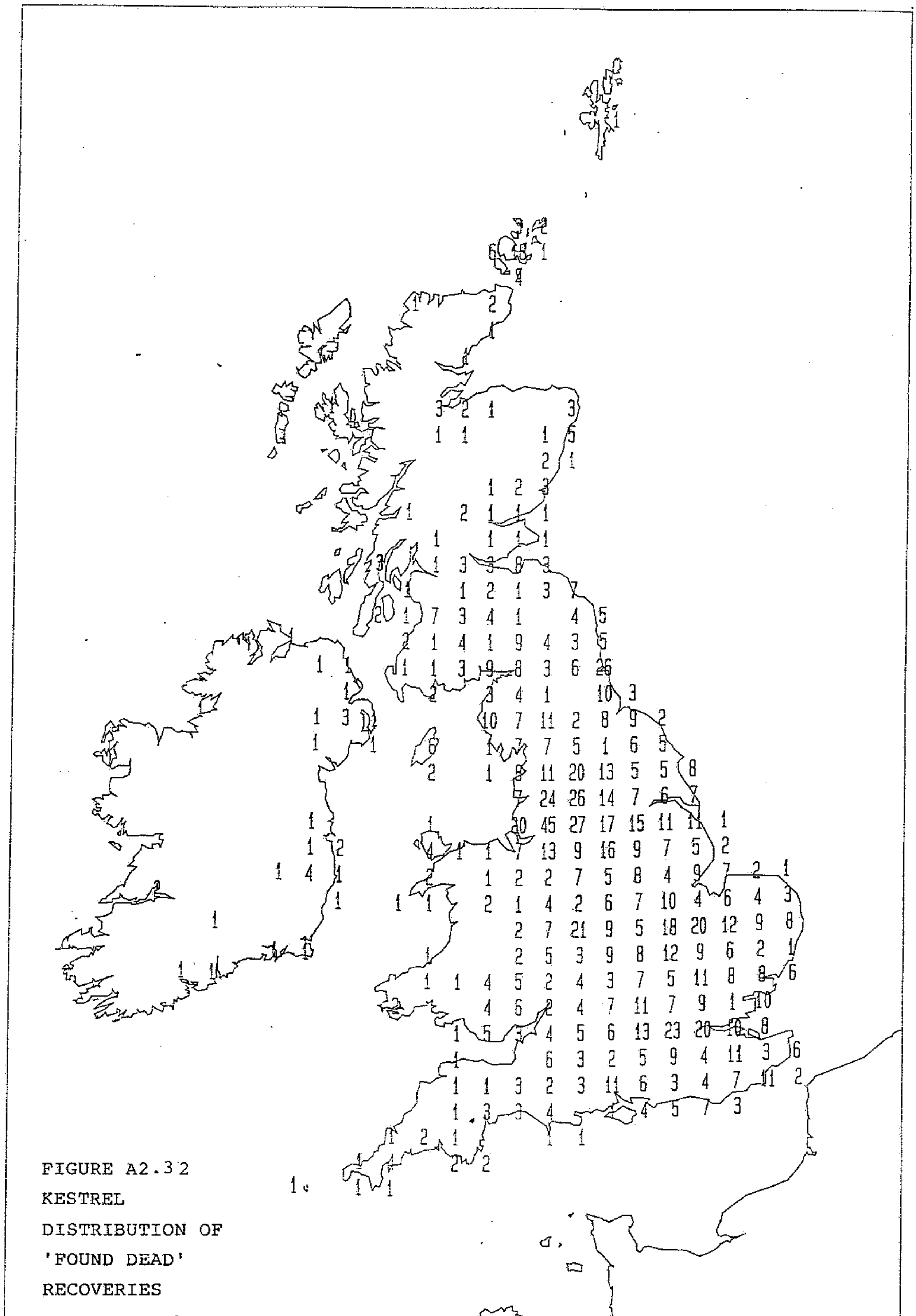

FIGURE A2.32
KESTREL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

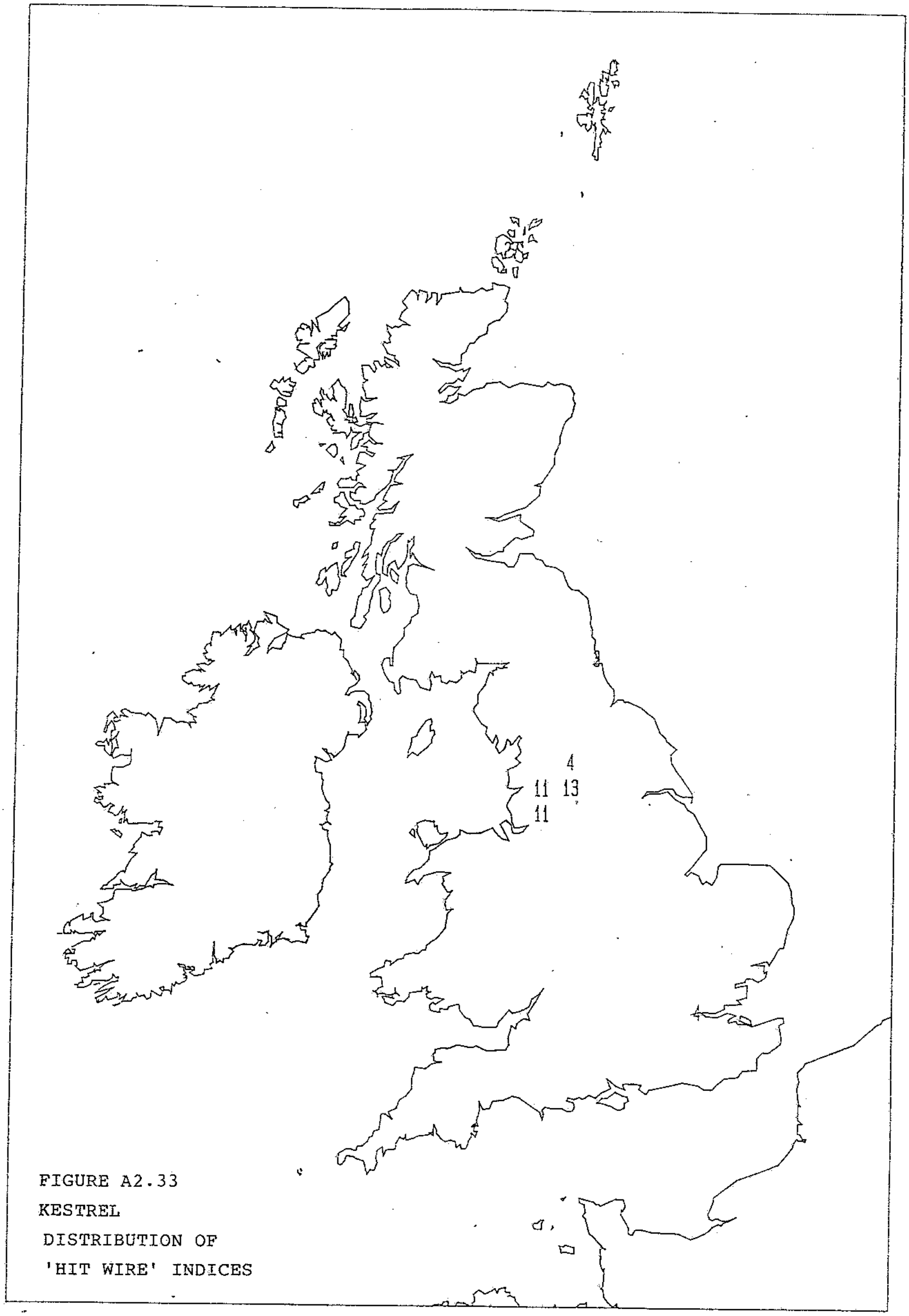


FIGURE A2.33
KESTREL
DISTRIBUTION OF
'HIT WIRE' INDICES

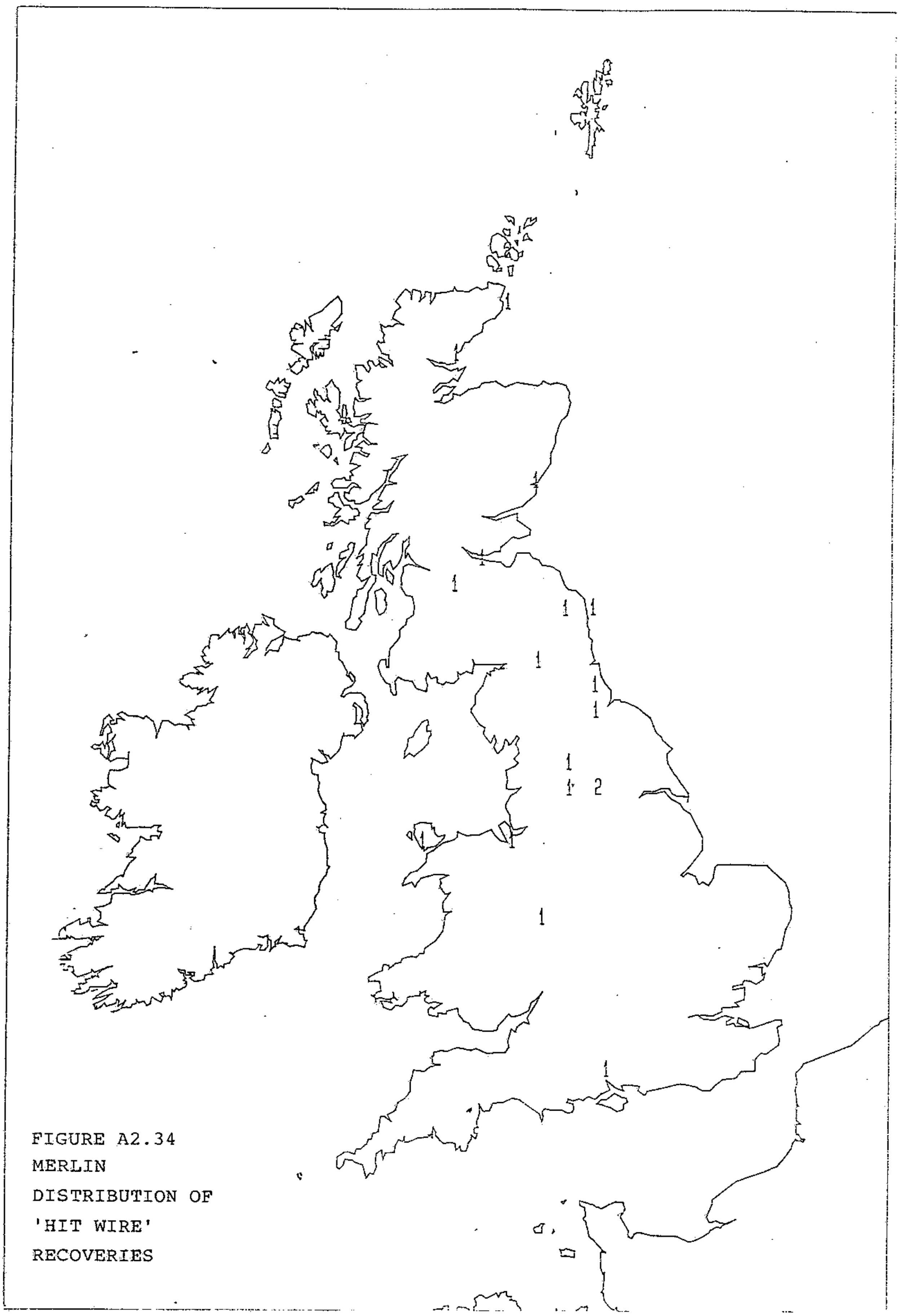


FIGURE A2.34
MERLIN
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

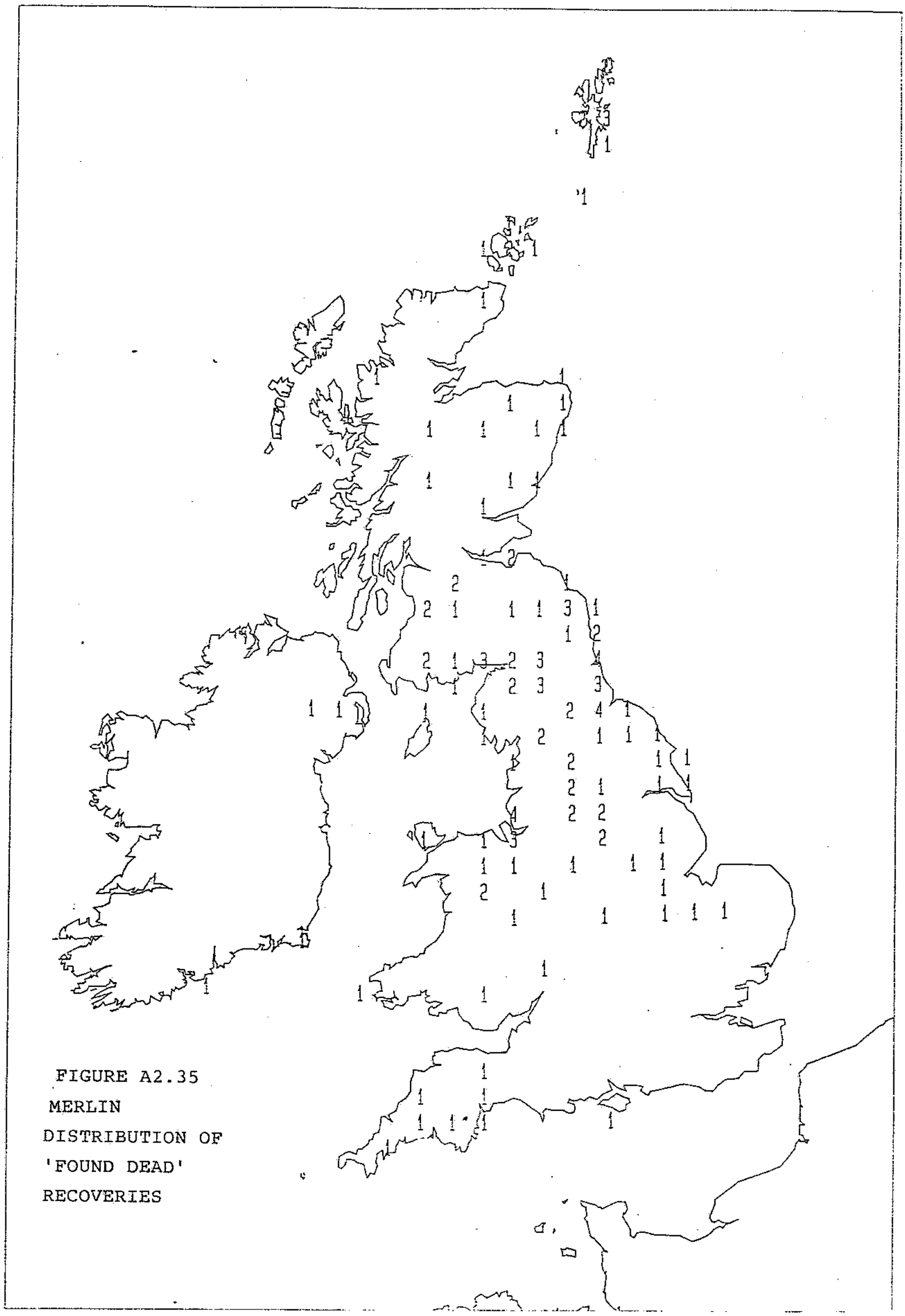

FIGURE A2.35
MERLIN
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

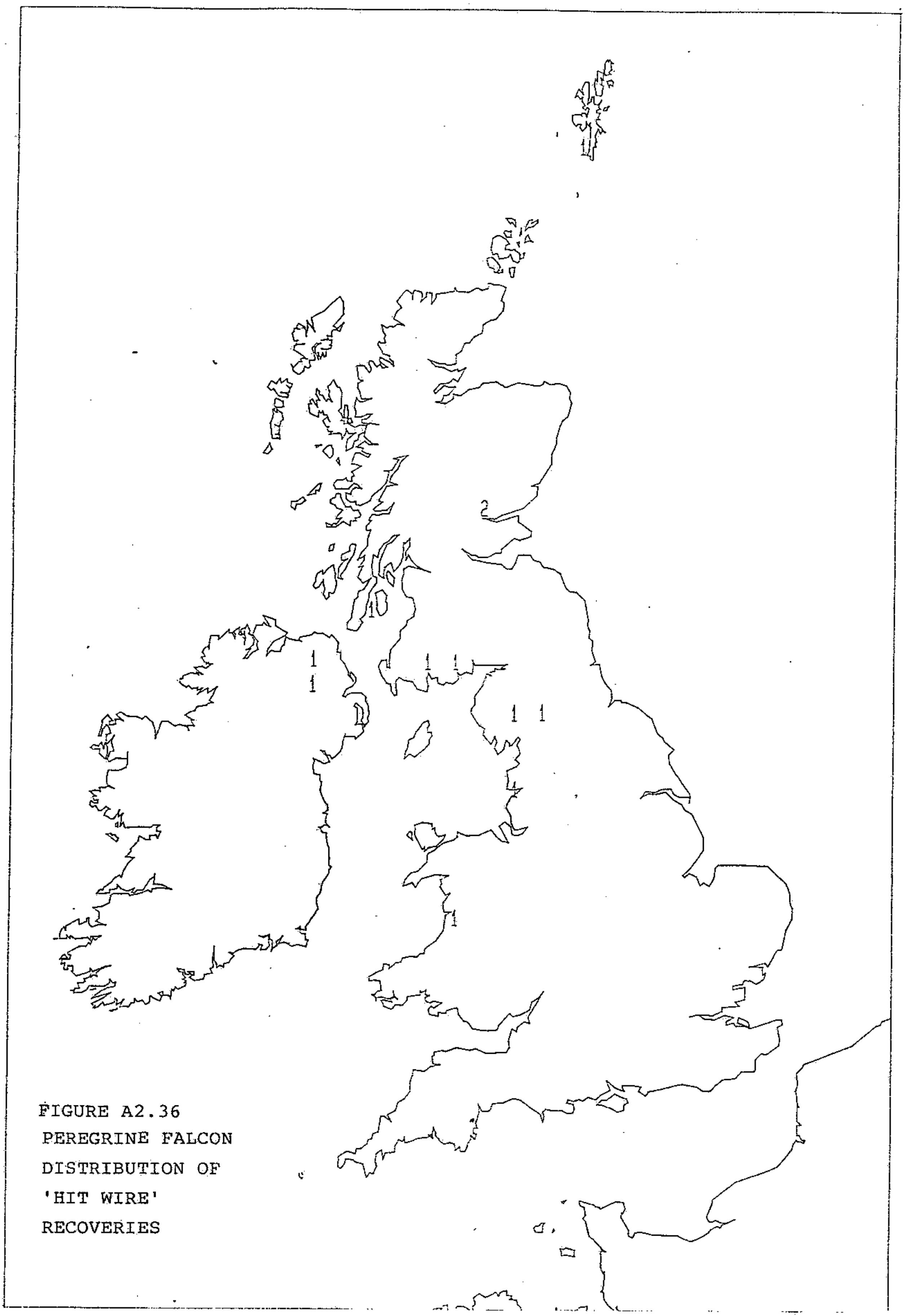


FIGURE A2.36
PEREGRINE FALCON
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

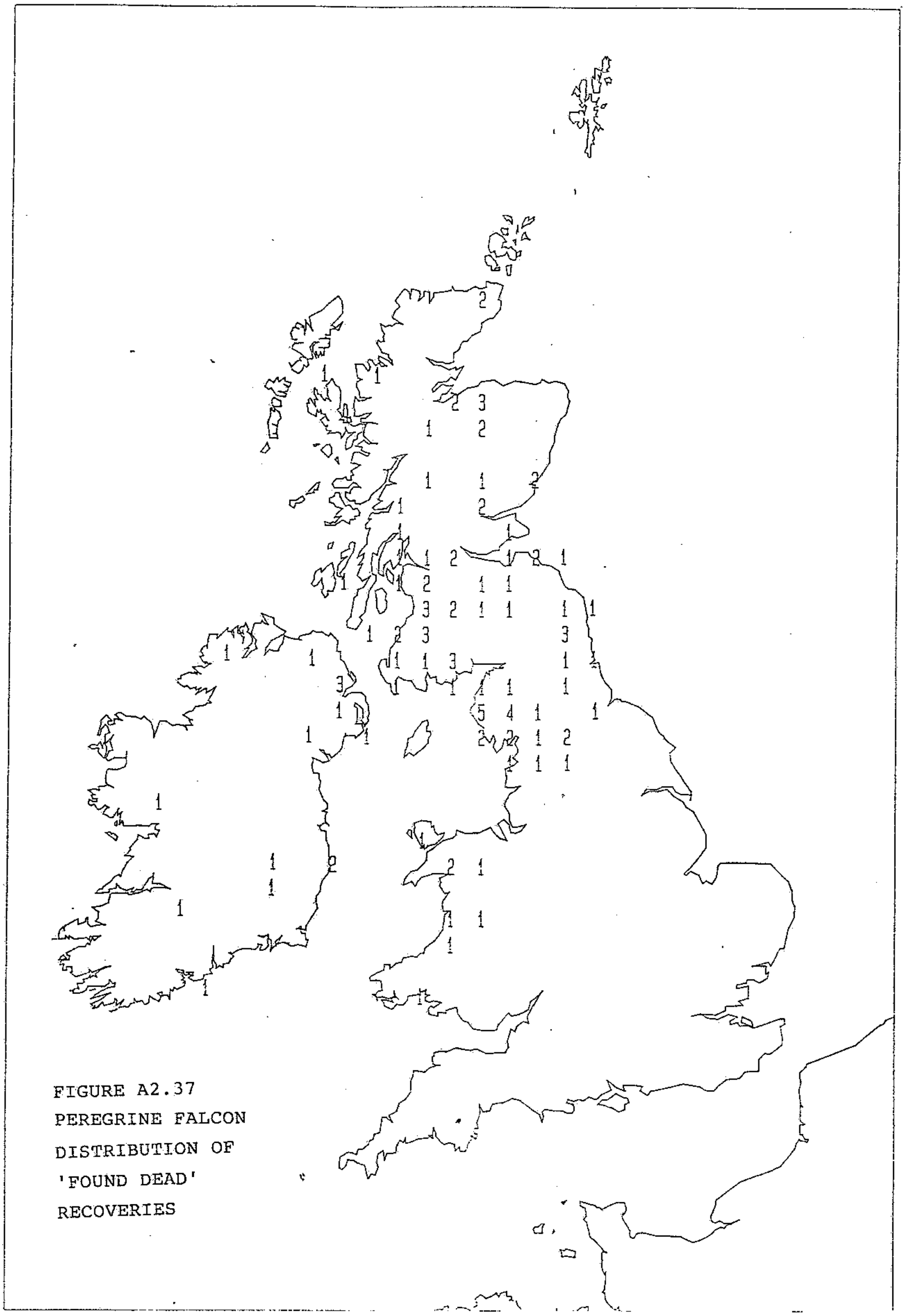

FIGURE A2.37
PEREGRINE FALCON
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

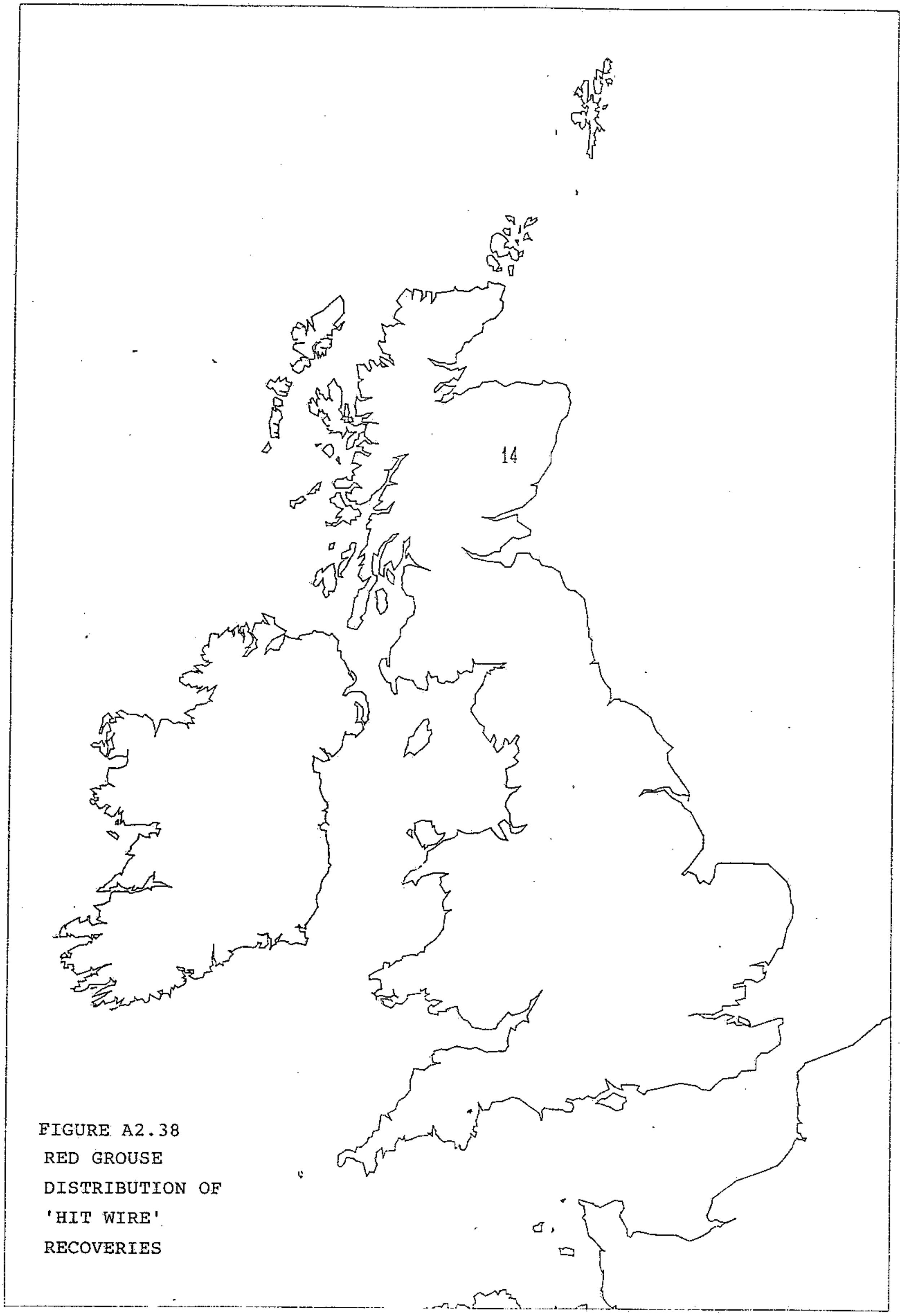


FIGURE A2.38
RED GROUSE
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

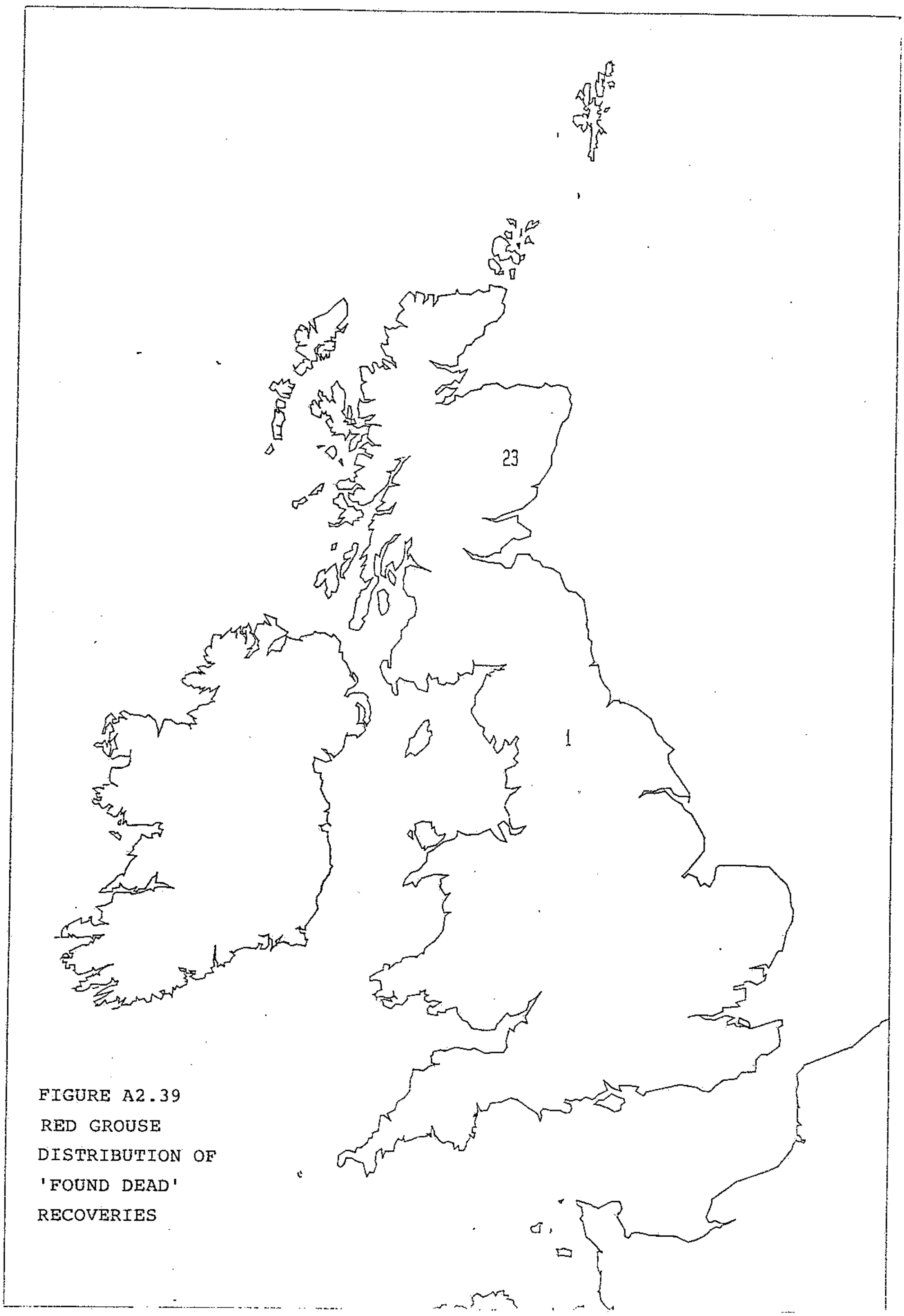


FIGURE A2.39
RED GROUSE
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

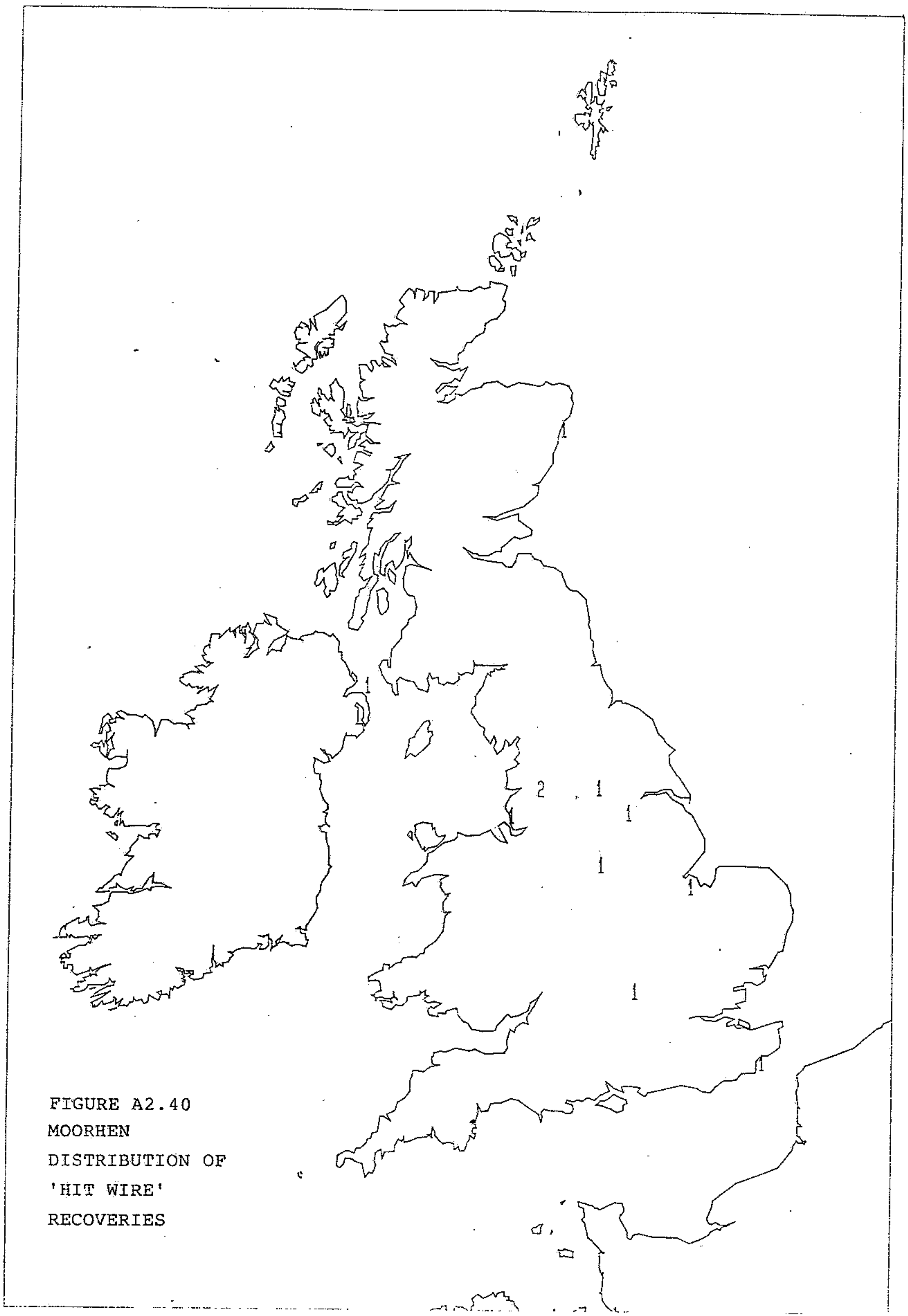


FIGURE A2.40
MOORHEN
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

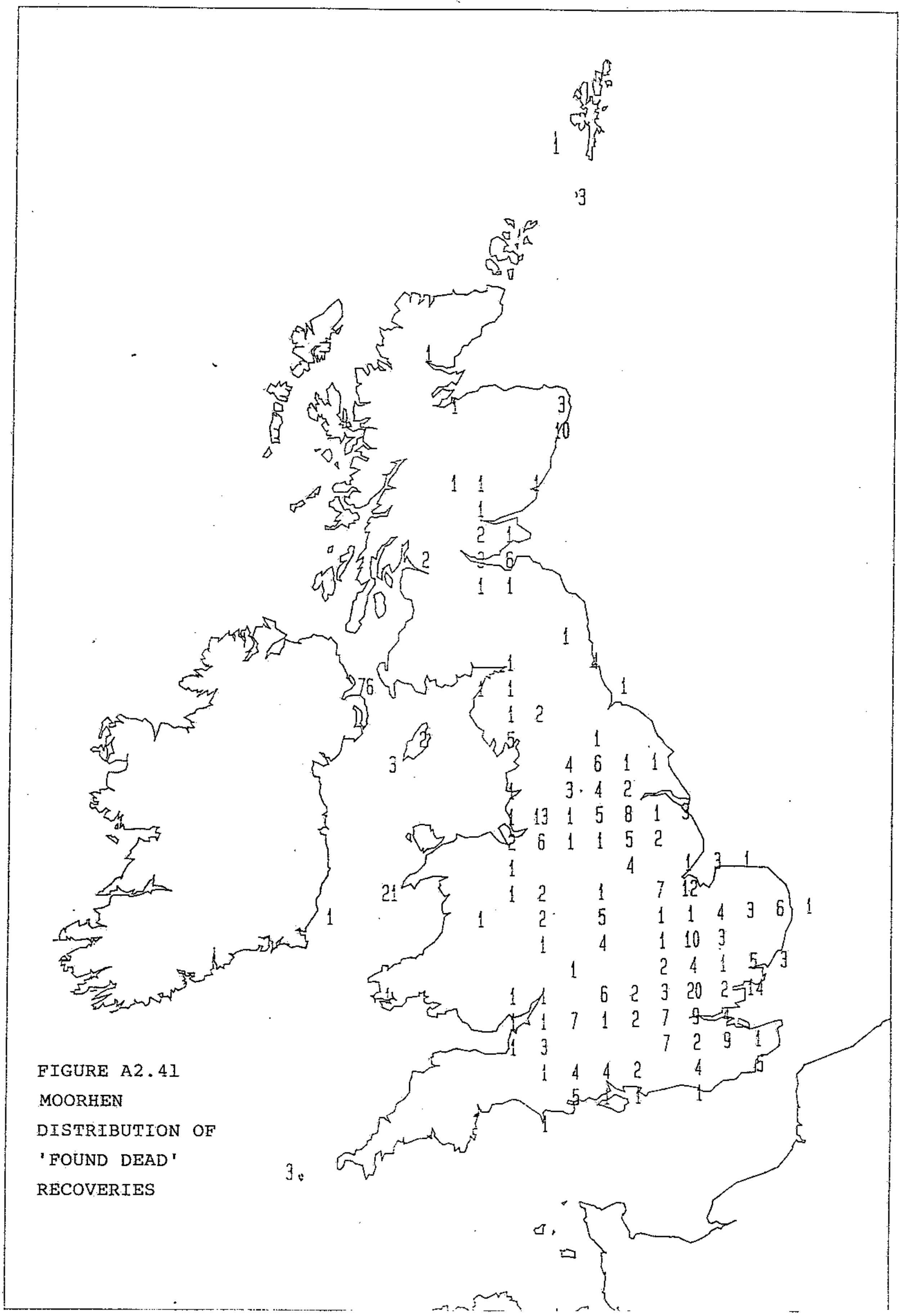

FIGURE A2.41
MOORHEN
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

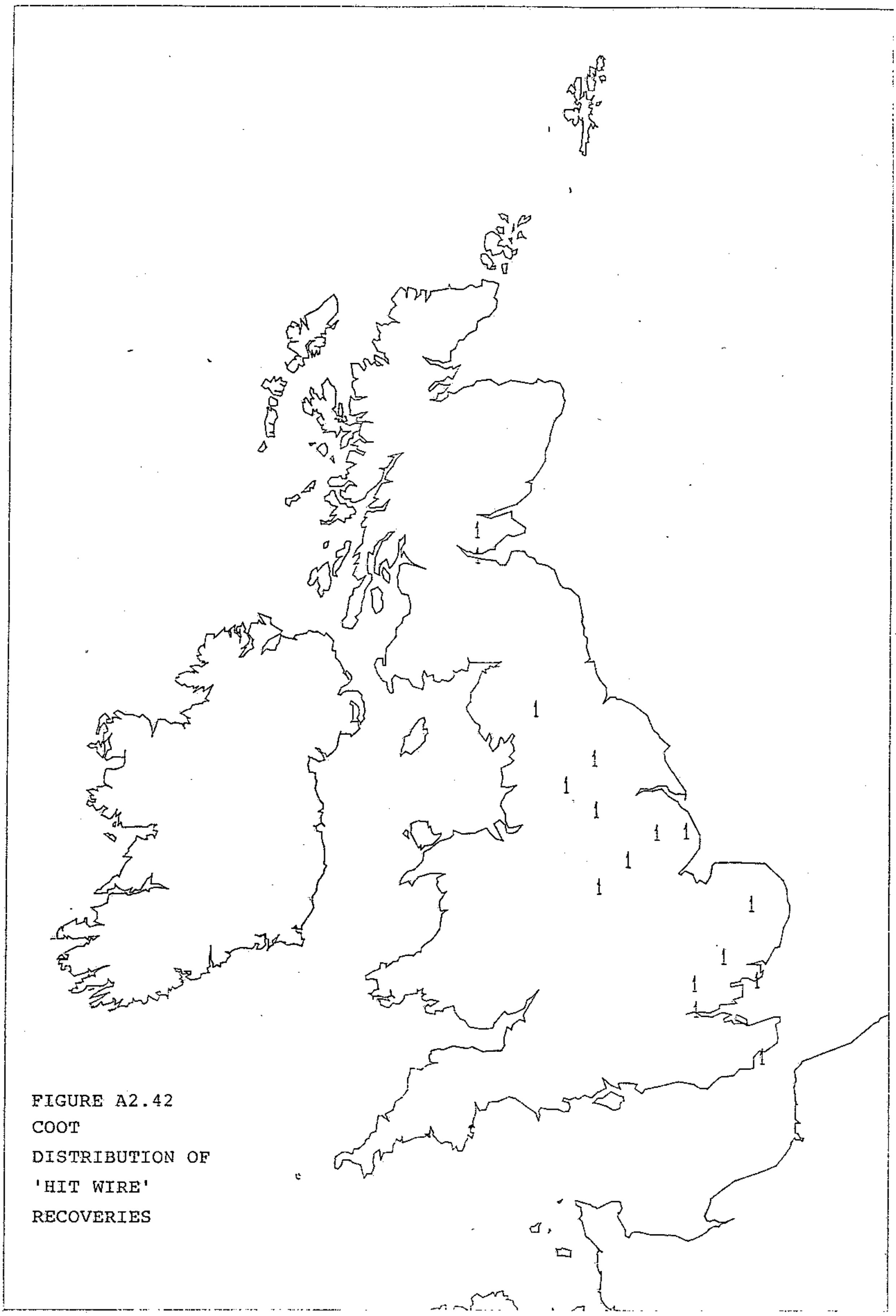


FIGURE A2.42
COOT
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

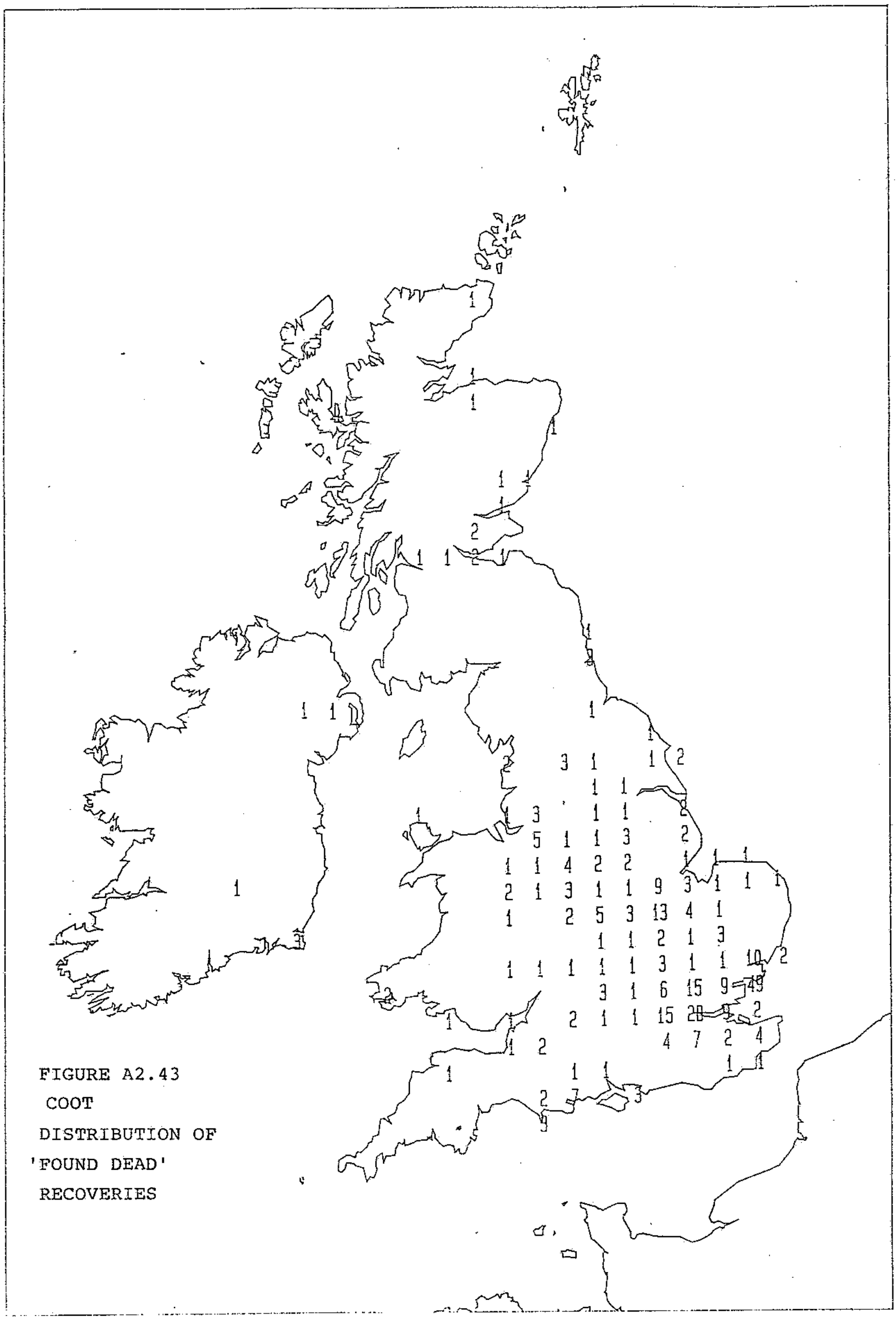

FIGURE A2.43
COOT
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

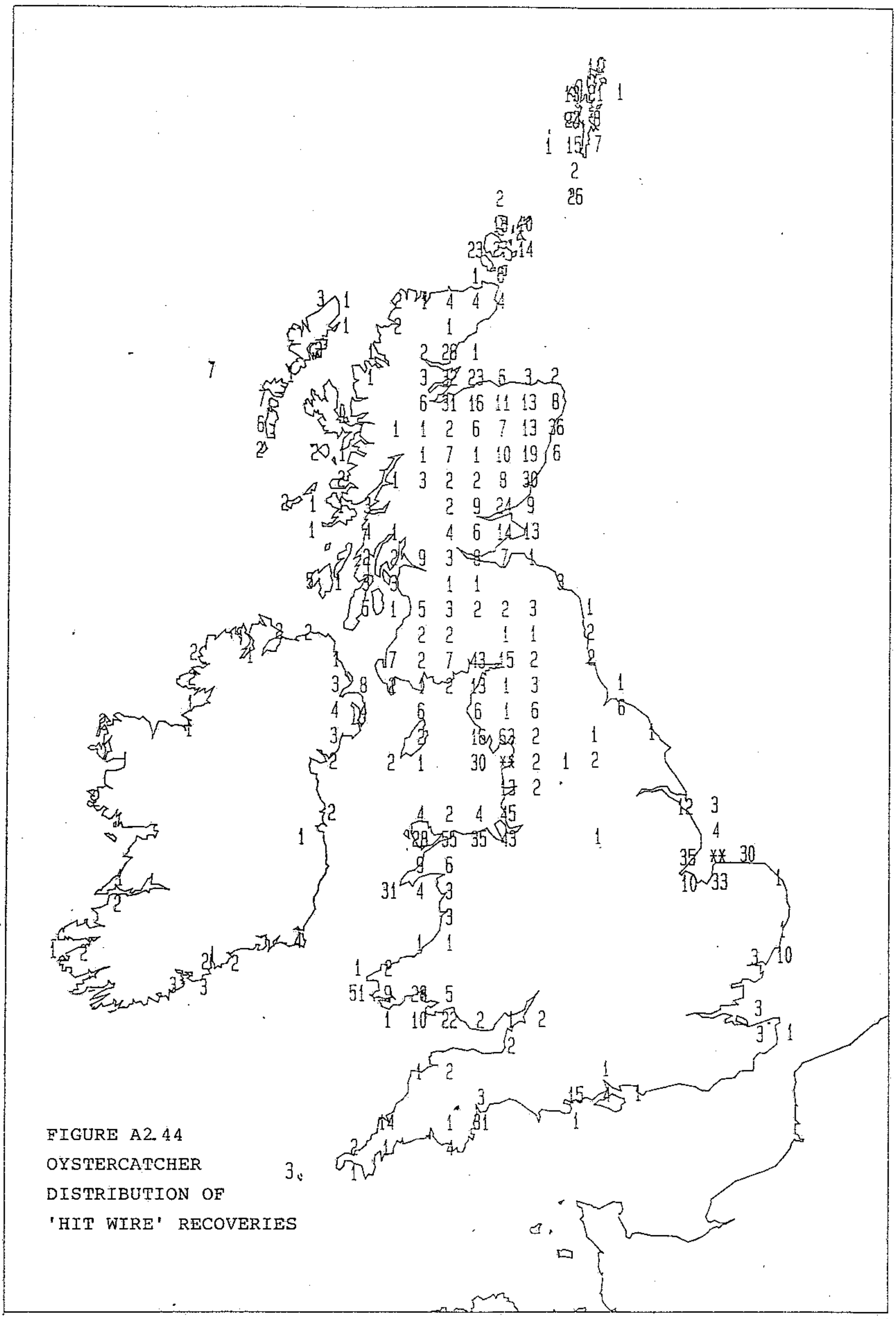

FIGURE A2.44
OYSTERCATCHER
DISTRIBUTION OF
'HIT WIRE' RECOVERIES

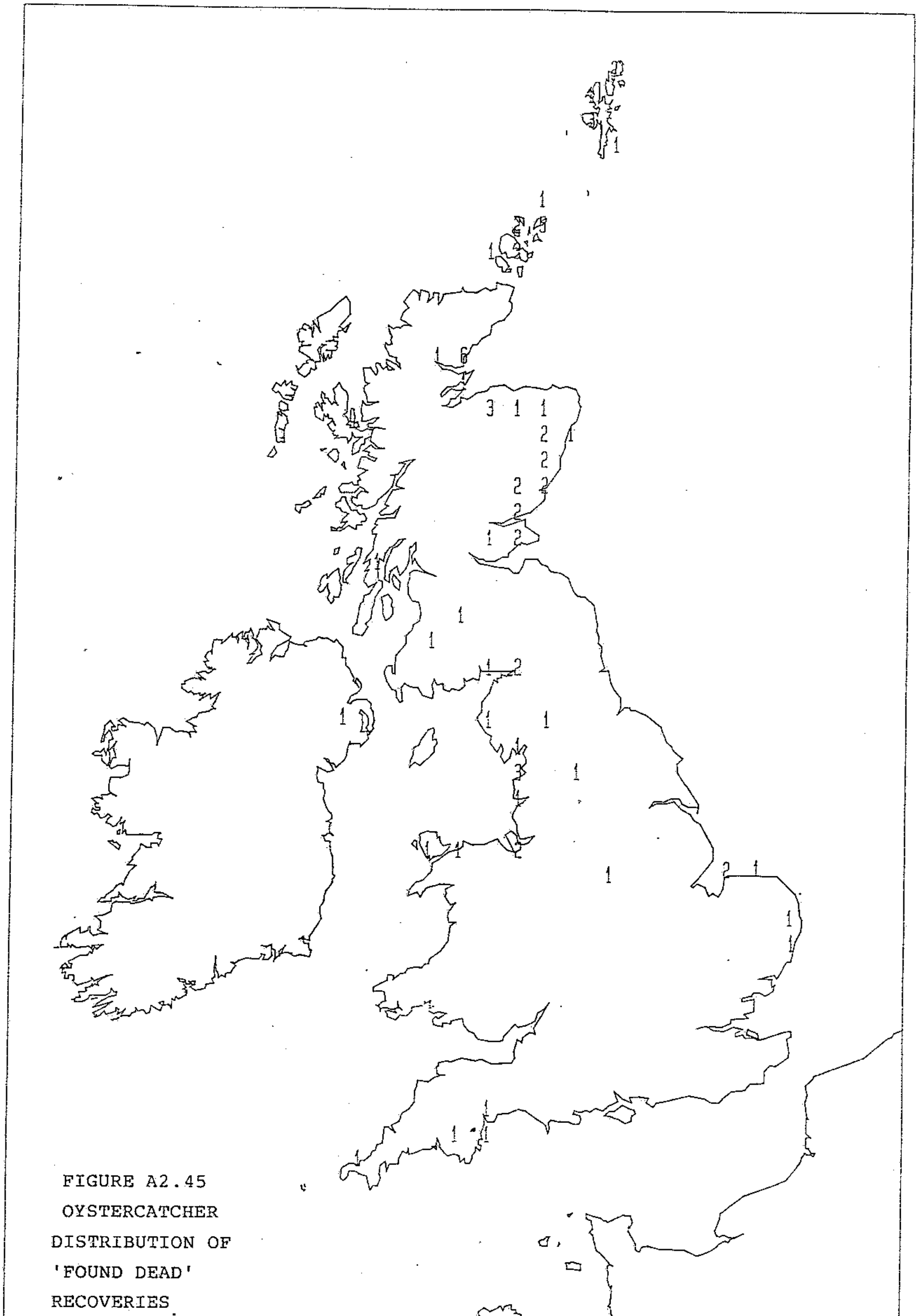

FIGURE A2.45
OYSTERCATCHER
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

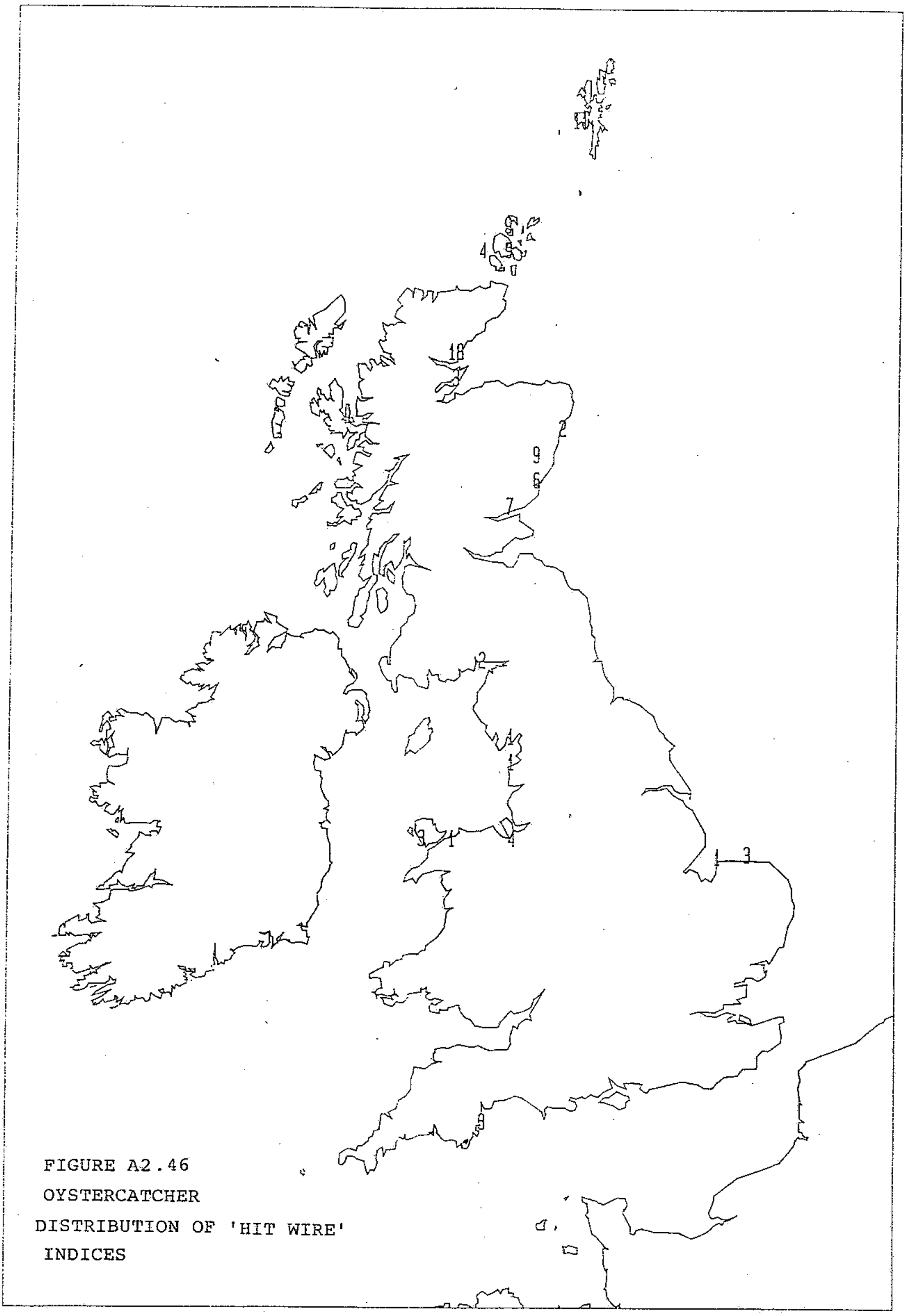


FIGURE A2.46
OYSTERCATCHER
DISTRIBUTION OF 'HIT WIRE'
INDICES

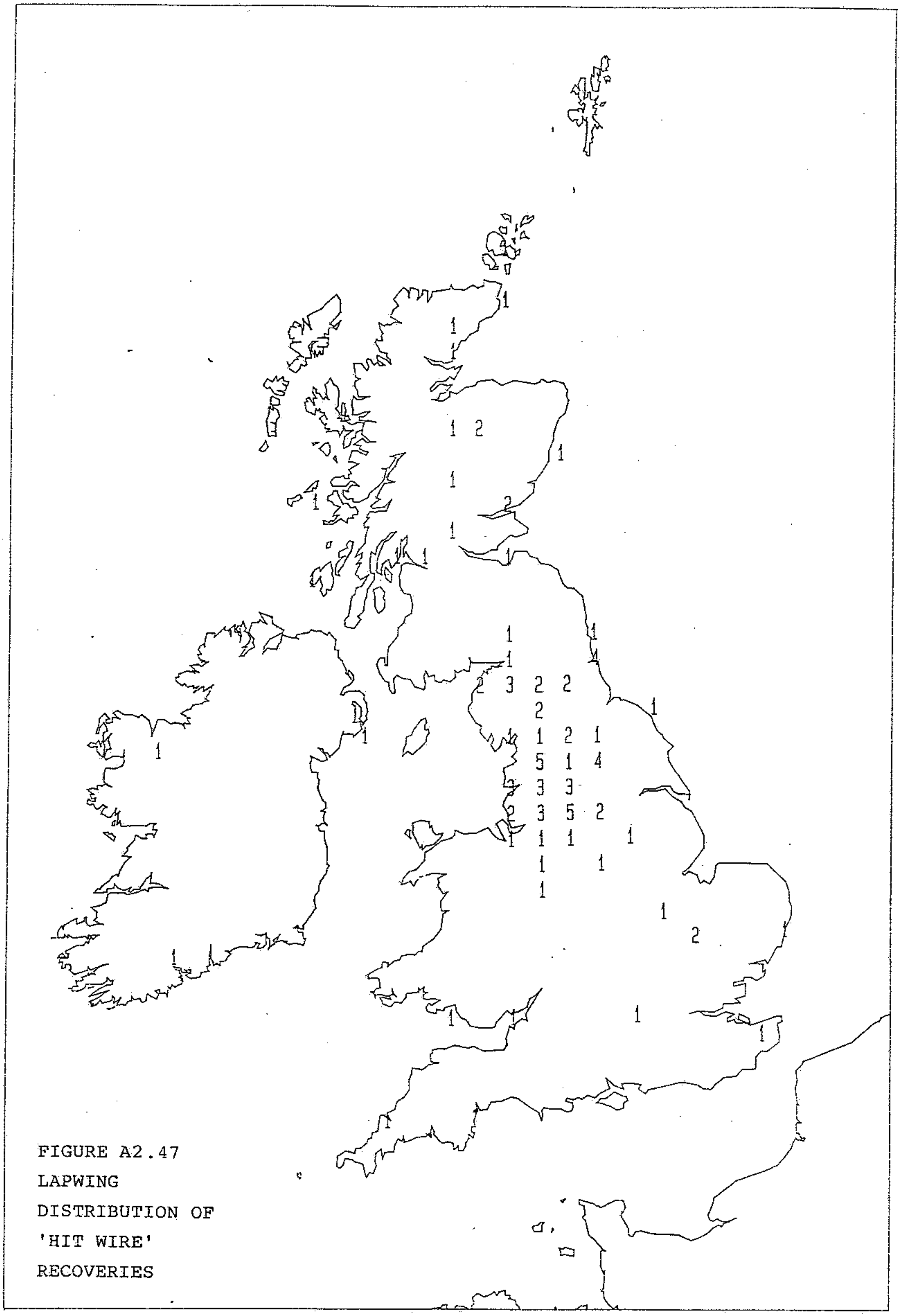

FIGURE A2.47
LAPWING
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

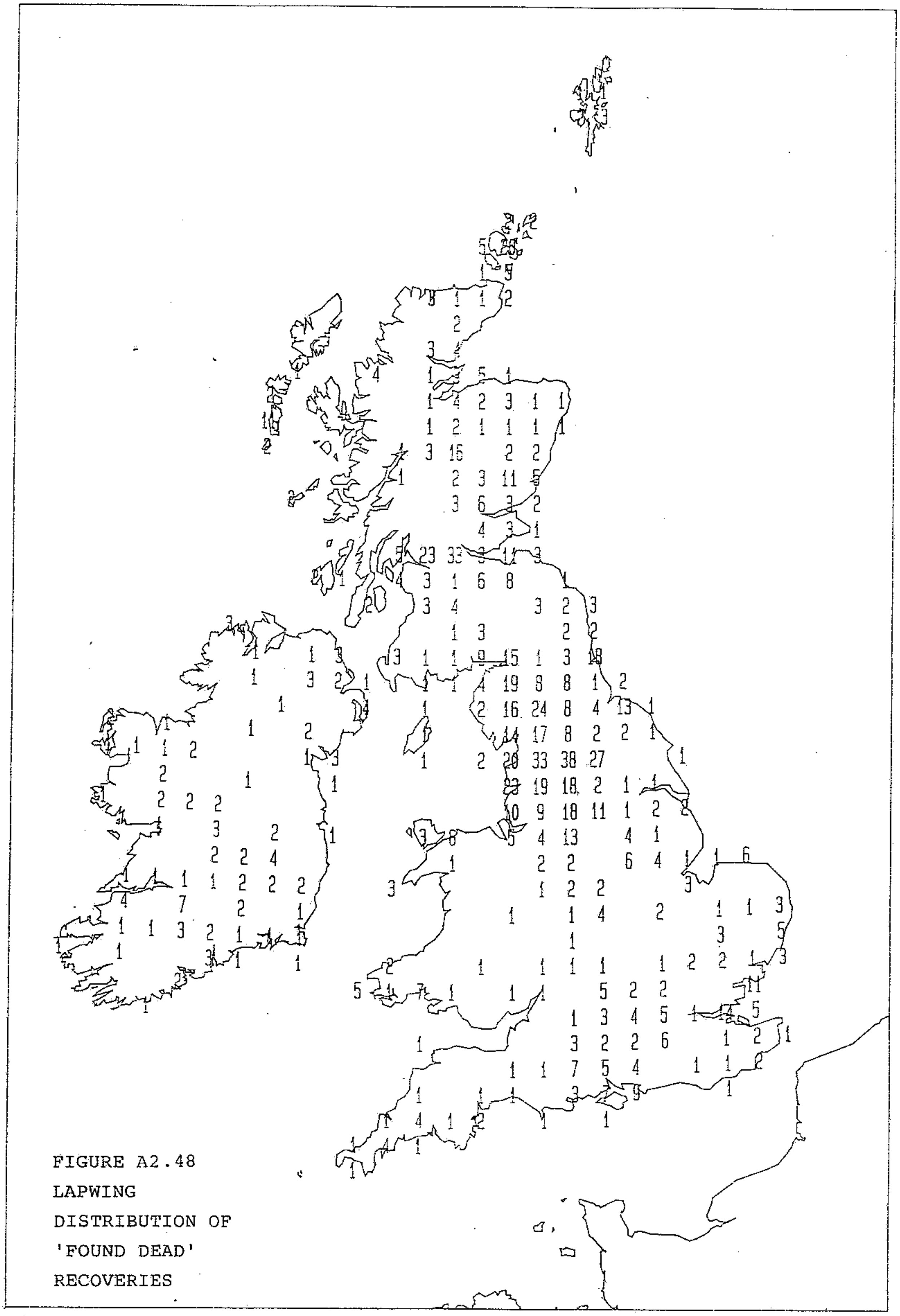

FIGURE A2.48
LAPWING
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

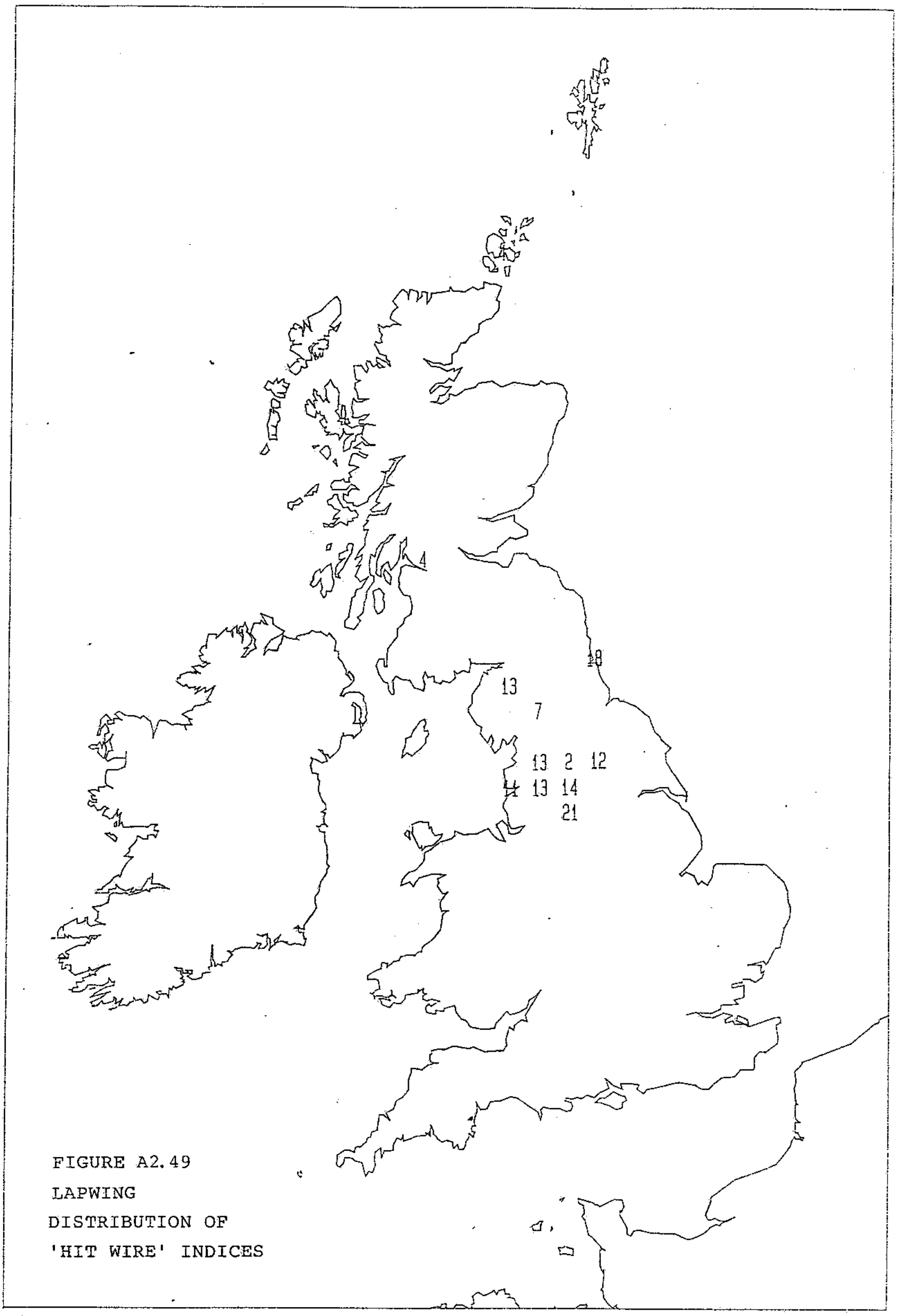


FIGURE A2.49
LAPWING
DISTRIBUTION OF
'HIT WIRE' INDICES

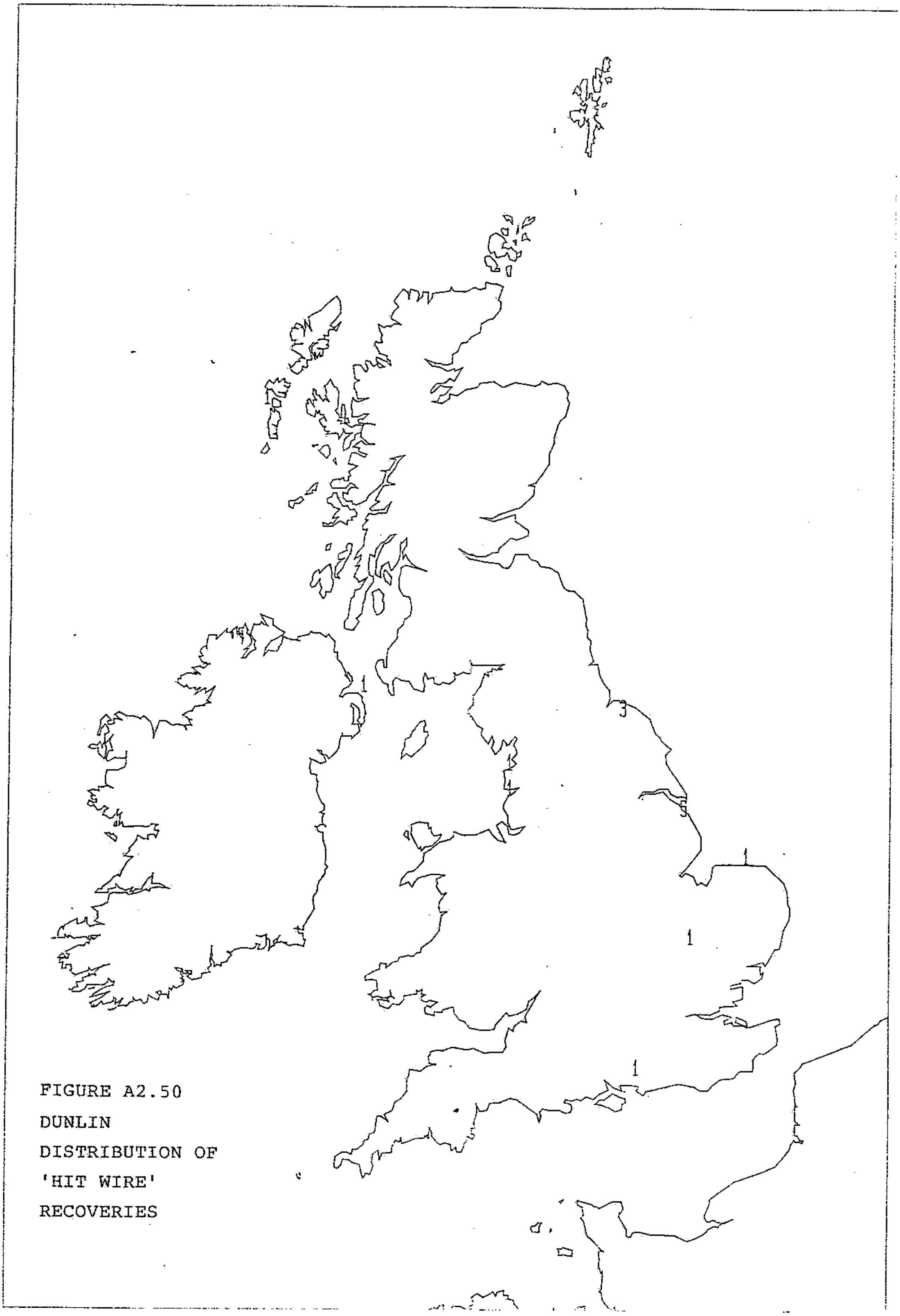


FIGURE A2.50
DUNLIN
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

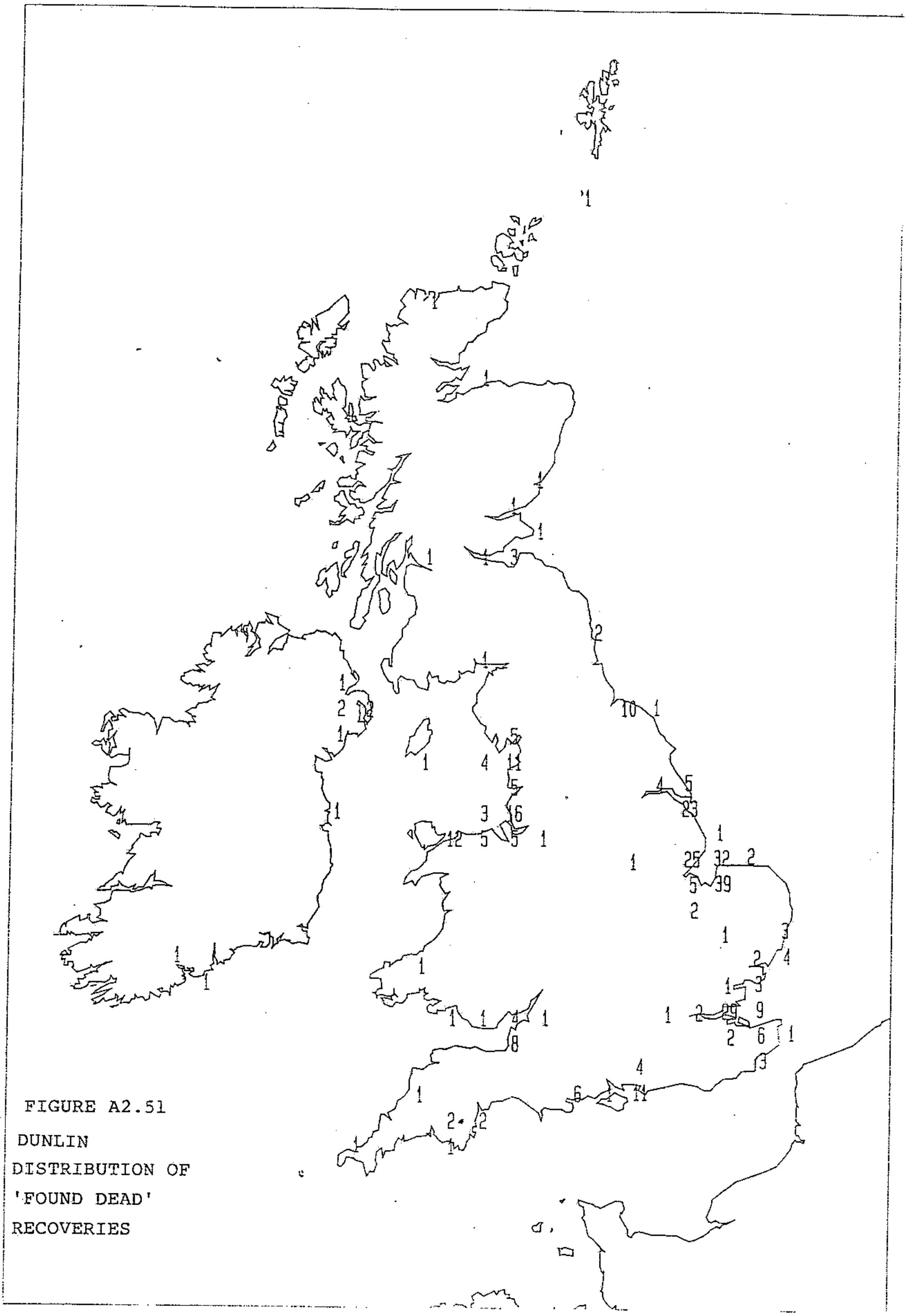

FIGURE A2.51

DUNLIN
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

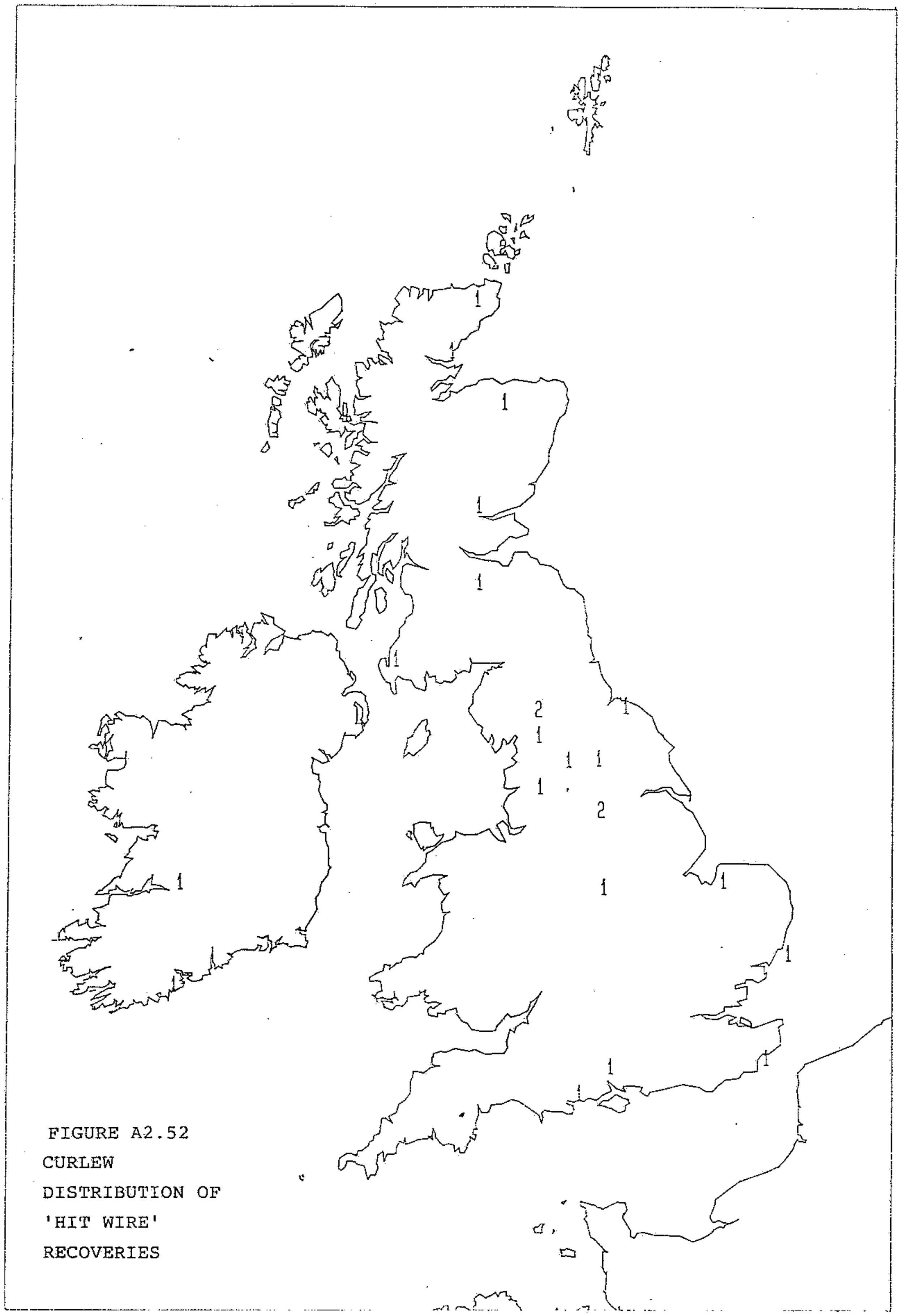


FIGURE A2.52
CURLEW
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

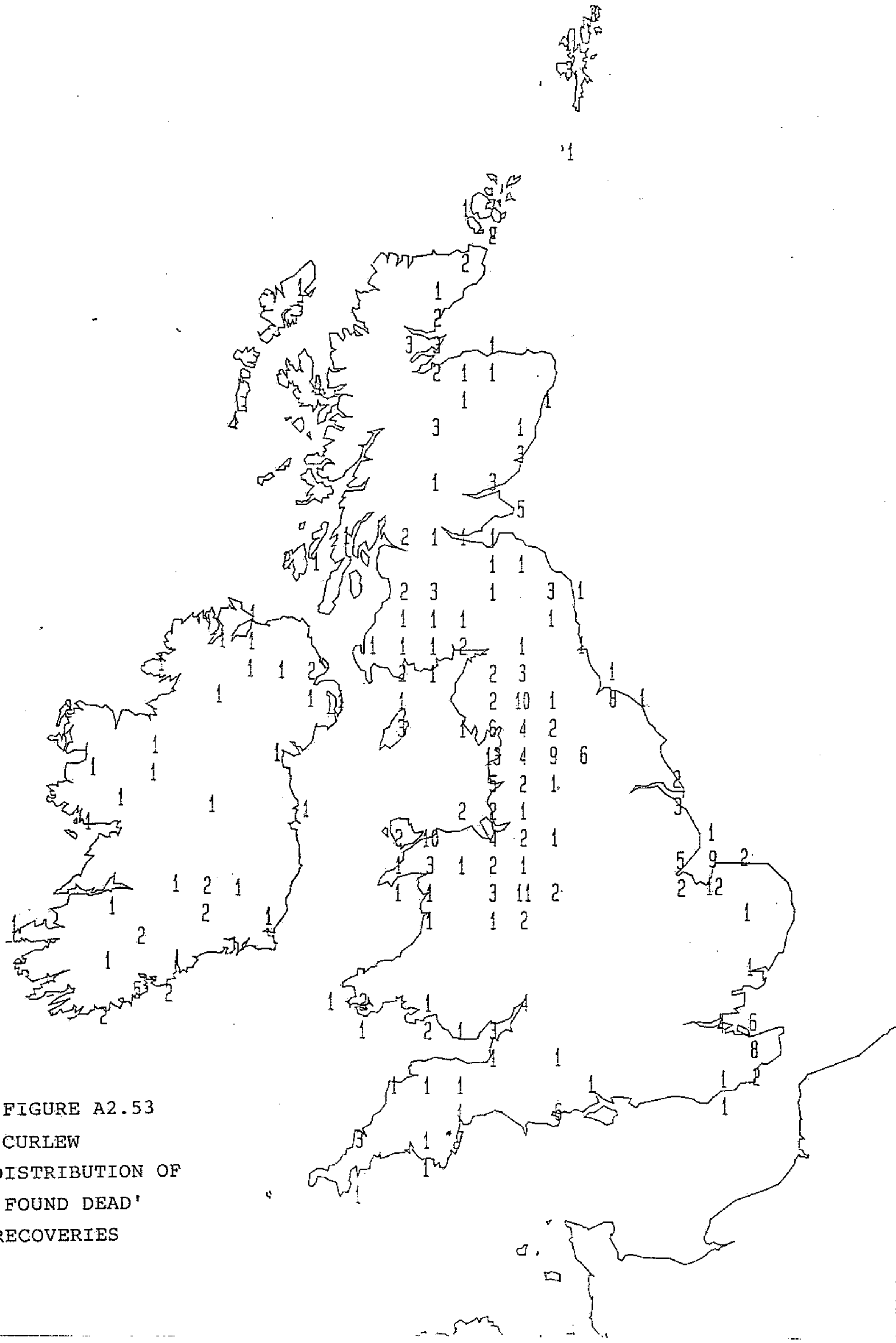

FIGURE A2.53
CURLEW
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

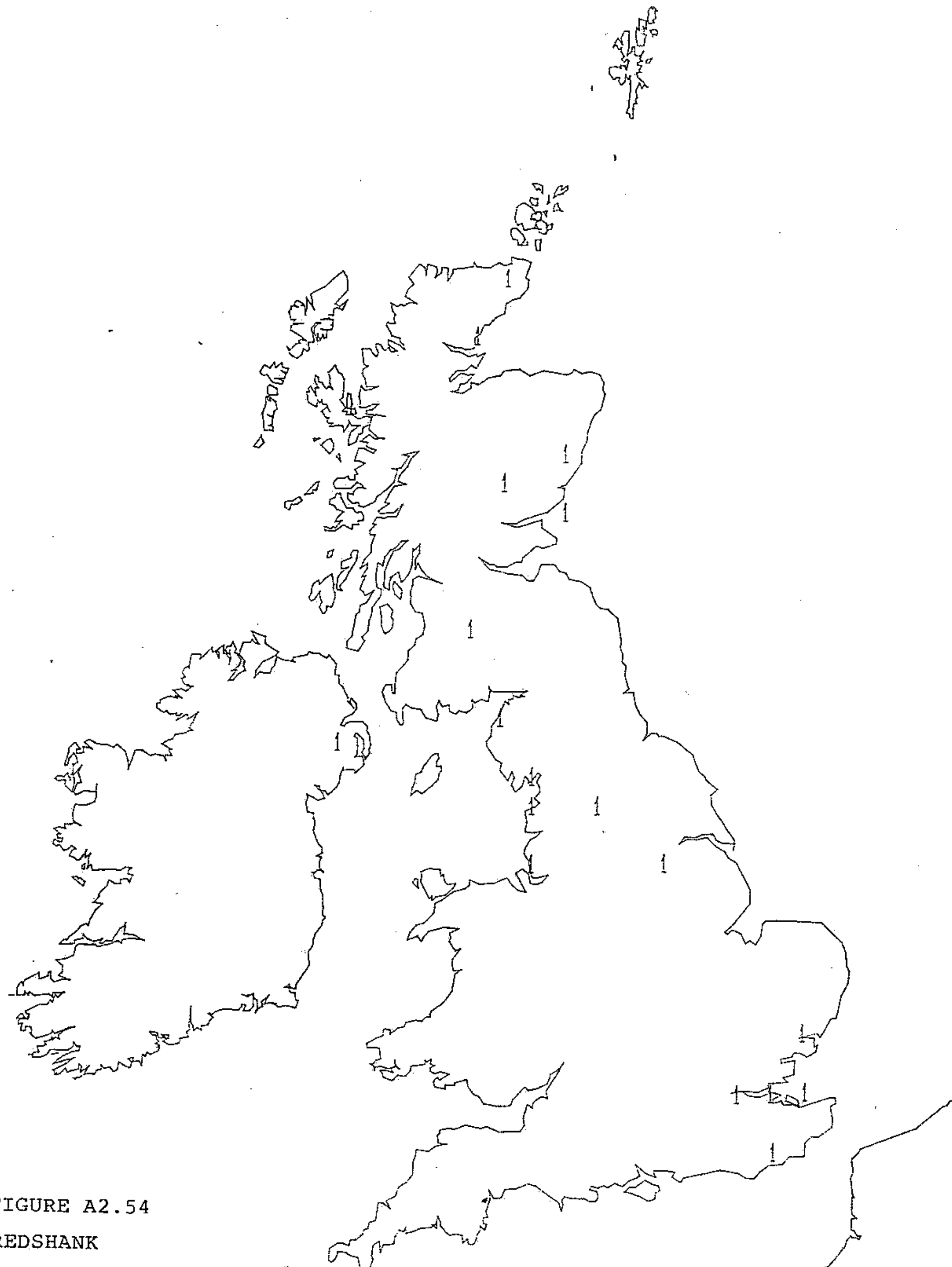

FIGURE A2.54
REDSHANK
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

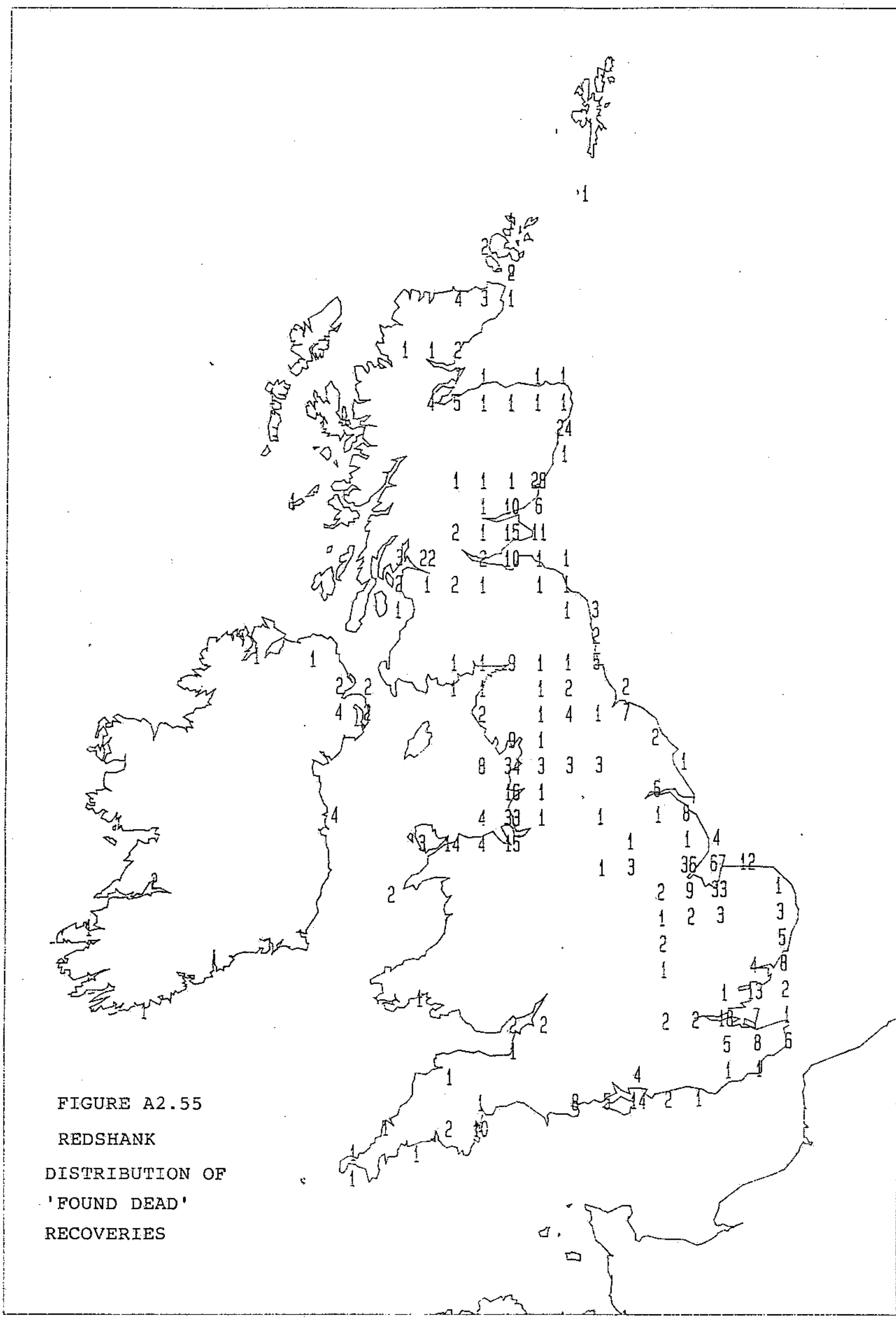

FIGURE A2.55
REDSHANK
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

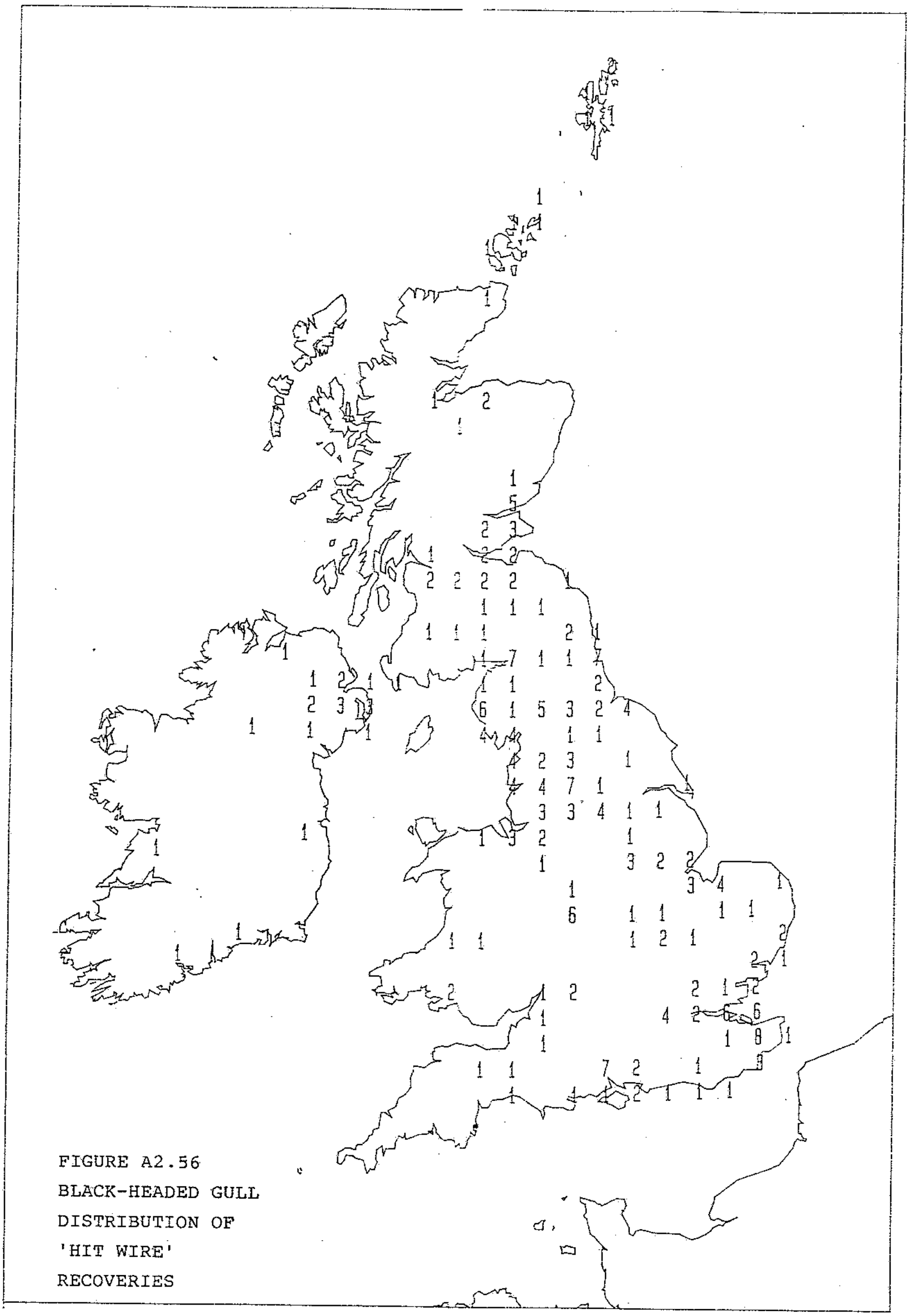

FIGURE A2.56
BLACK-HEADED GULL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

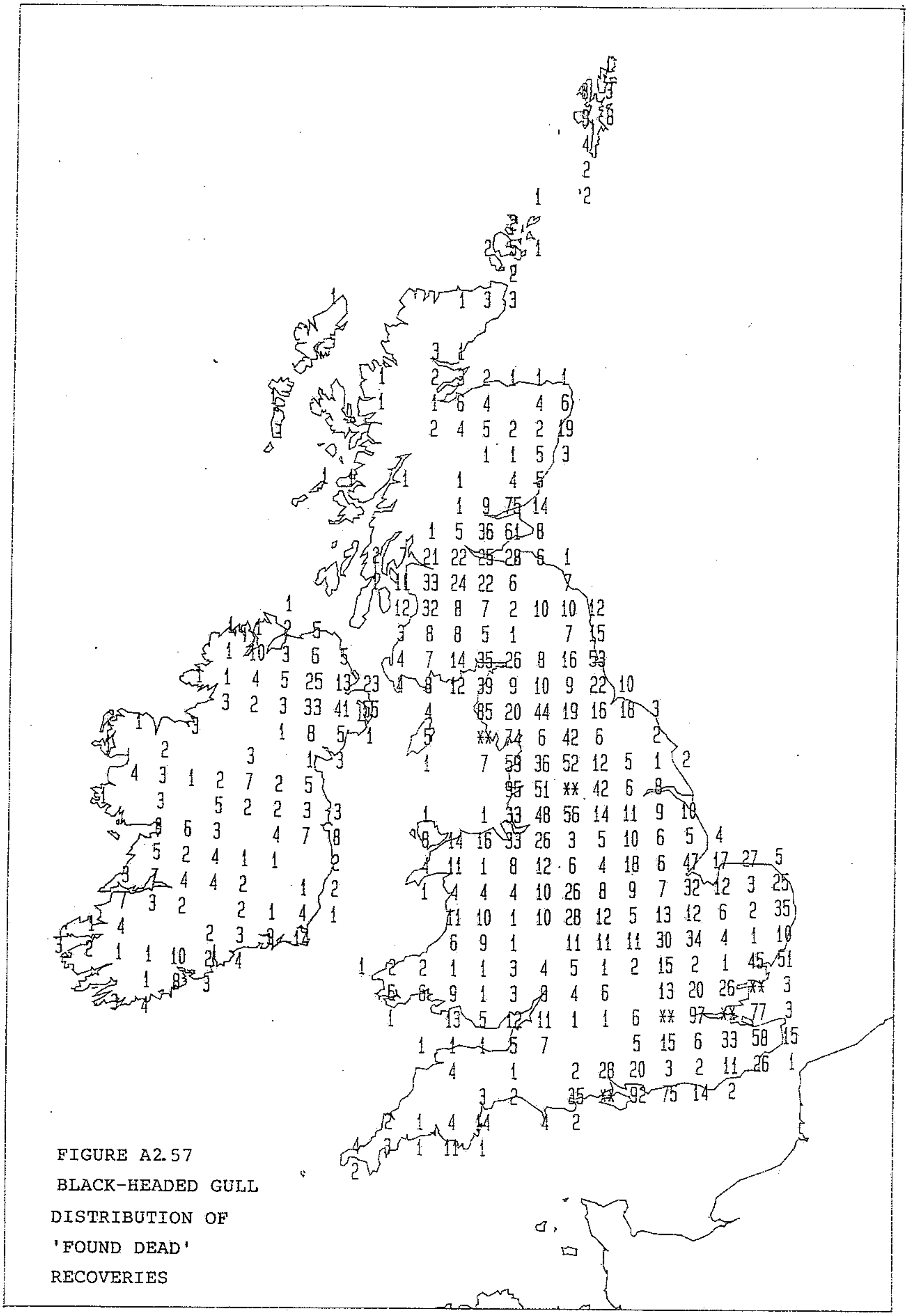

FIGURE A2.57
BLACK-HEADED GULL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

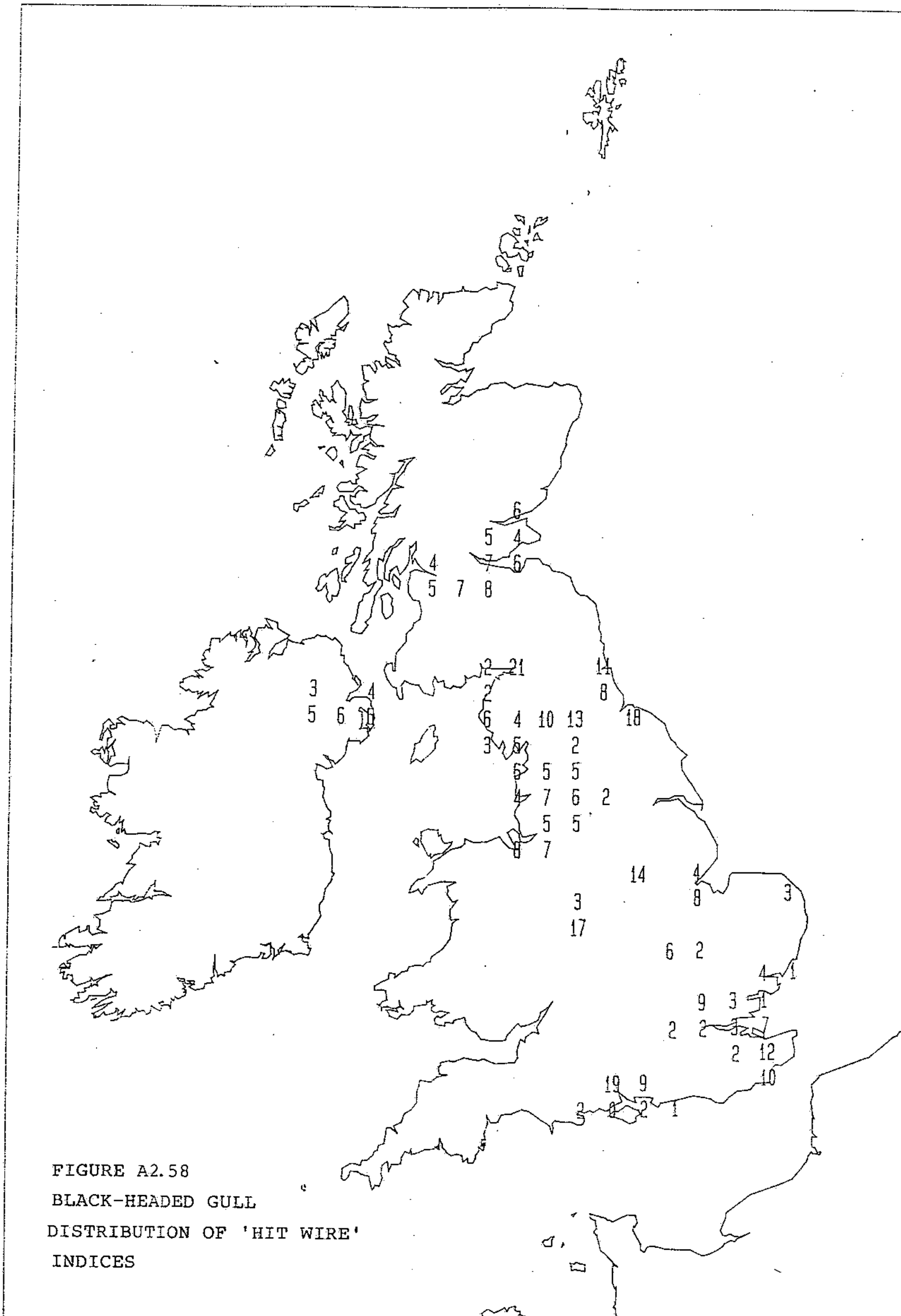


FIGURE A2.58
BLACK-HEADED GULL
DISTRIBUTION OF 'HIT WIRE'
INDICES

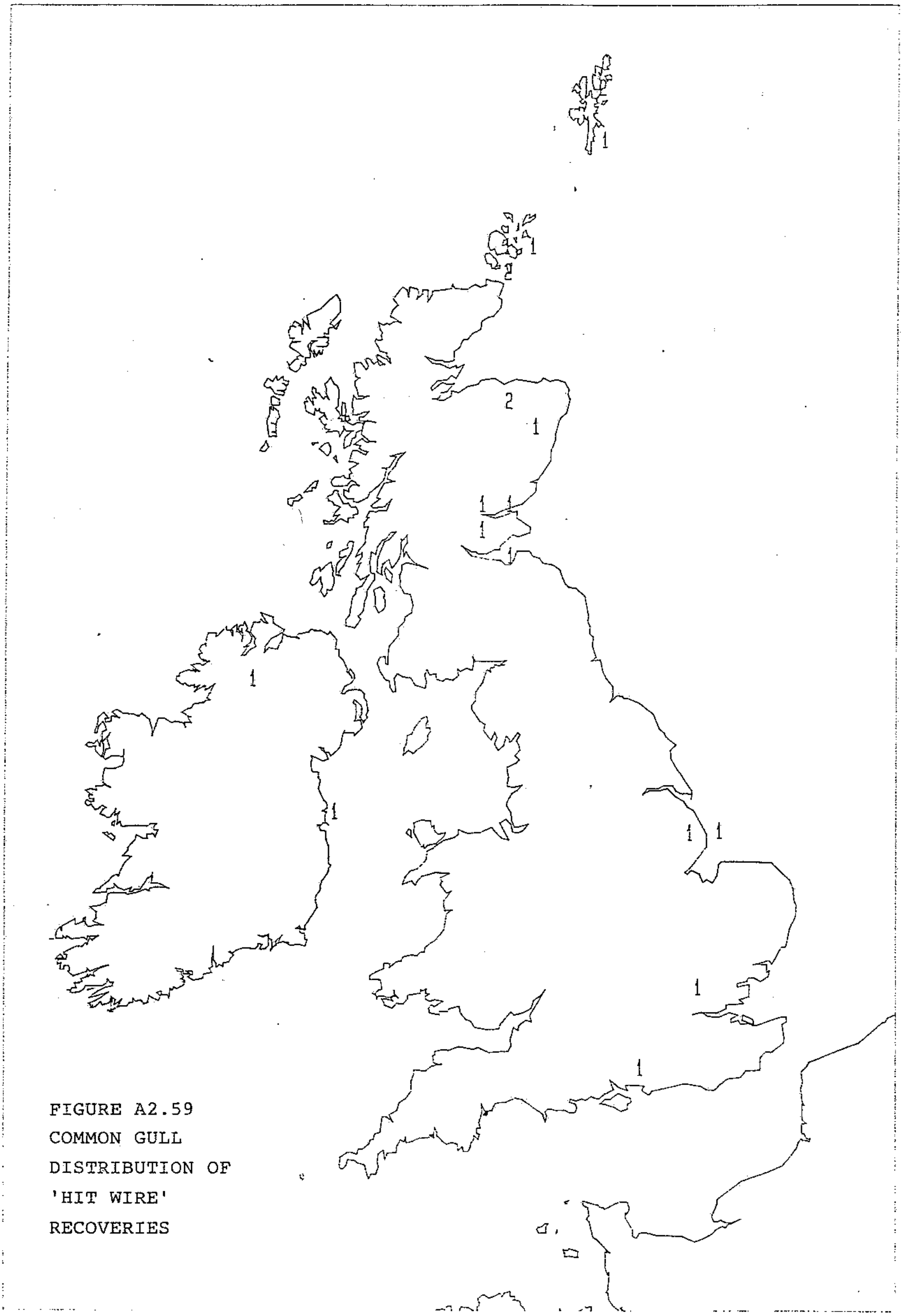

FIGURE A2.59
COMMON GULL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

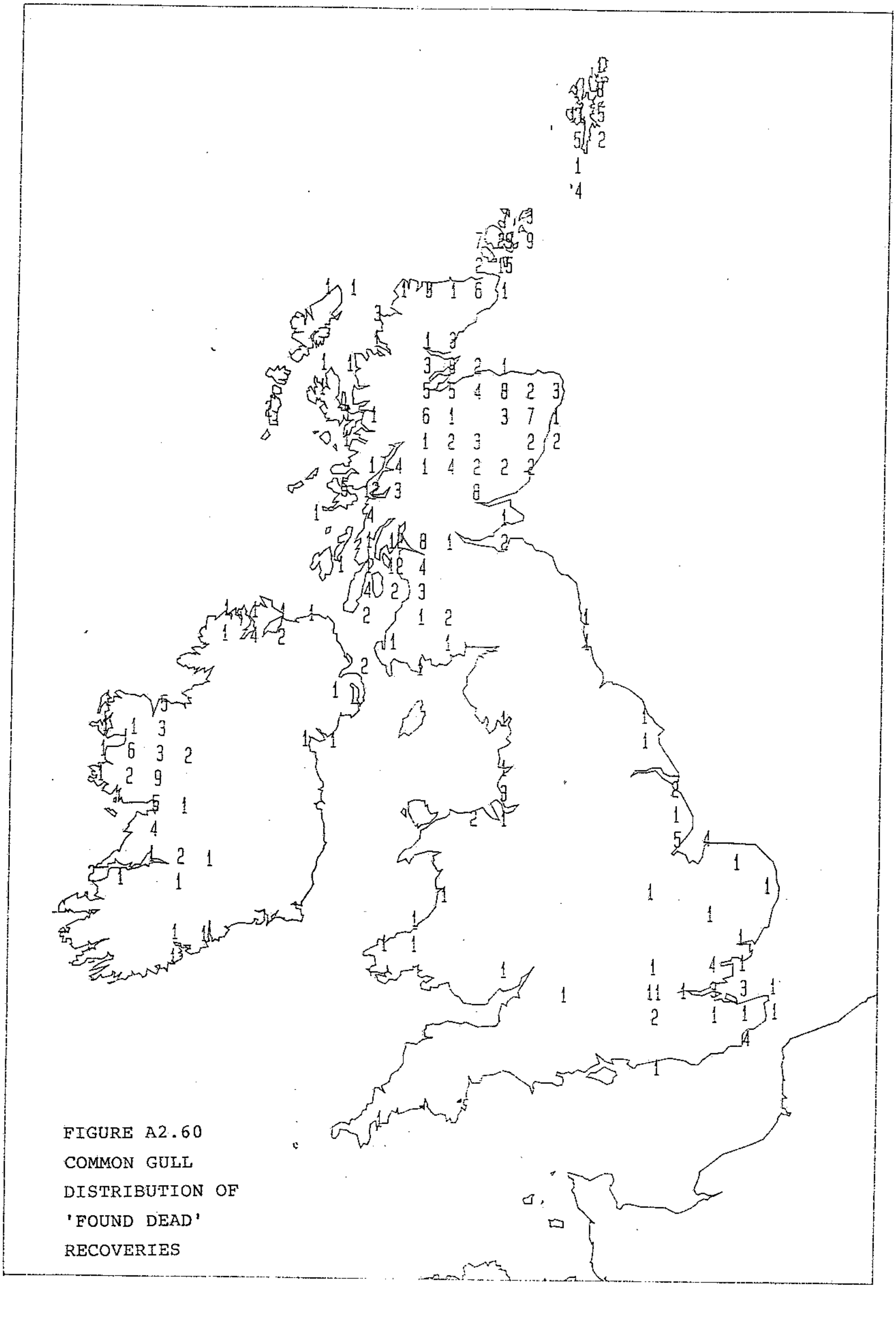

FIGURE A2.60
COMMON GULL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

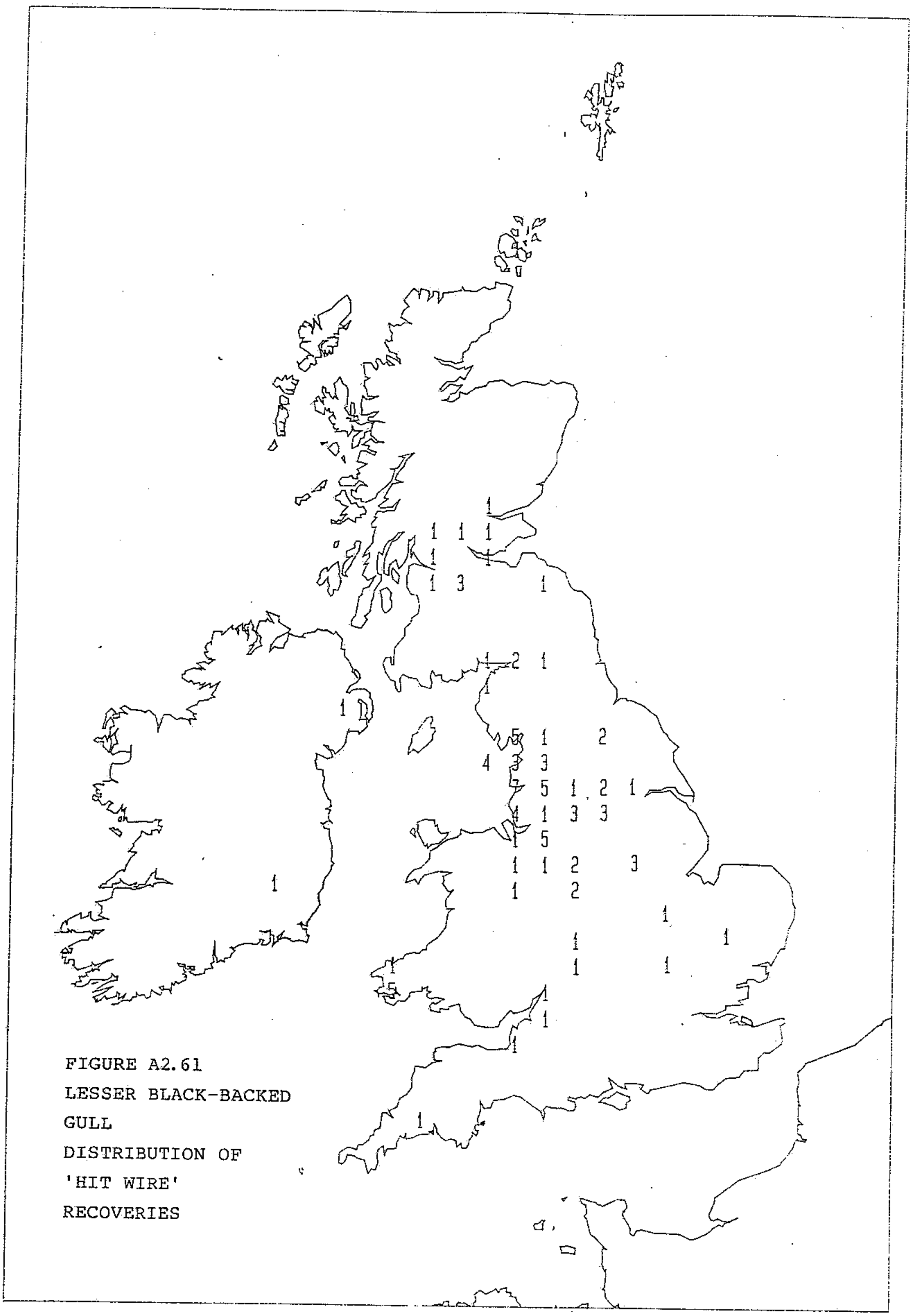

FIGURE A2.61
LESSER BLACK-BACKED
GULL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

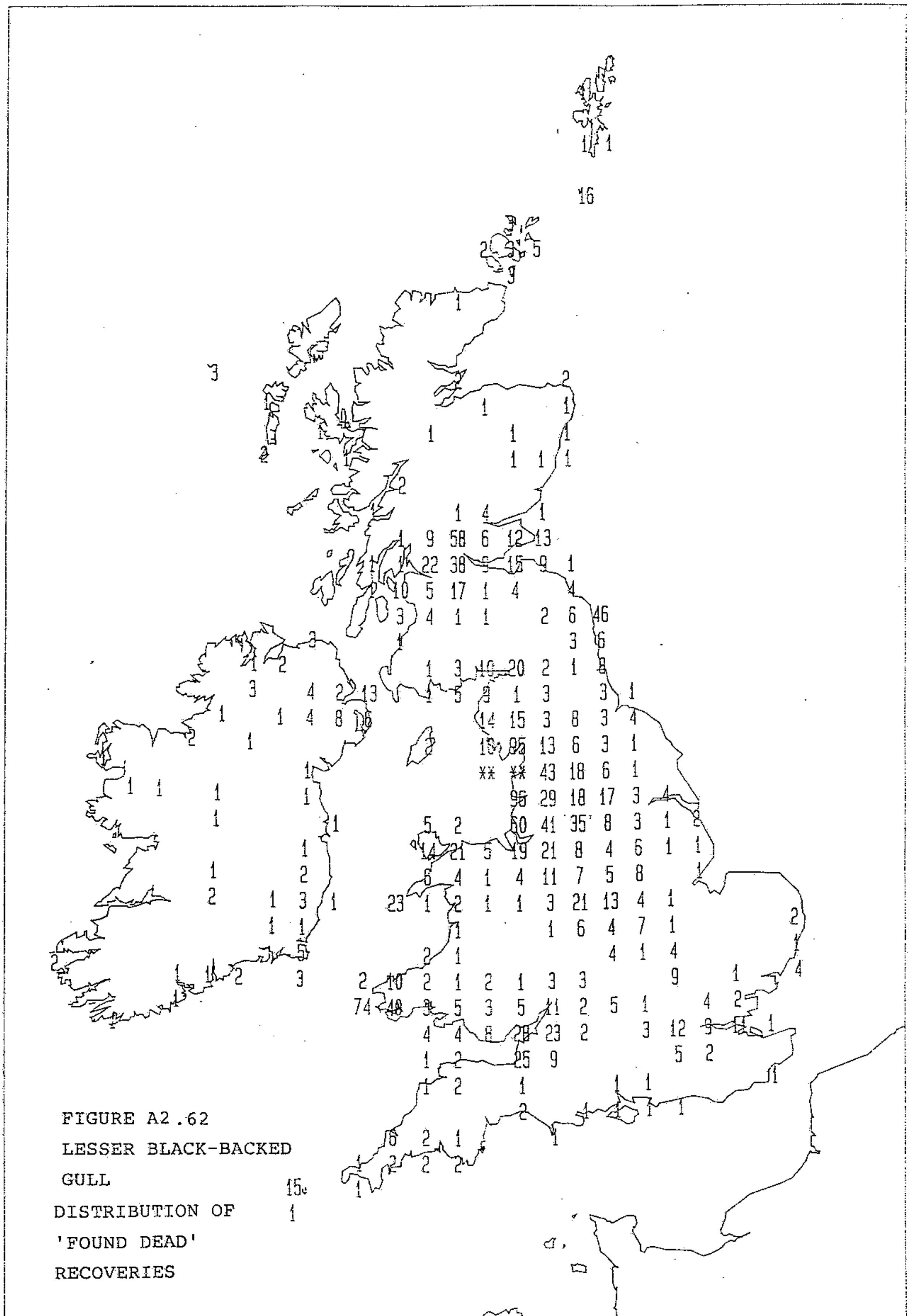

FIGURE A2.62
LESSER BLACK-BACKED GULL
DISTRIBUTION OF 'FOUND DEAD' RECOVERIES

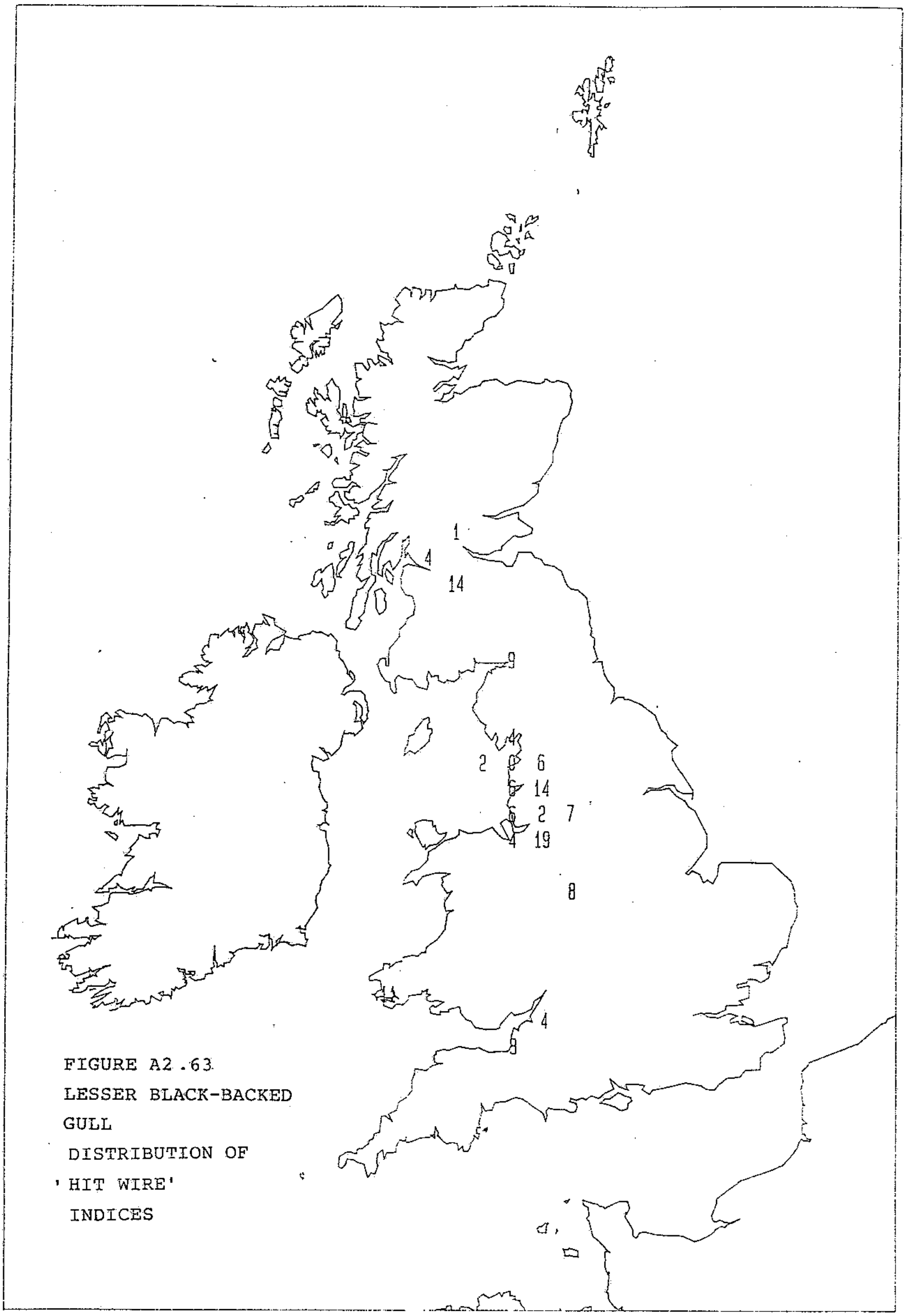


FIGURE A2.63
LESSER BLACK-BACKED GULL
DISTRIBUTION OF 'HIT WIRE' INDICES

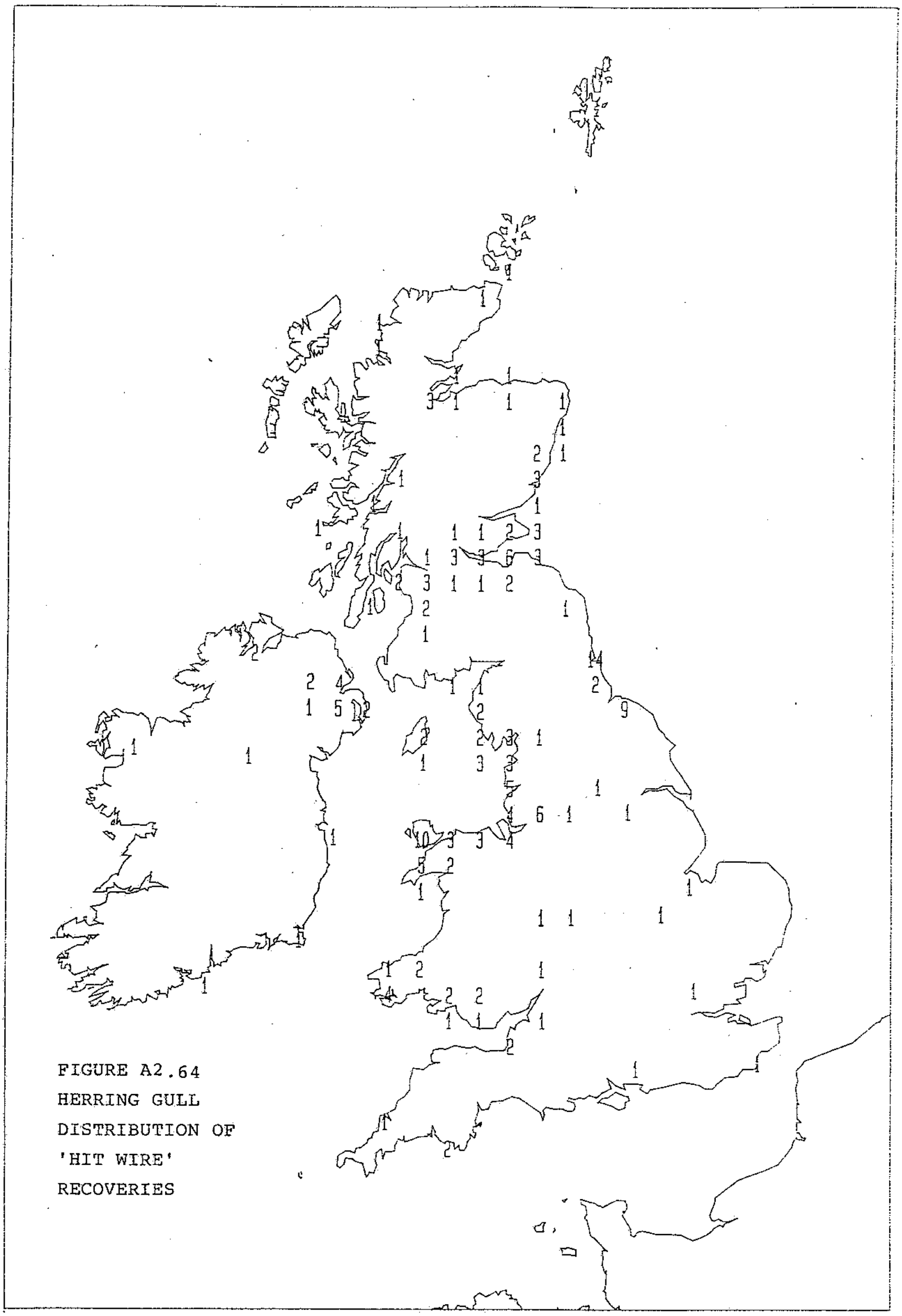

FIGURE A2.64
HERRING GULL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

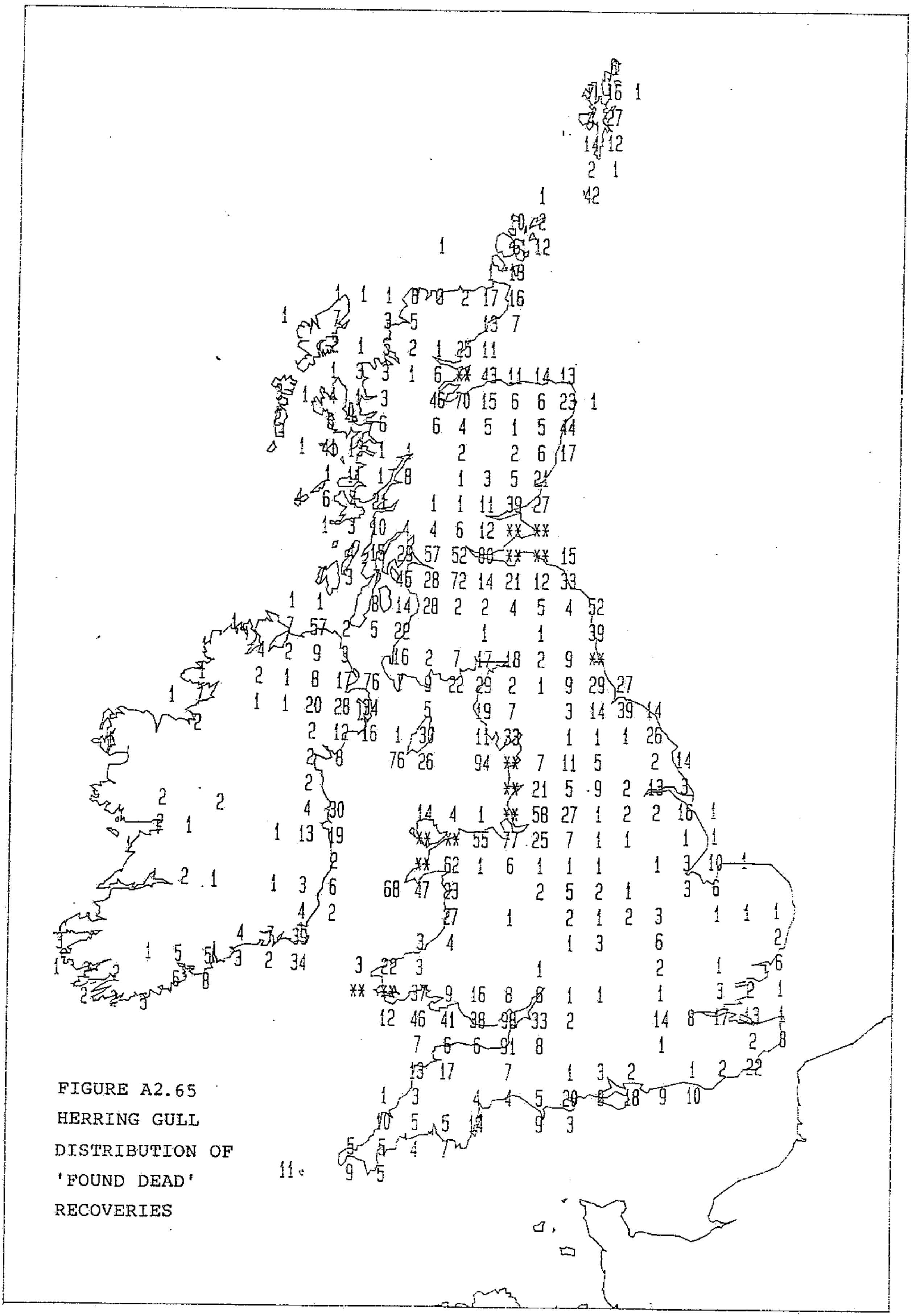

FIGURE A2.65
HERRING GULL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

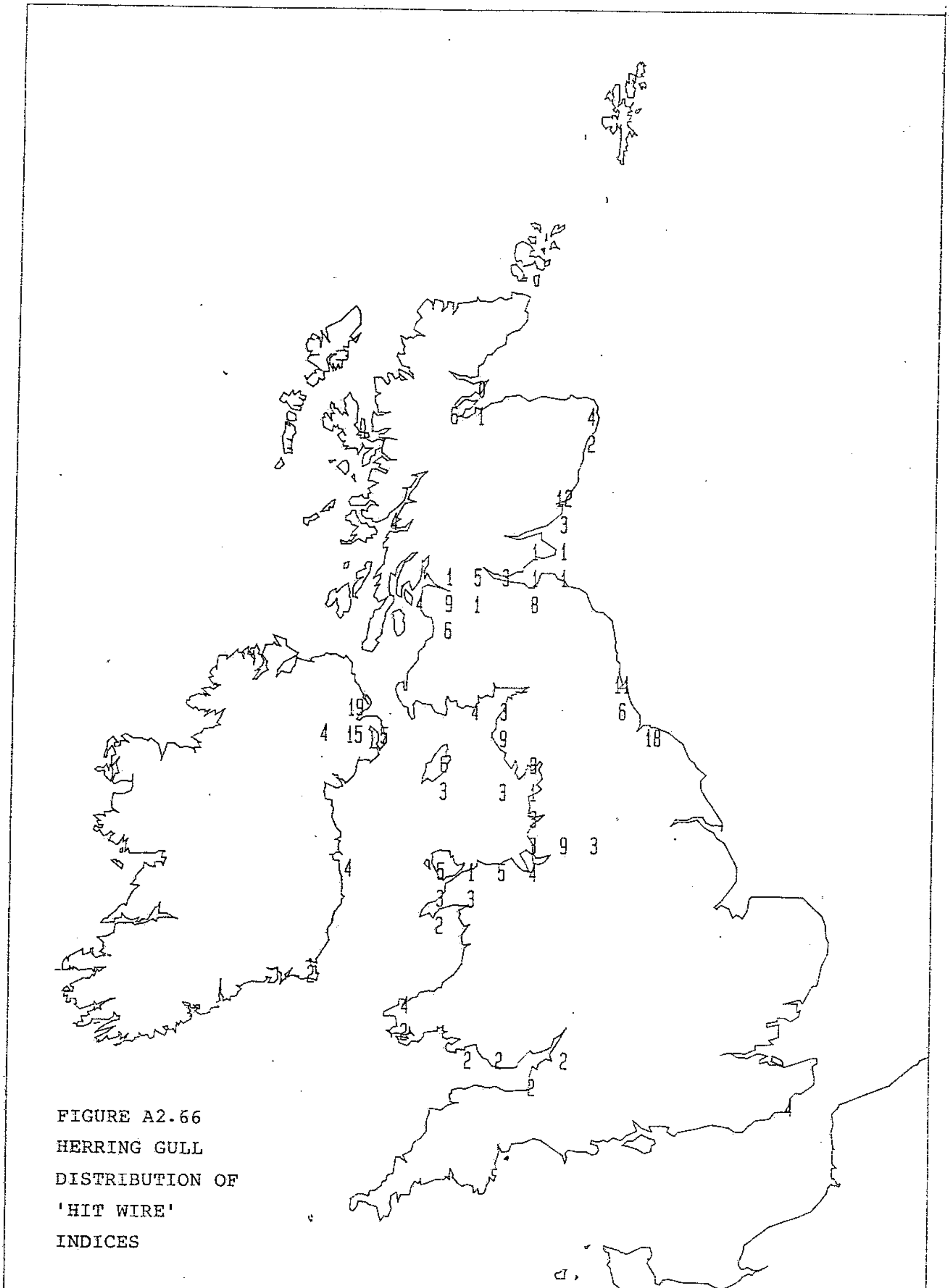

FIGURE A2.66
HERRING GULL
DISTRIBUTION OF
'HIT WIRE'
INDICES

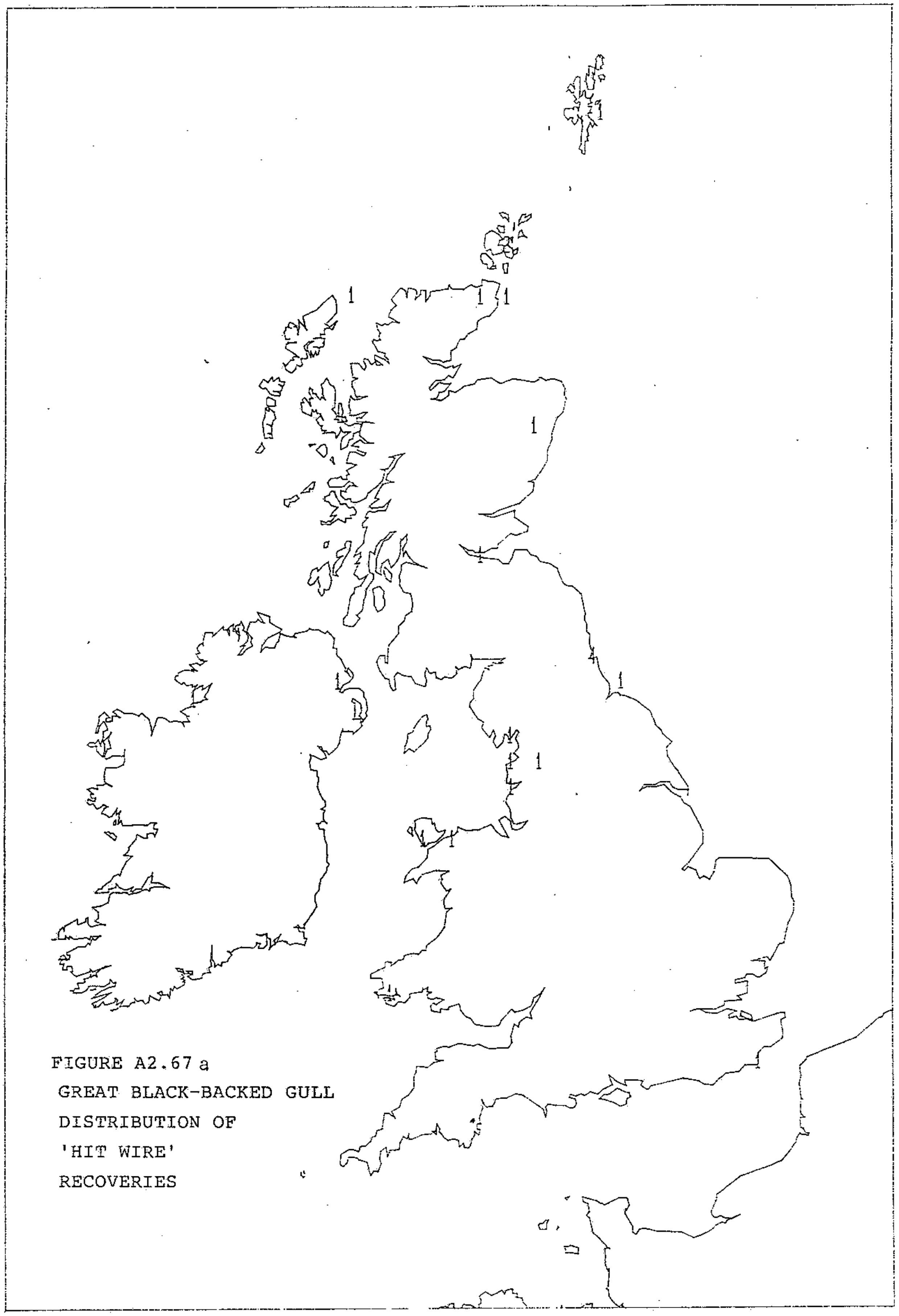


FIGURE A2.67 a
GREAT BLACK-BACKED GULL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

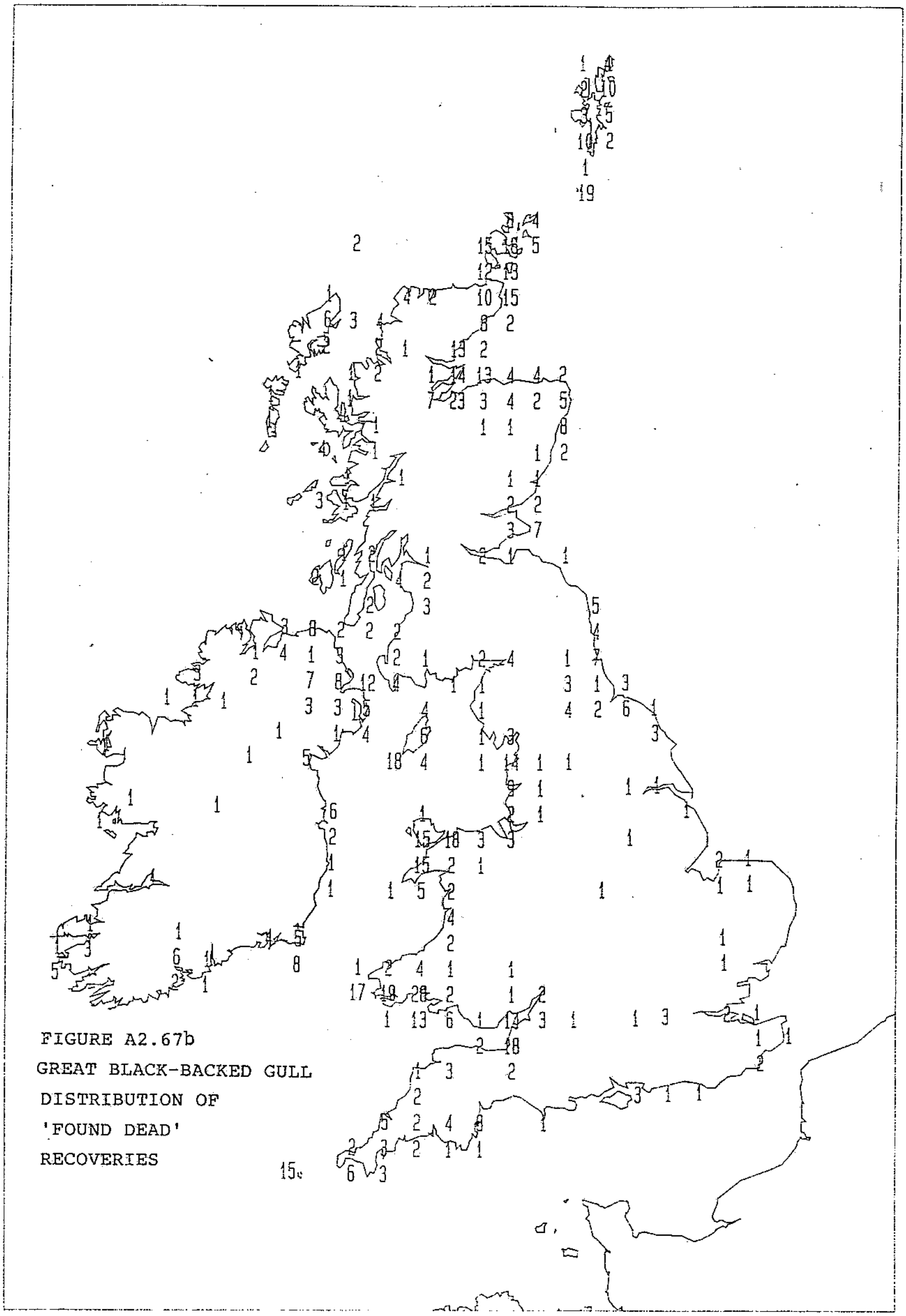

FIGURE A2.67b
GREAT BLACK-BACKED GULL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

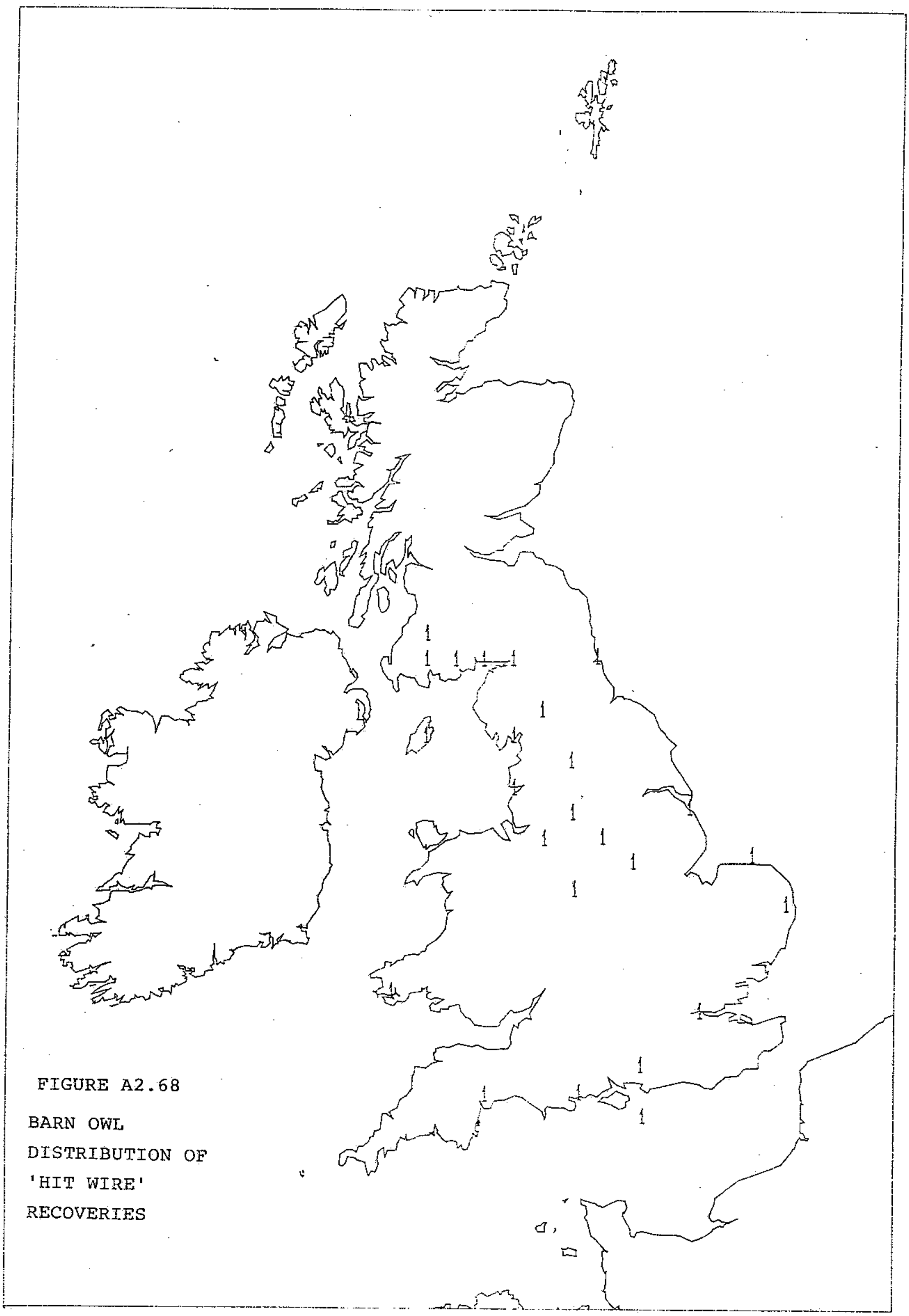


FIGURE A2.68

BARN OWL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

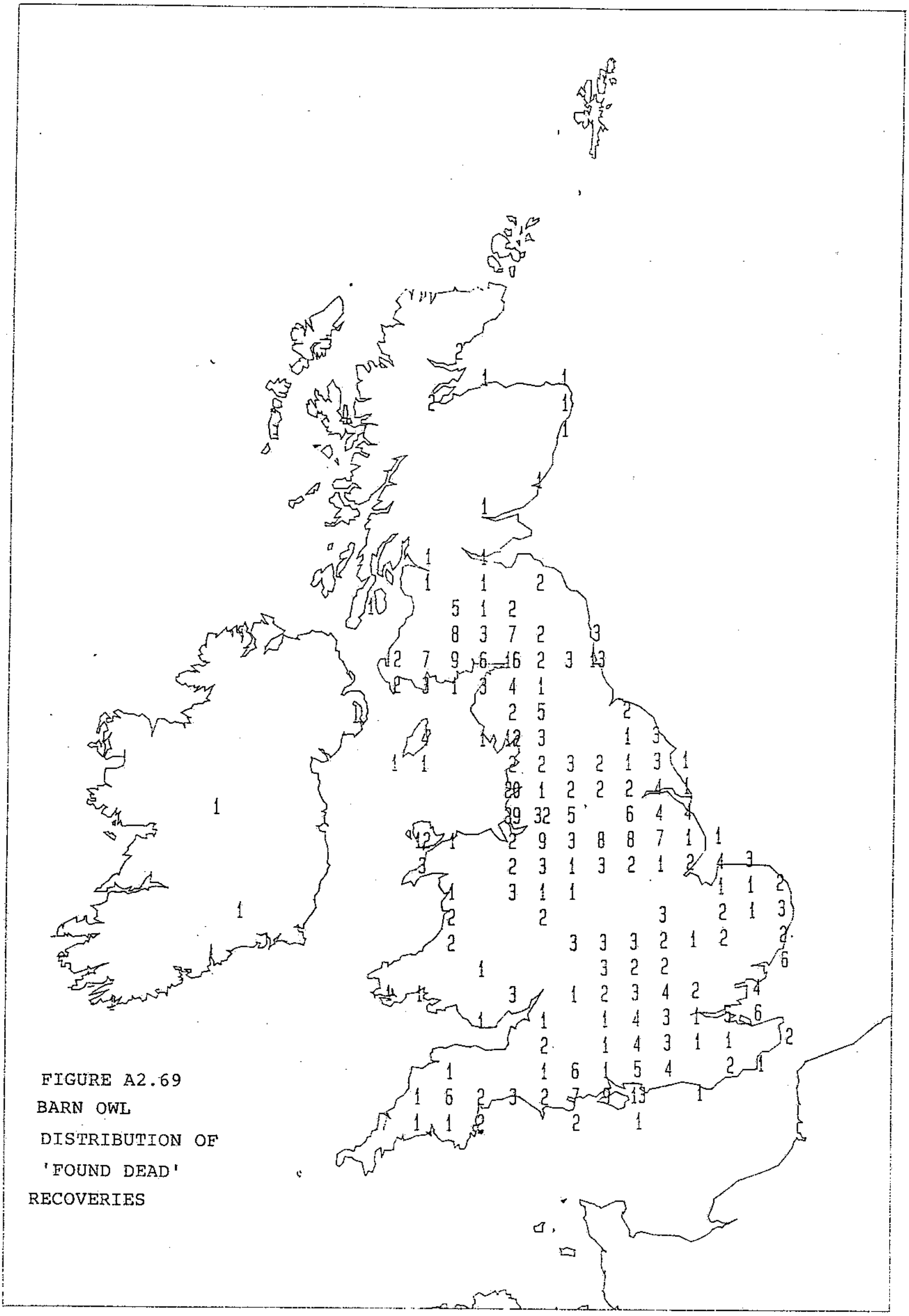

FIGURE A2.69
BARN OWL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

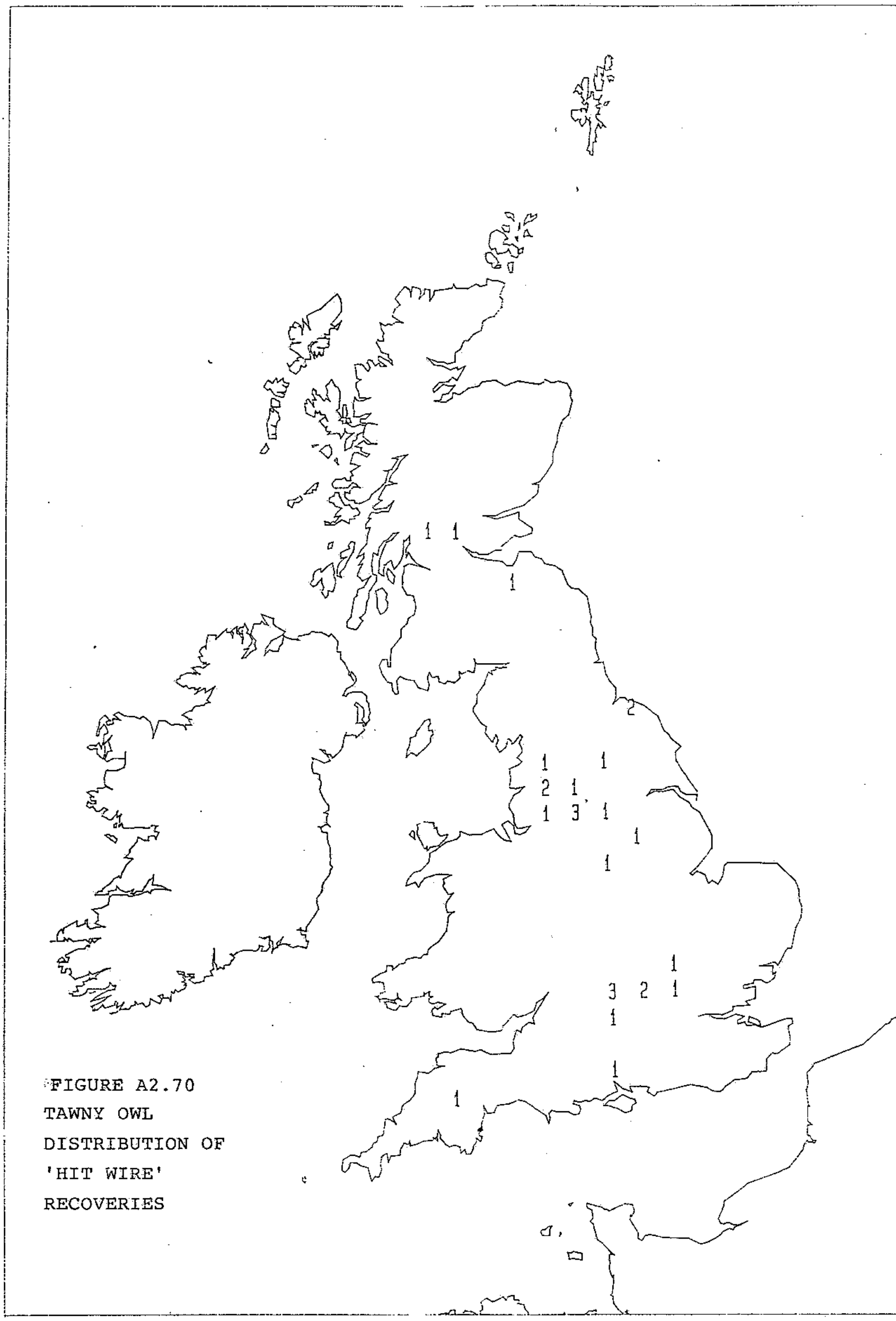


FIGURE A2.70
TAWNY OWL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

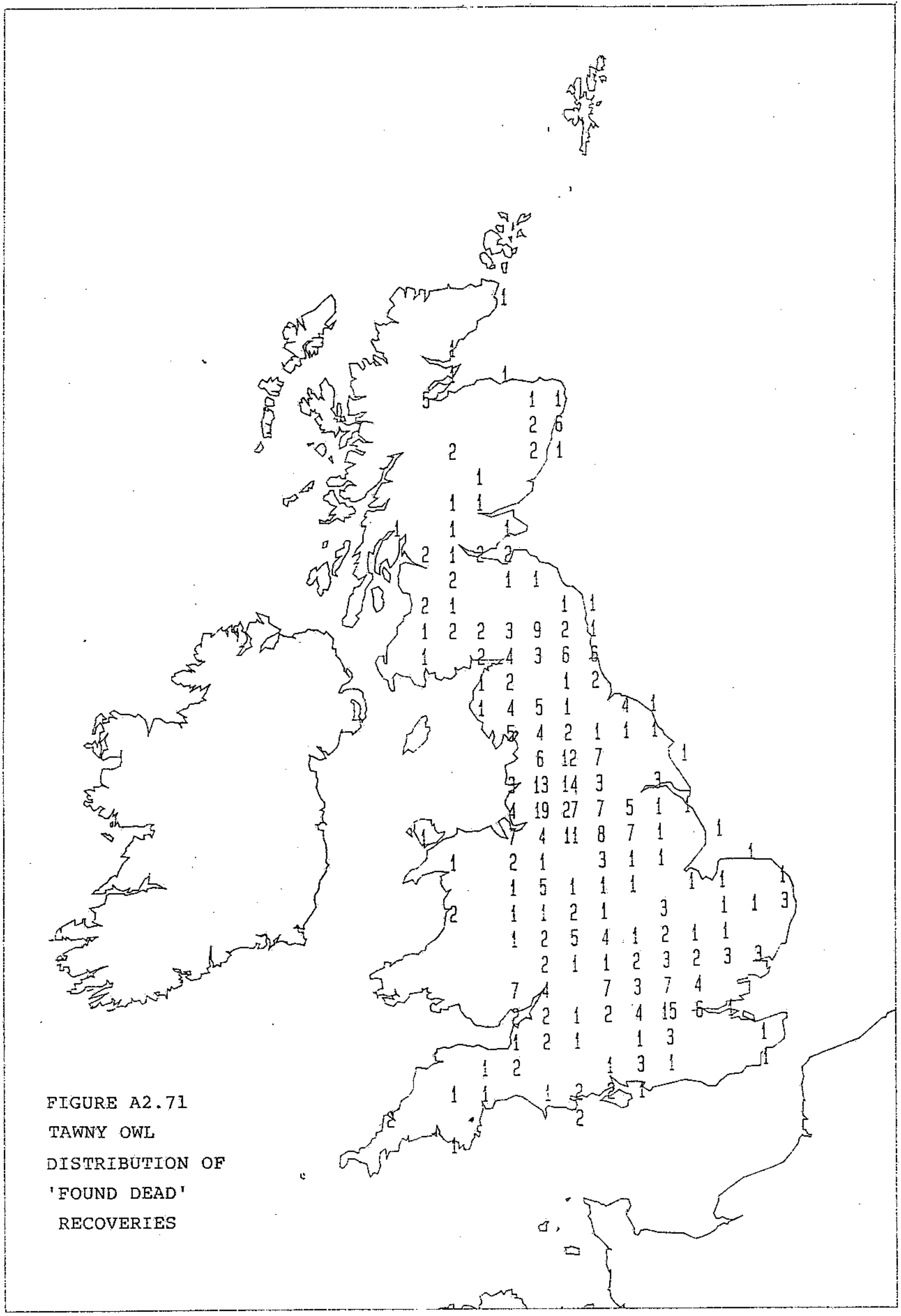

FIGURE A2.71
TAWNY OWL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

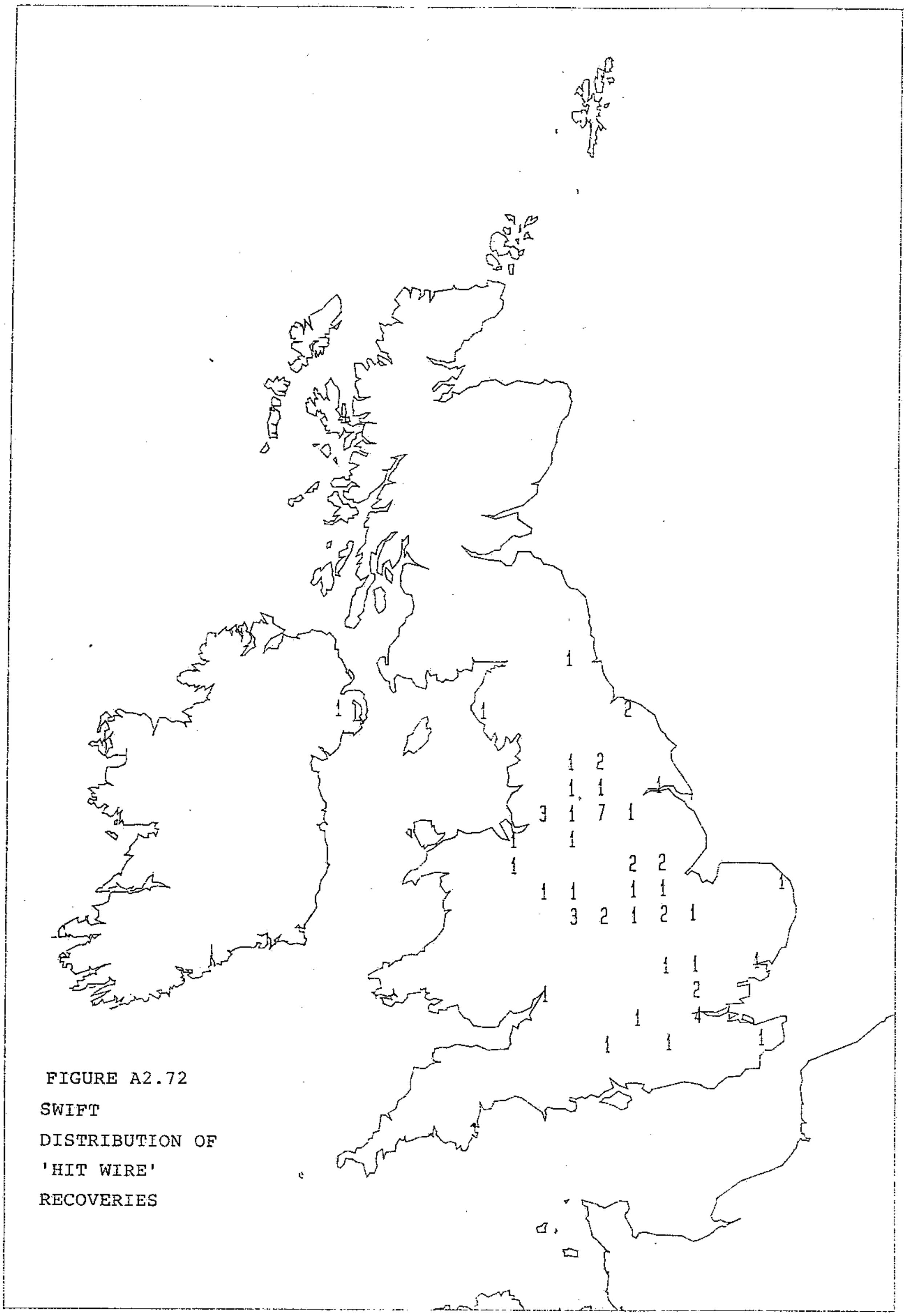


FIGURE A2.72
SWIFT
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

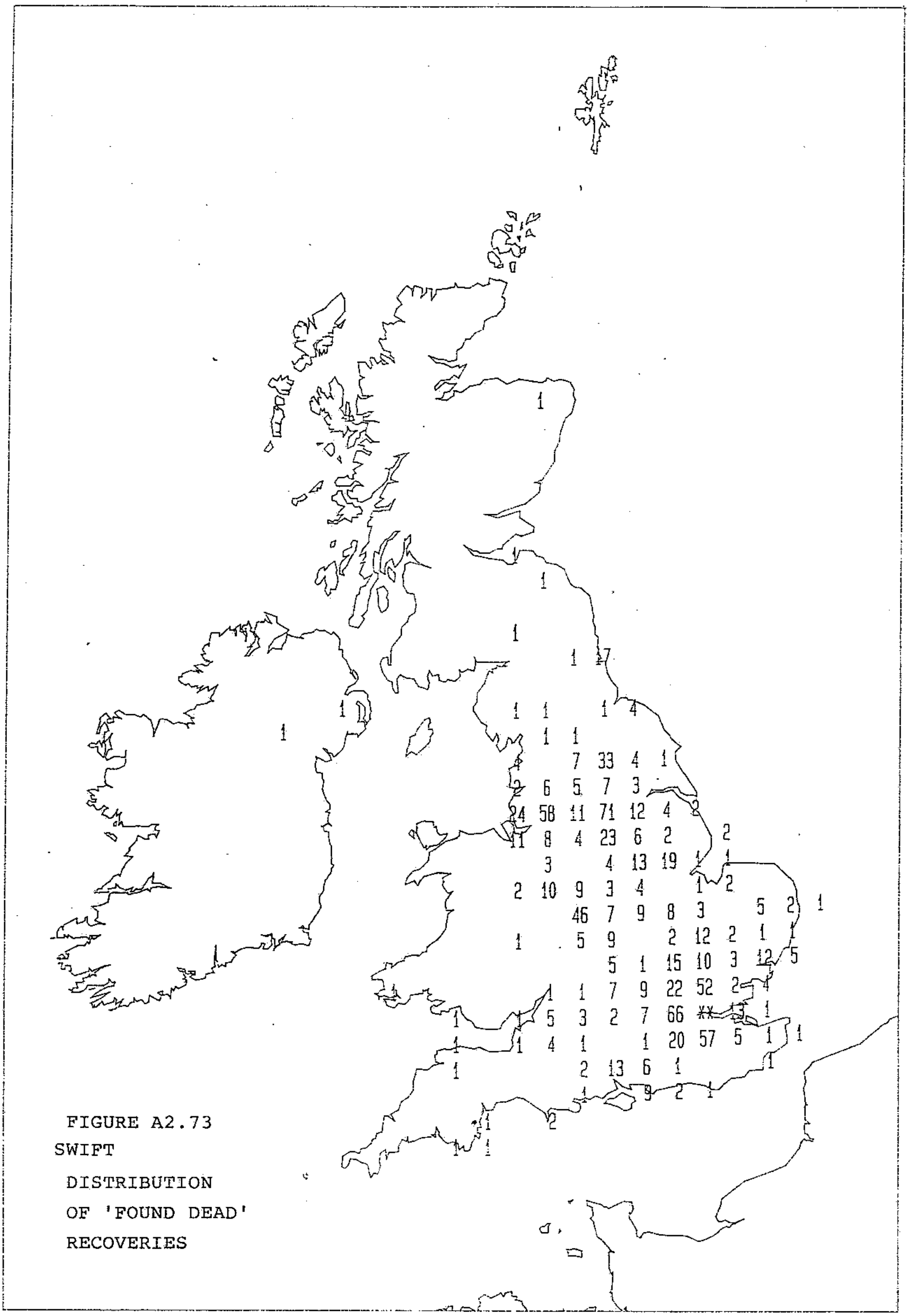

FIGURE A2.73
SWIFT
DISTRIBUTION
OF 'FOUND DEAD'
RECOVERIES

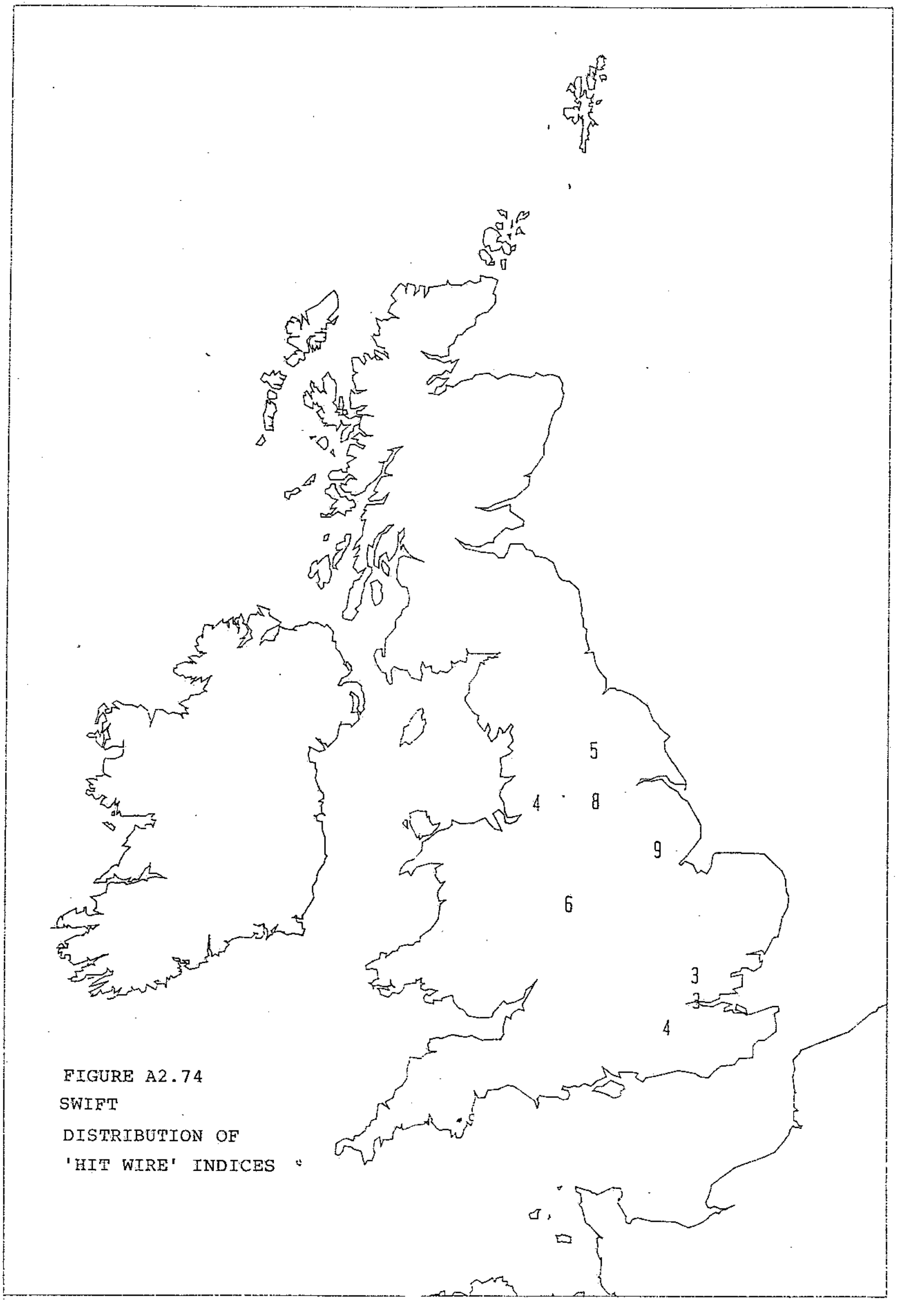


FIGURE A2.74
SWIFT
DISTRIBUTION OF
'HIT WIRE' INDICES

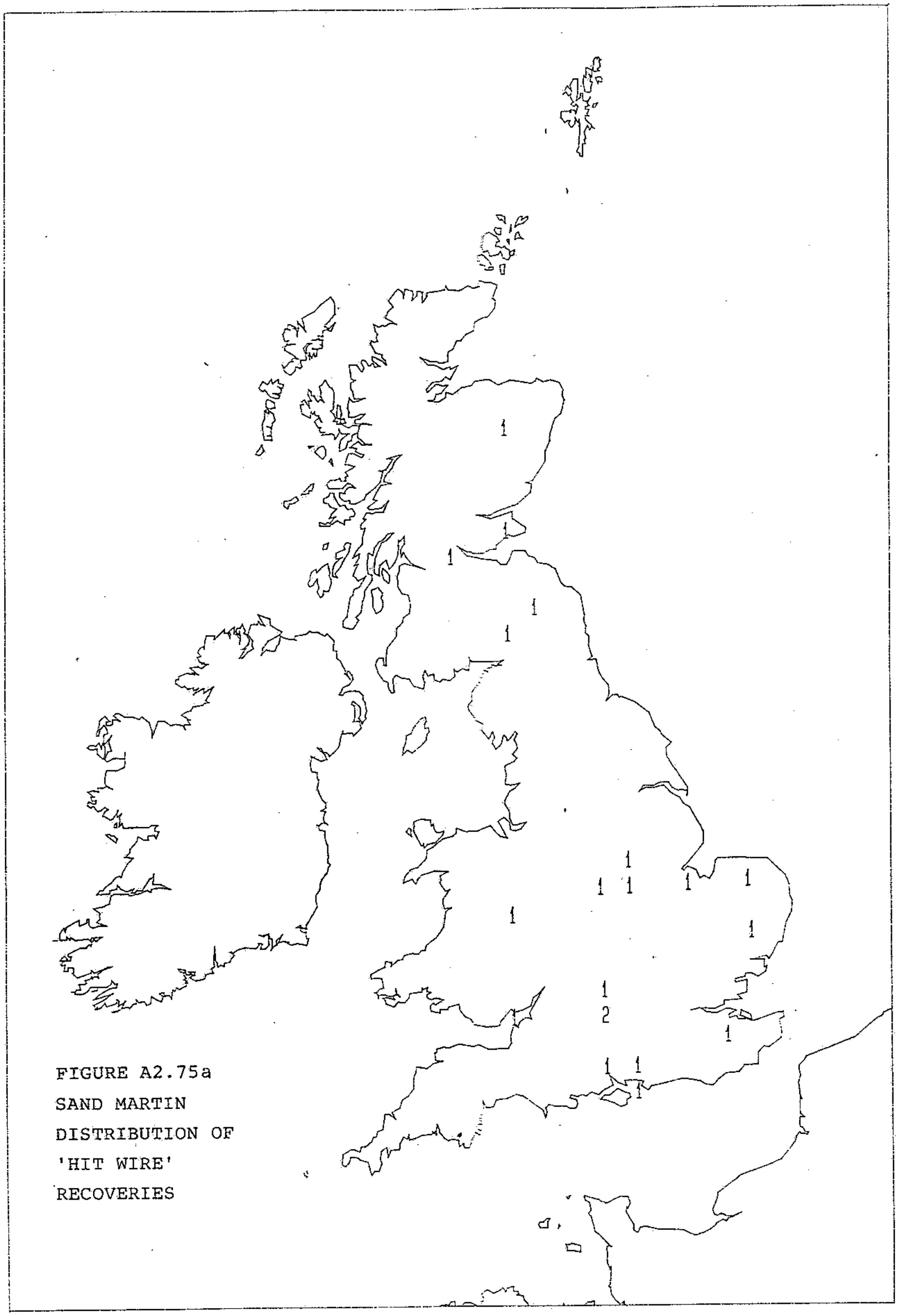

FIGURE A2.75a
SAND MARTIN
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

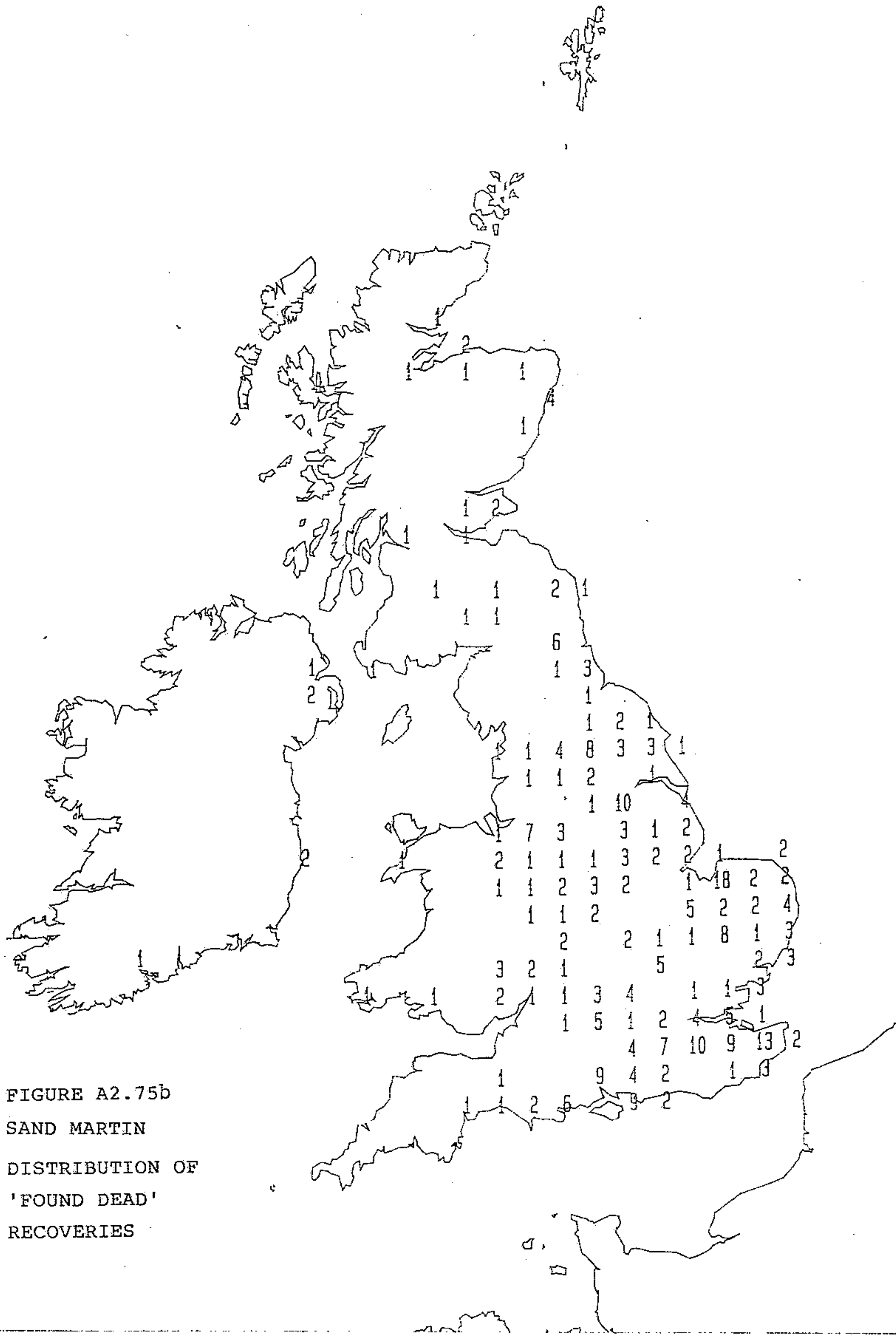

FIGURE A2.75b
SAND MARTIN
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

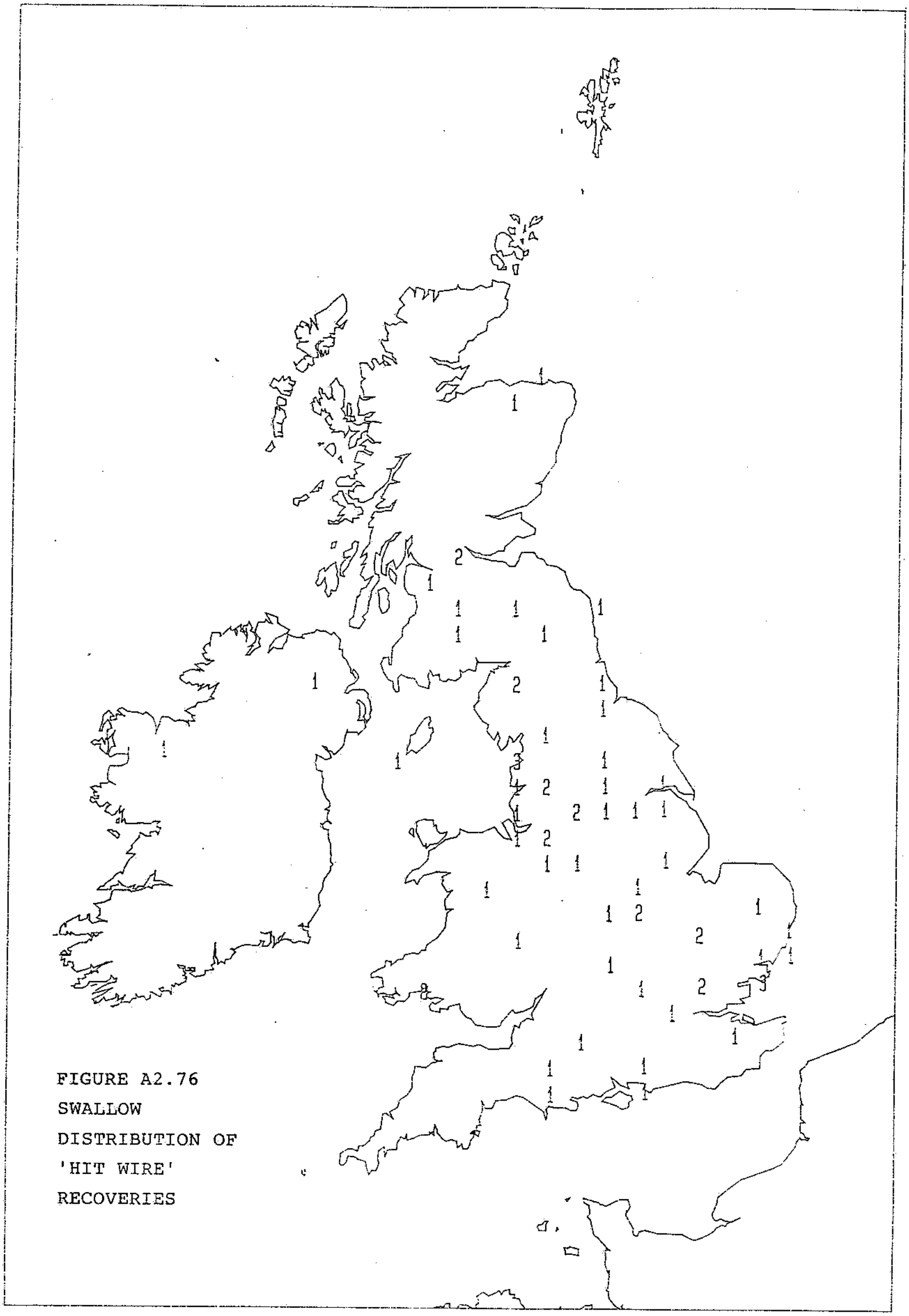

FIGURE A2.76
SWALLOW
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

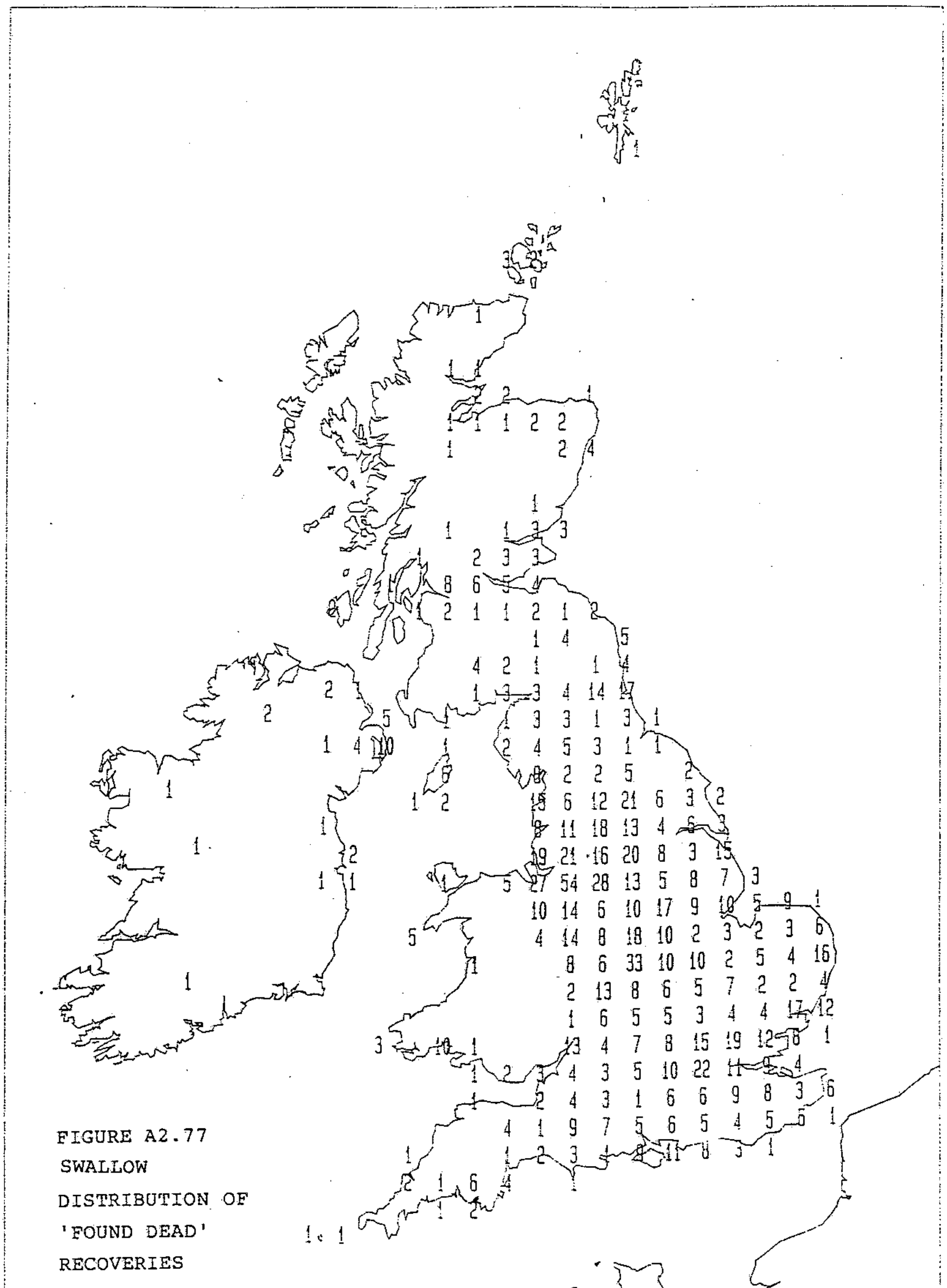

FIGURE A2.77
SWALLOW
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

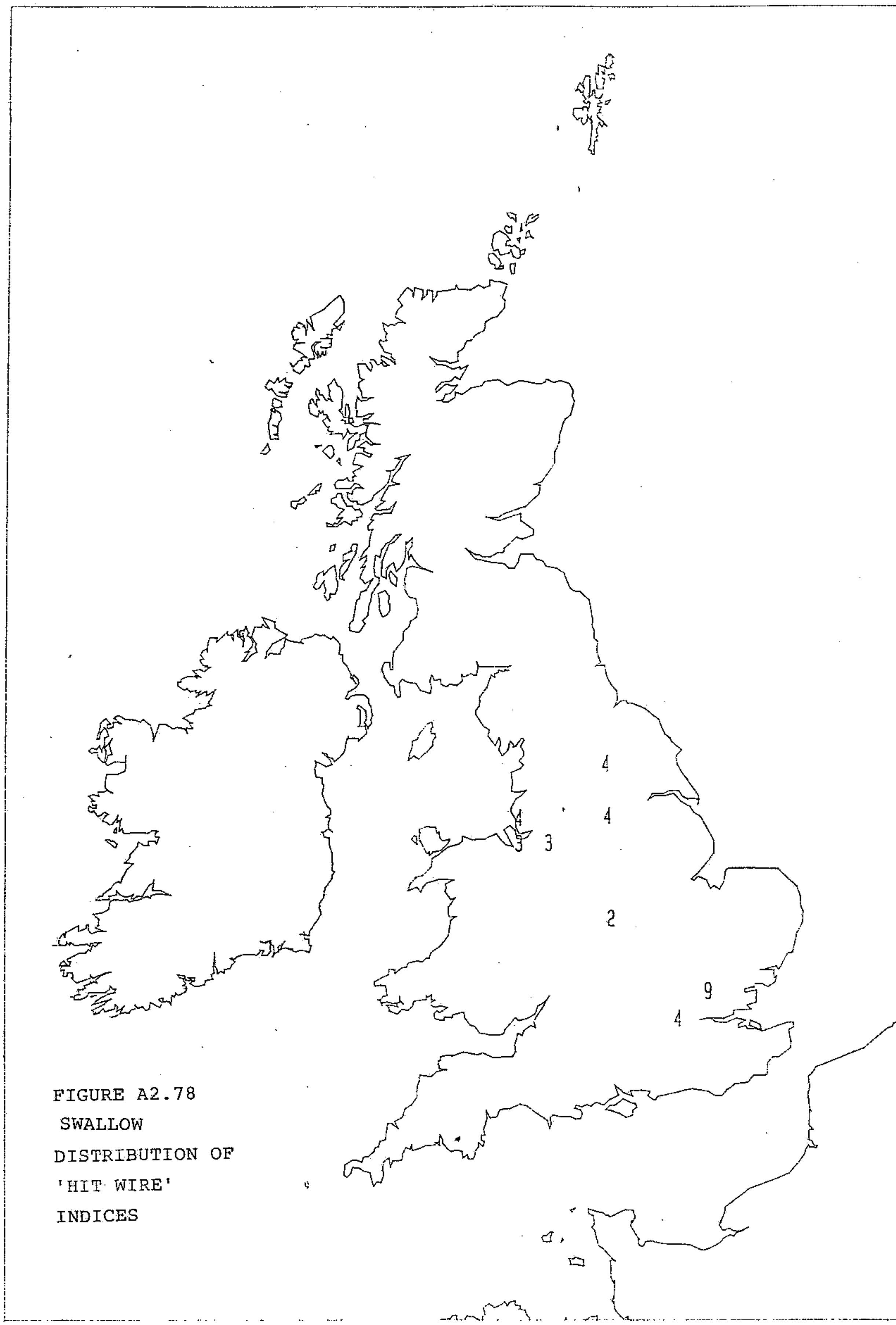


FIGURE A2.78
SWALLOW
DISTRIBUTION OF
'HIT WIRE'
INDICES

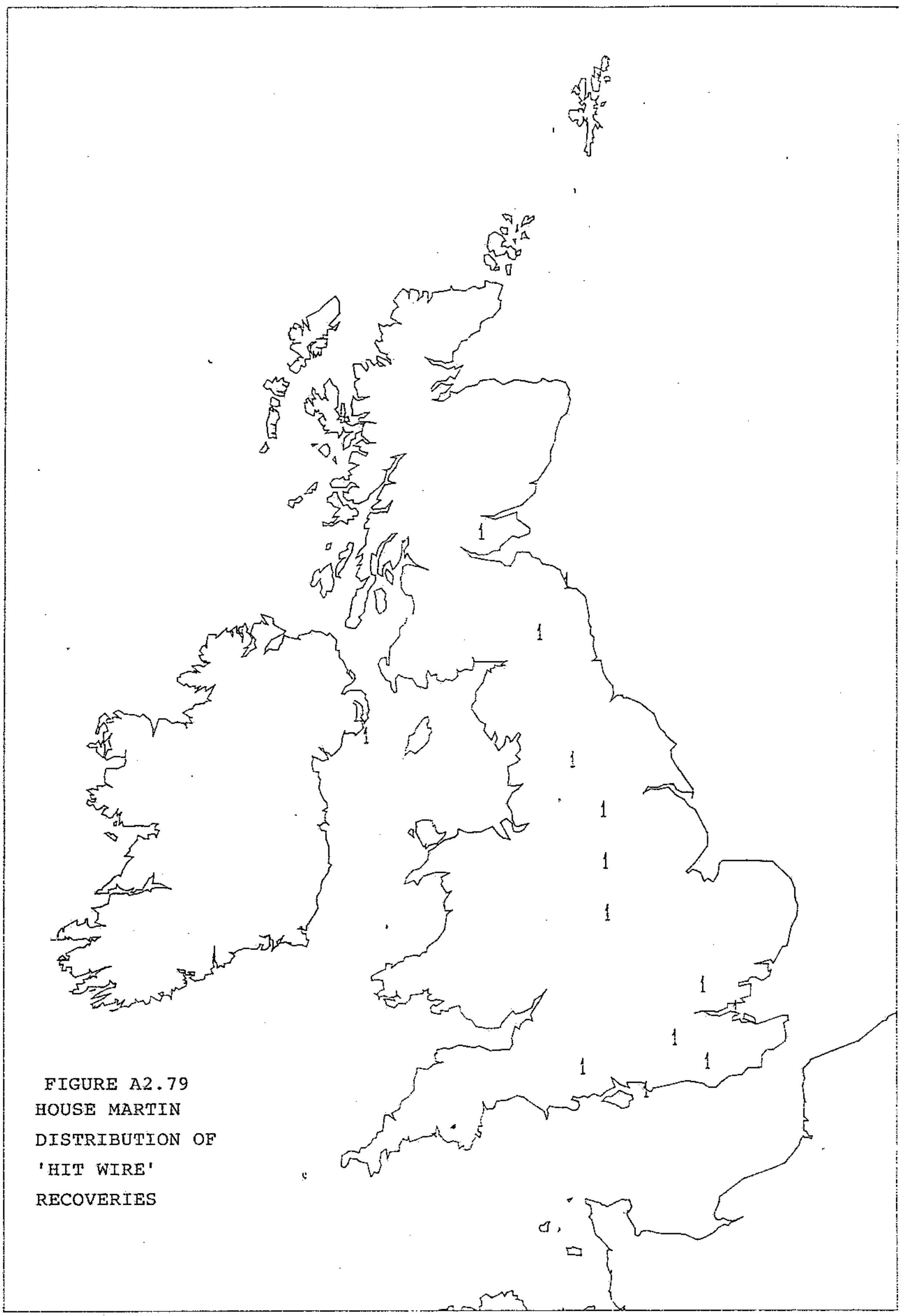


FIGURE A2.79
HOUSE MARTIN
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

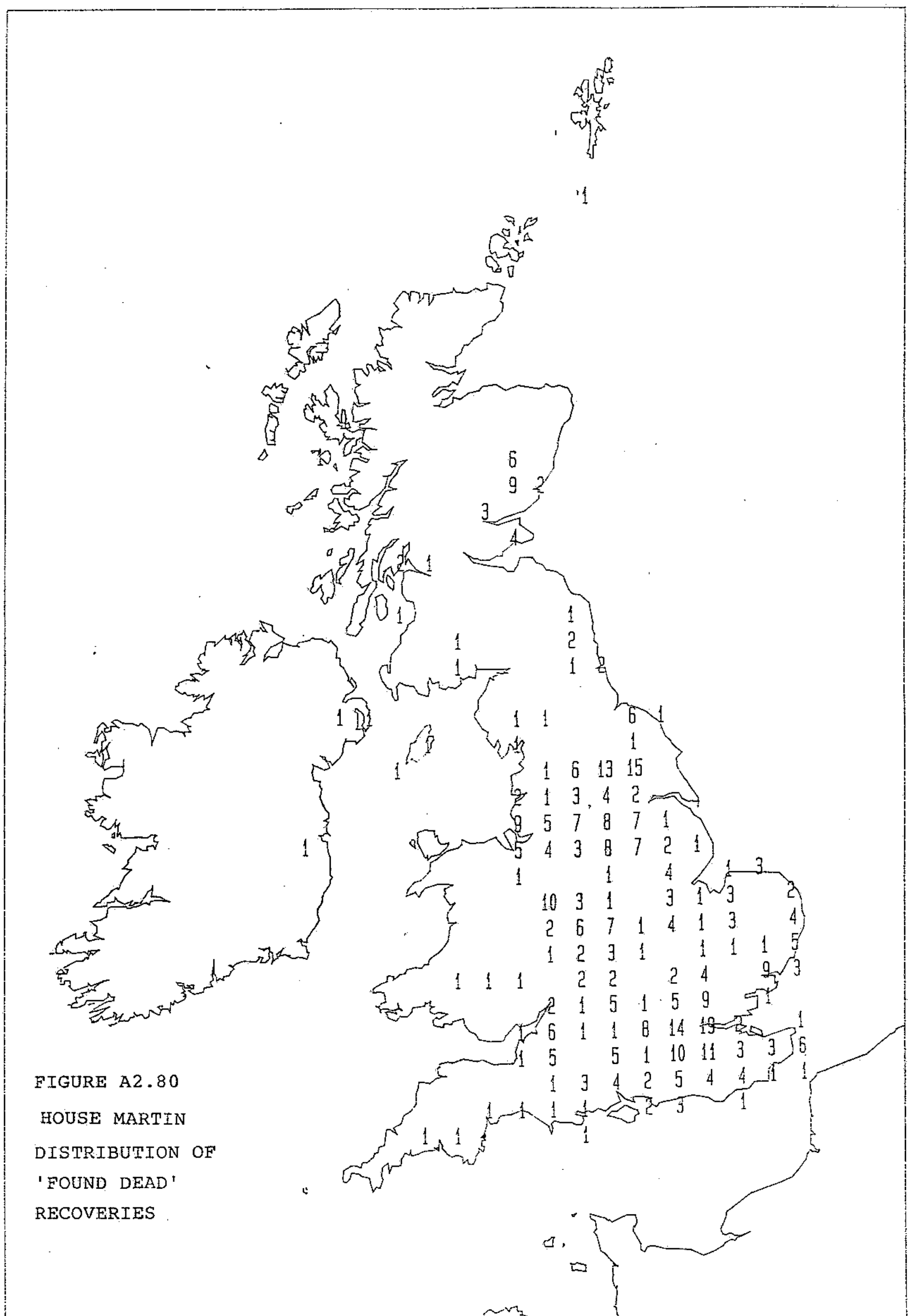

FIGURE A2.80
HOUSE MARTIN
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

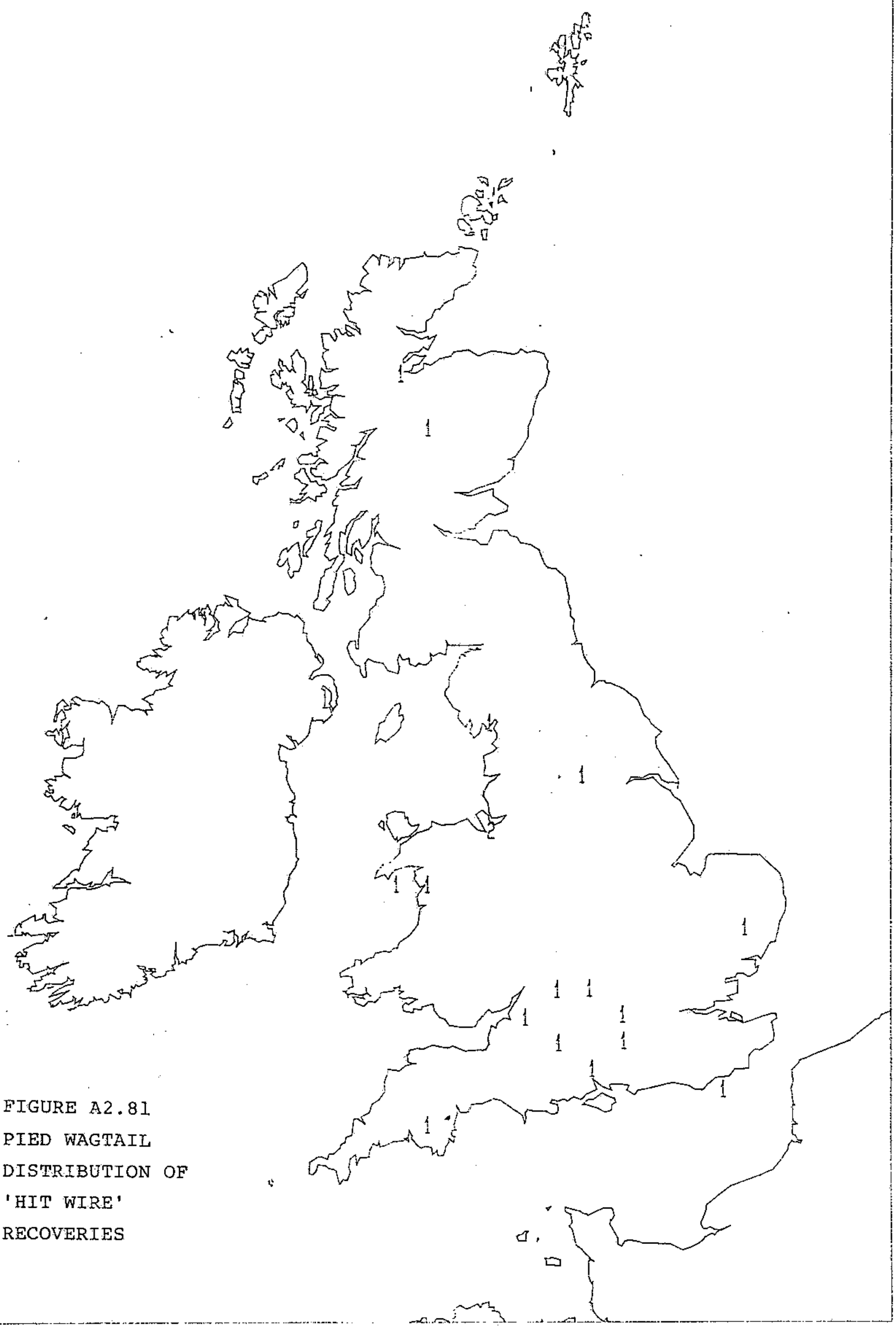

FIGURE A2.81
PIED WAGTAIL
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

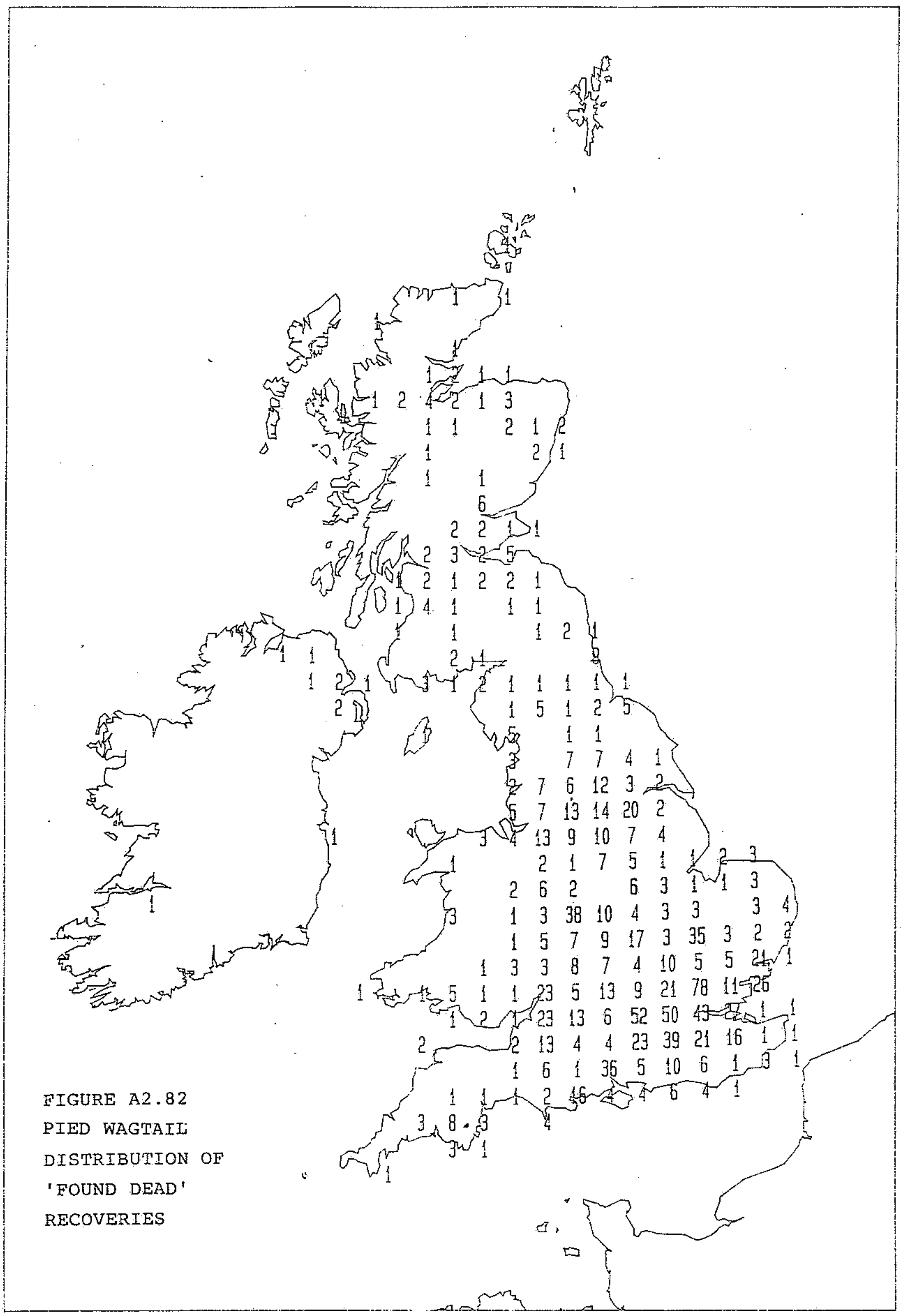

FIGURE A2.82
PIED WAGTAIL
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

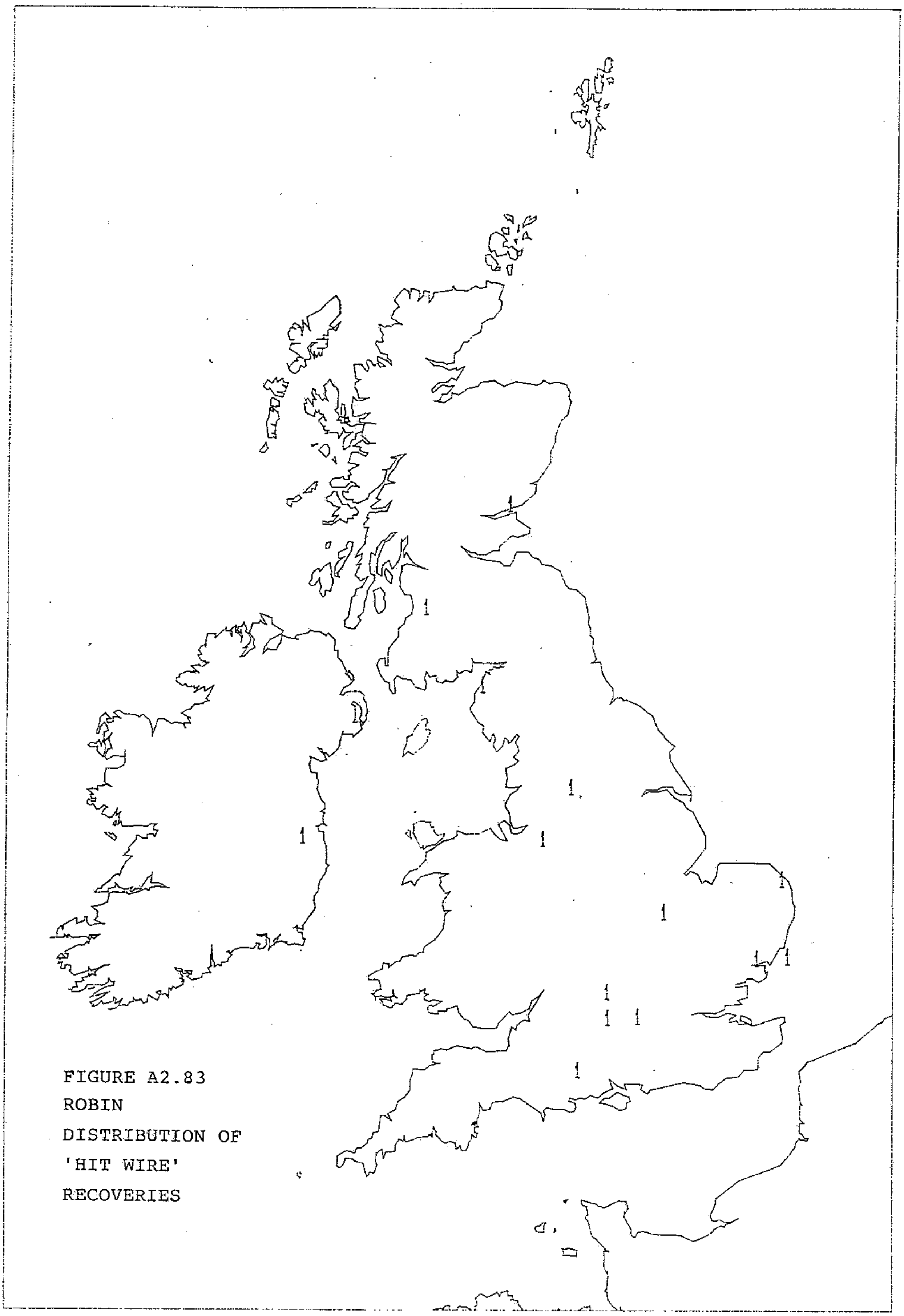

FIGURE A2.83
ROBIN
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

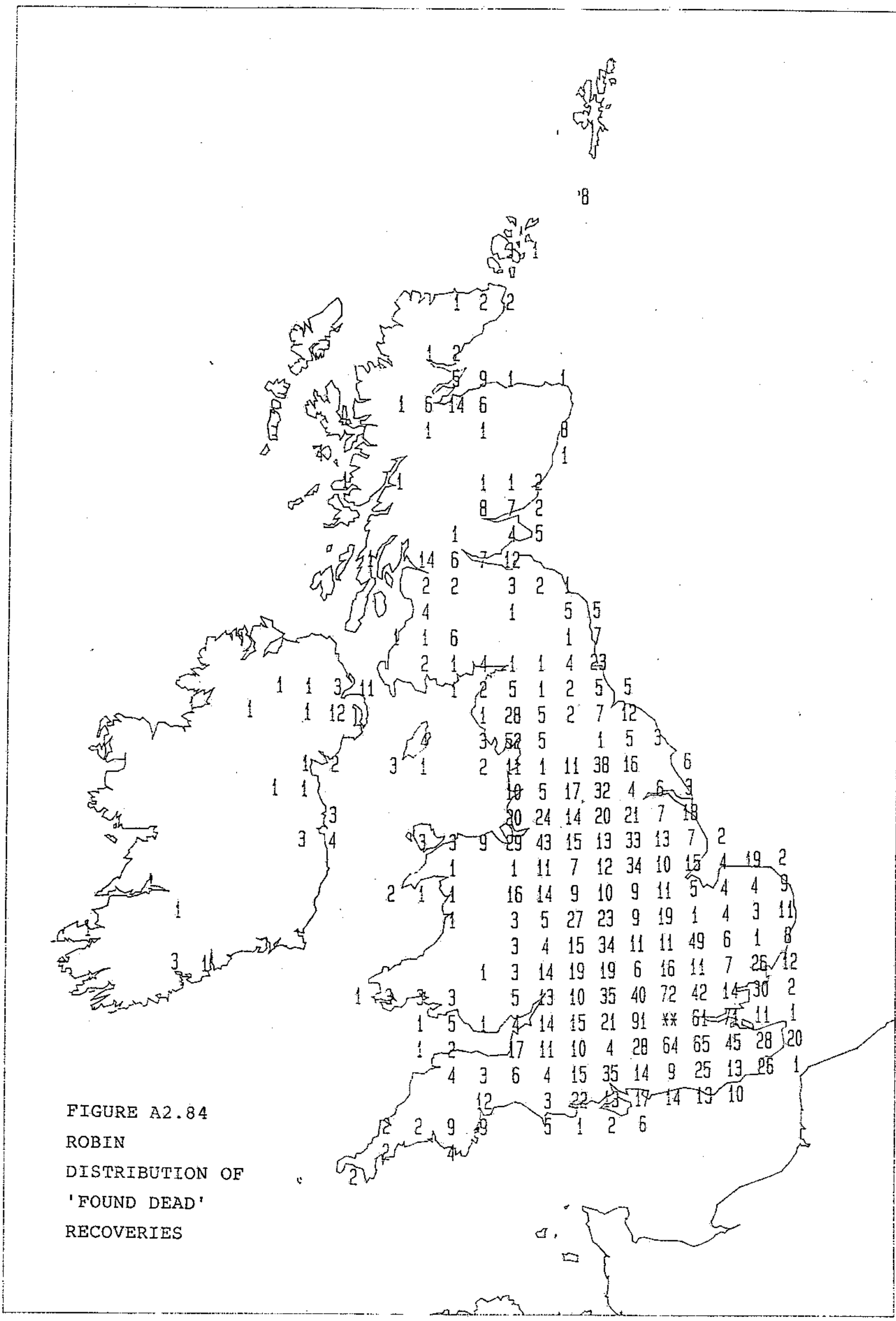

FIGURE A2.84
ROBIN
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

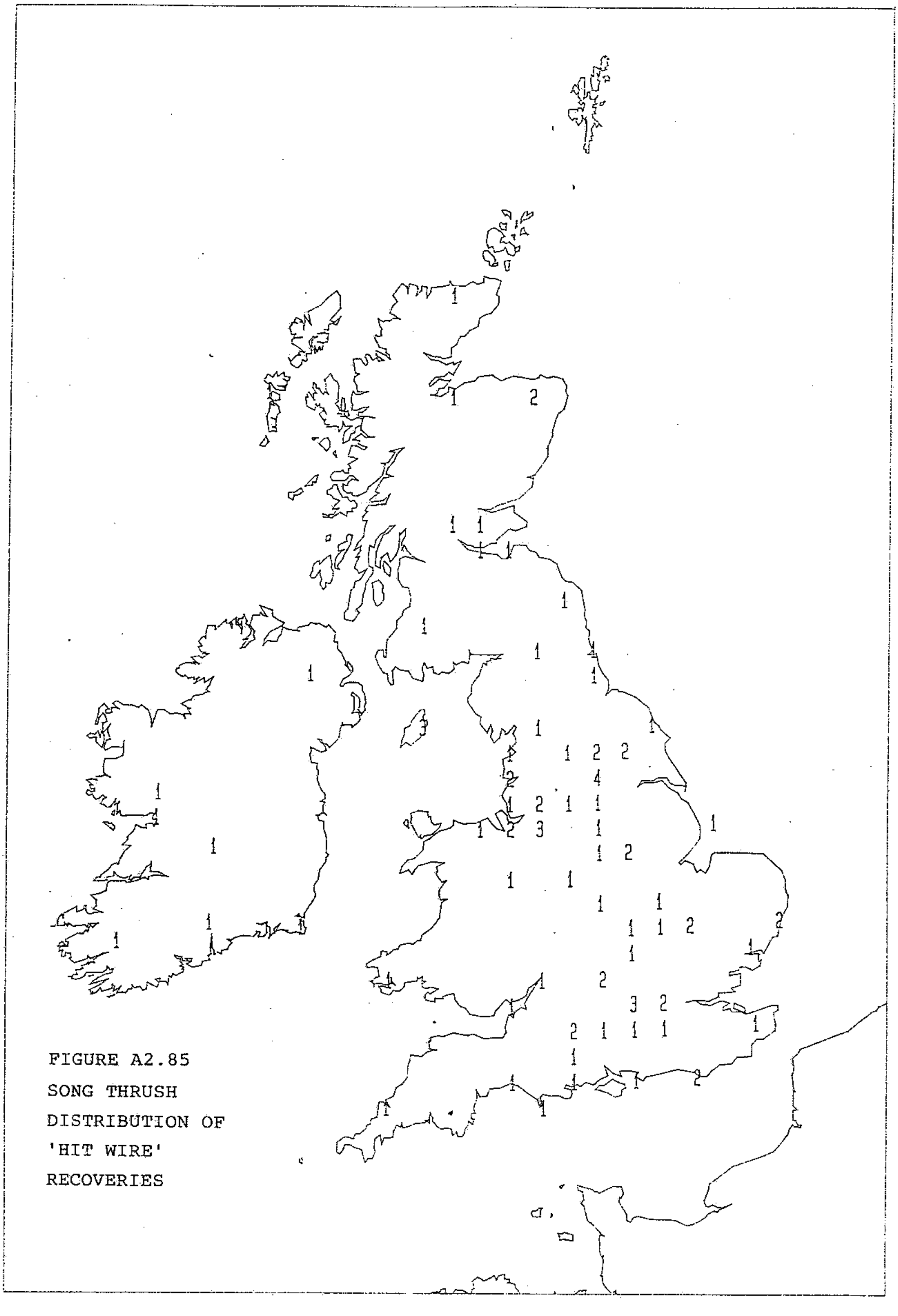

FIGURE A2.85
SONG THRUSH
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

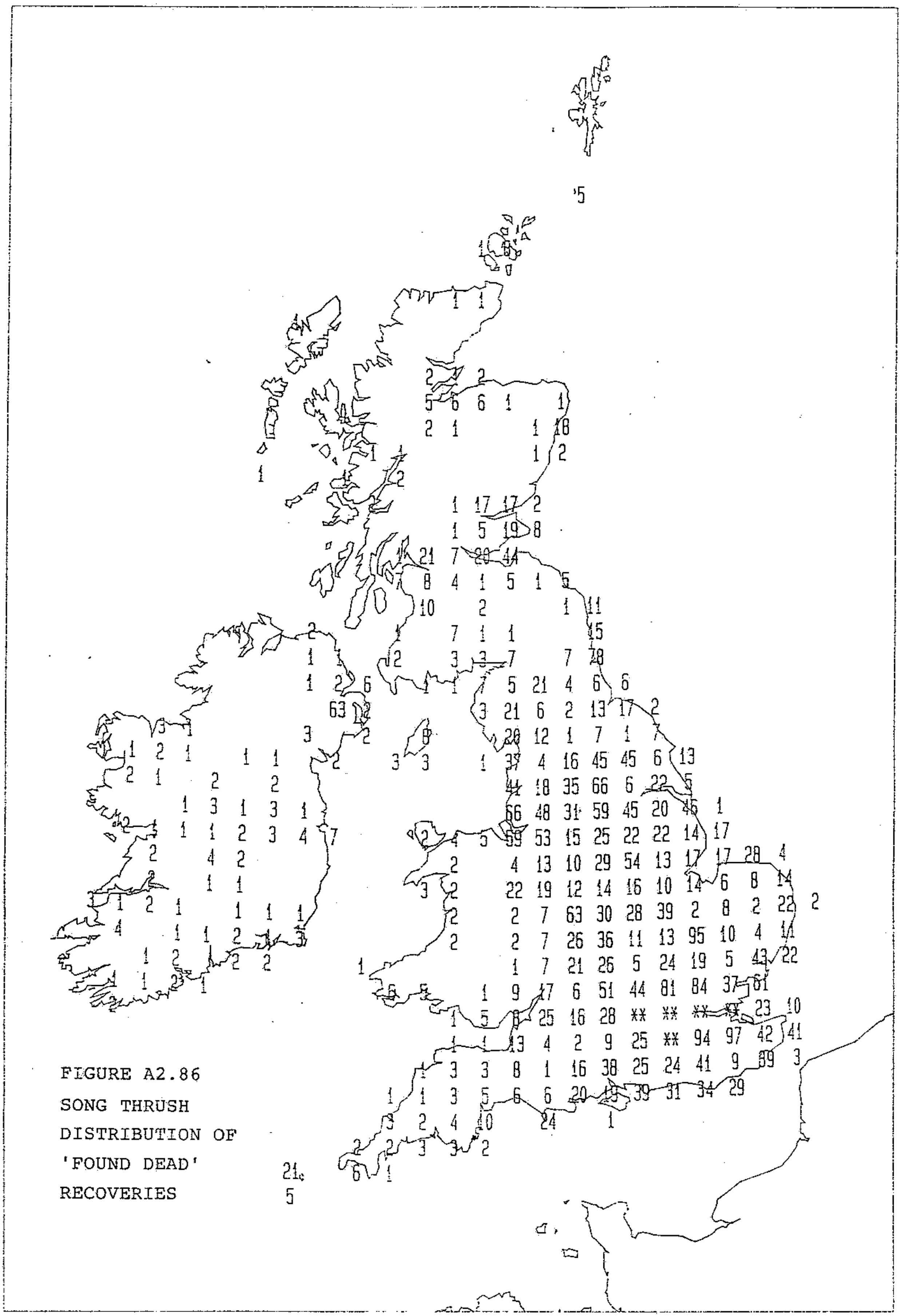

FIGURE A2.86
SONG THRUSH
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

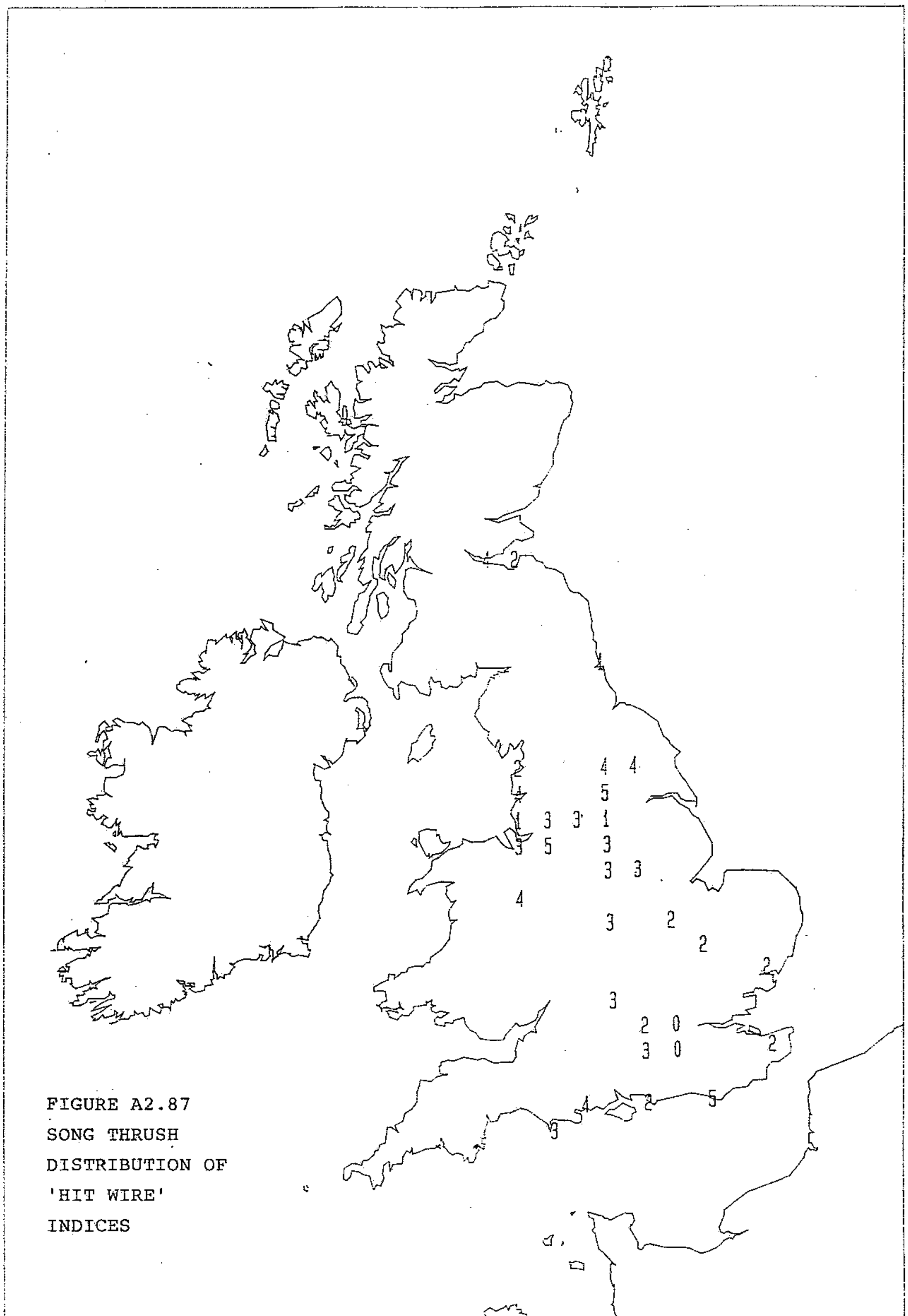


FIGURE A2.87
SONG THRUSH
DISTRIBUTION OF
'HIT WIRE'
INDICES

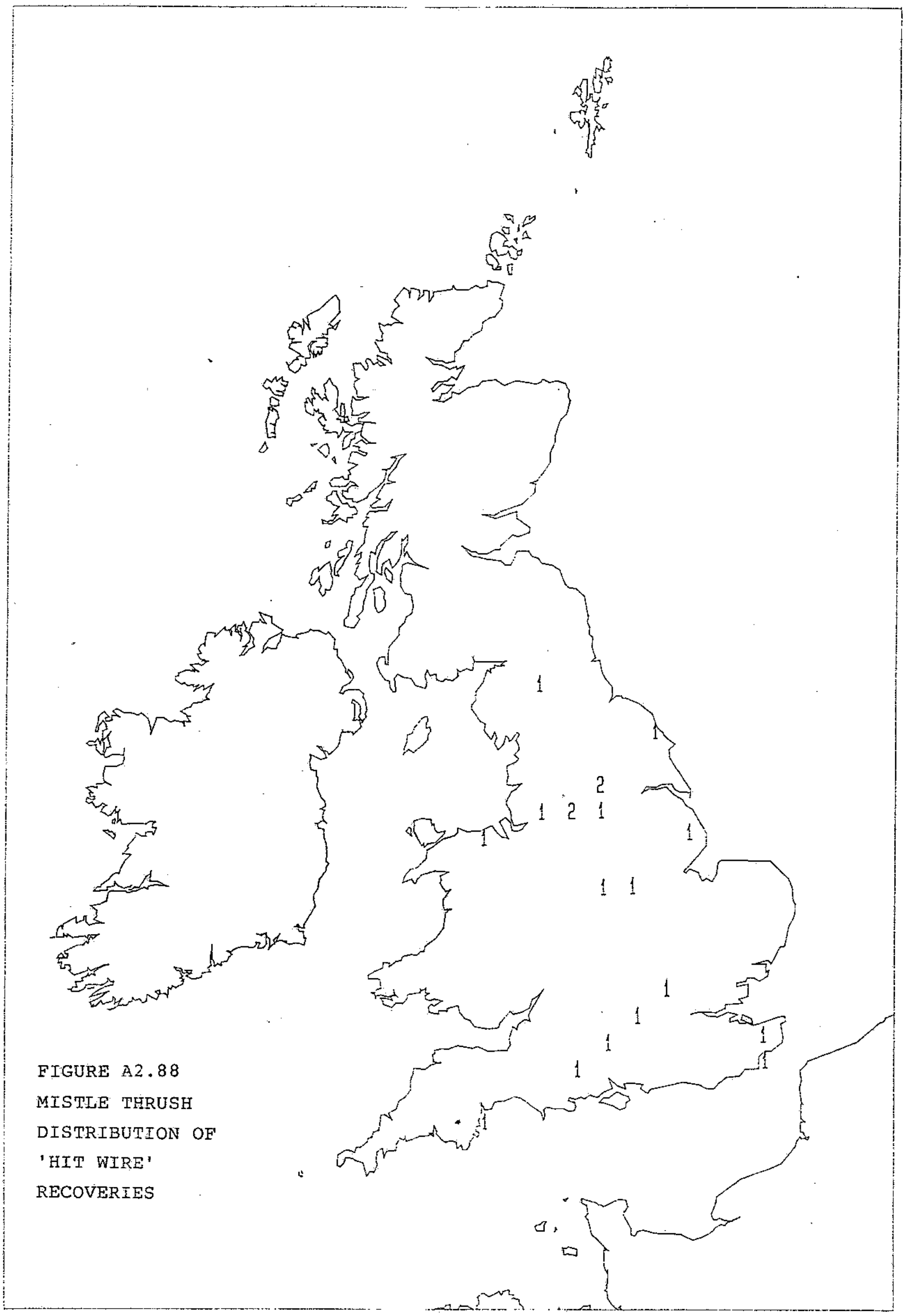


FIGURE A2.88
MISTLE THRUSH
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

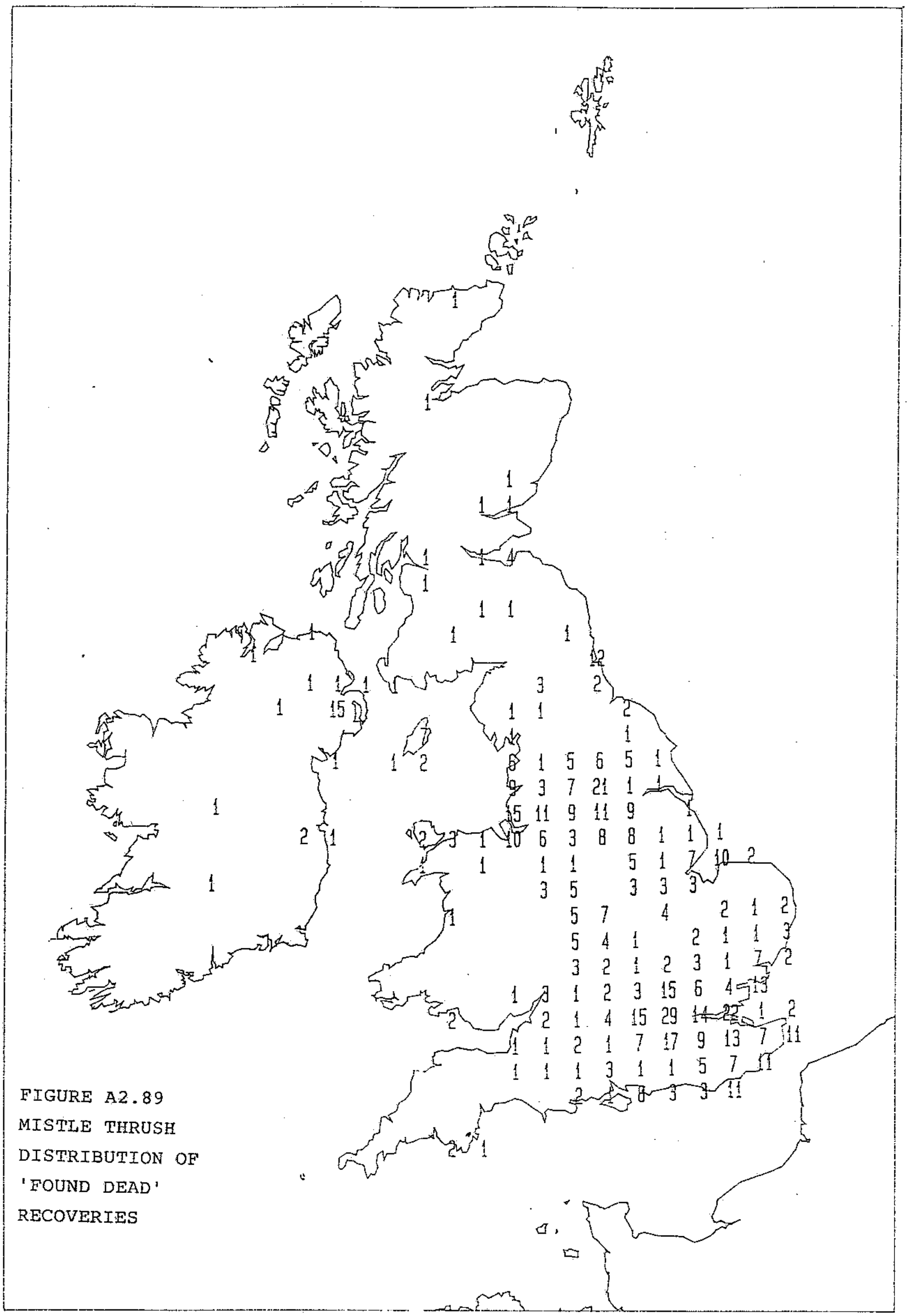

FIGURE A2.89
MISTLE THRUSH
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

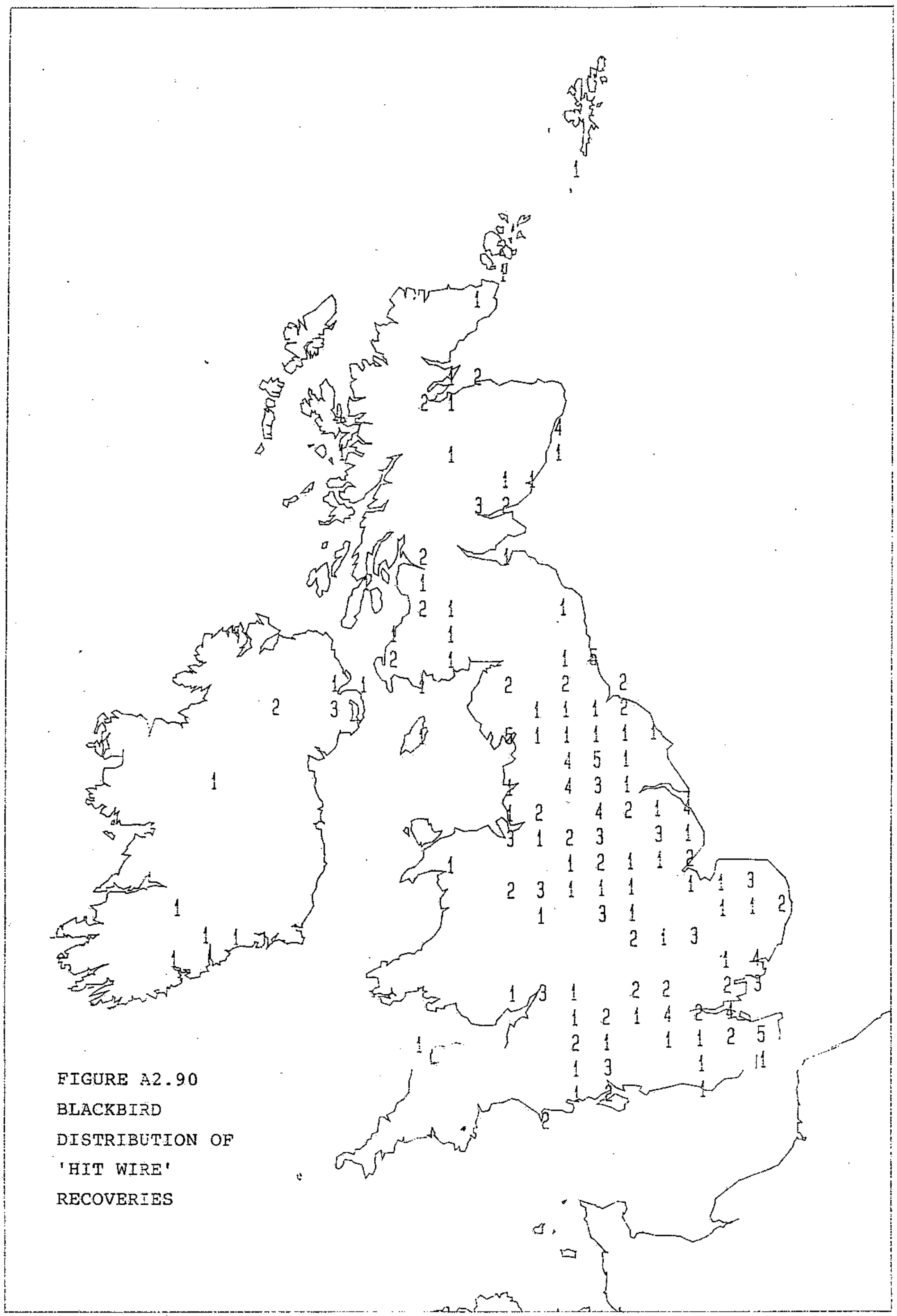

FIGURE A2.90
BLACKBIRD
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

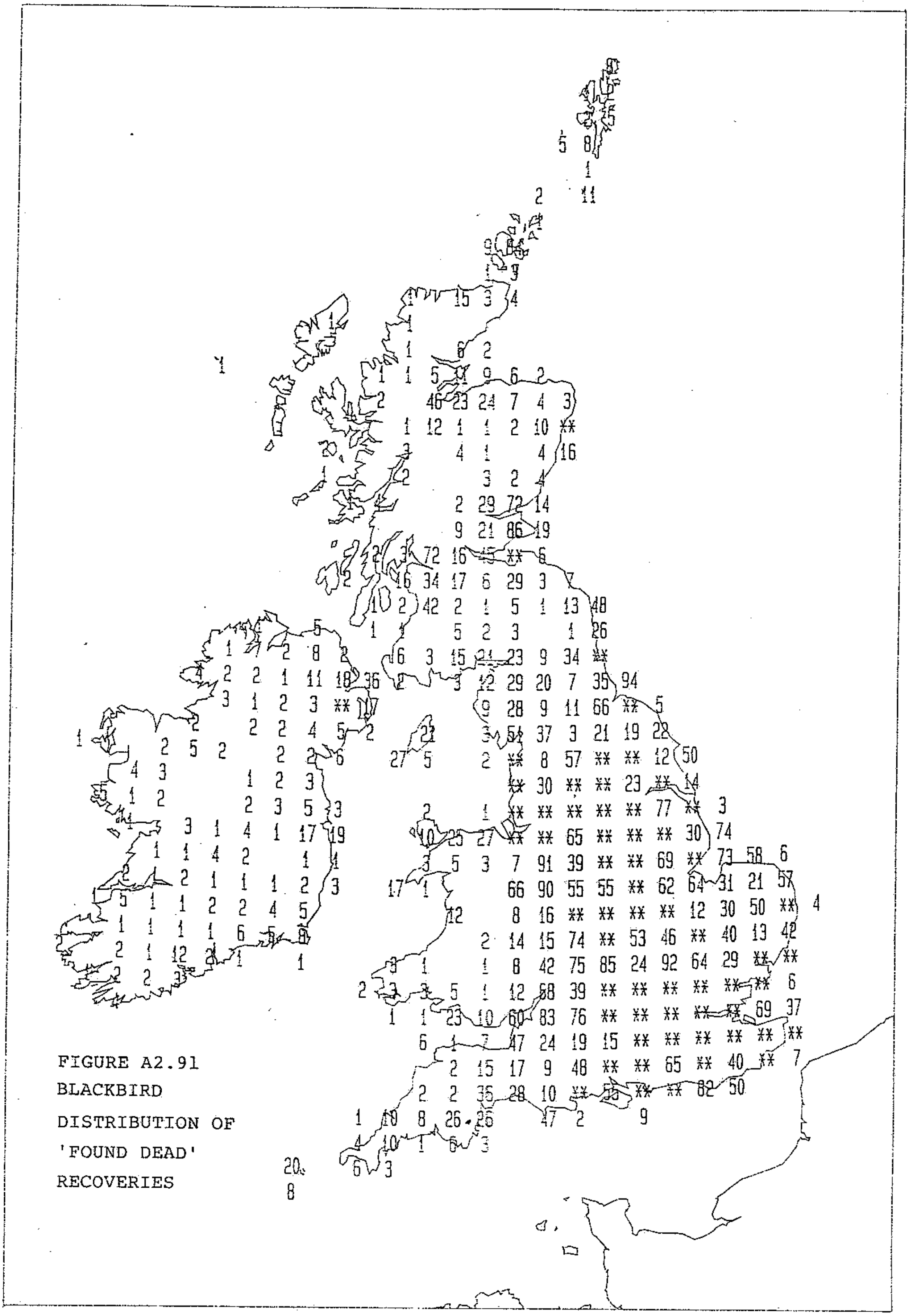

FIGURE A2.91
BLACKBIRD
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

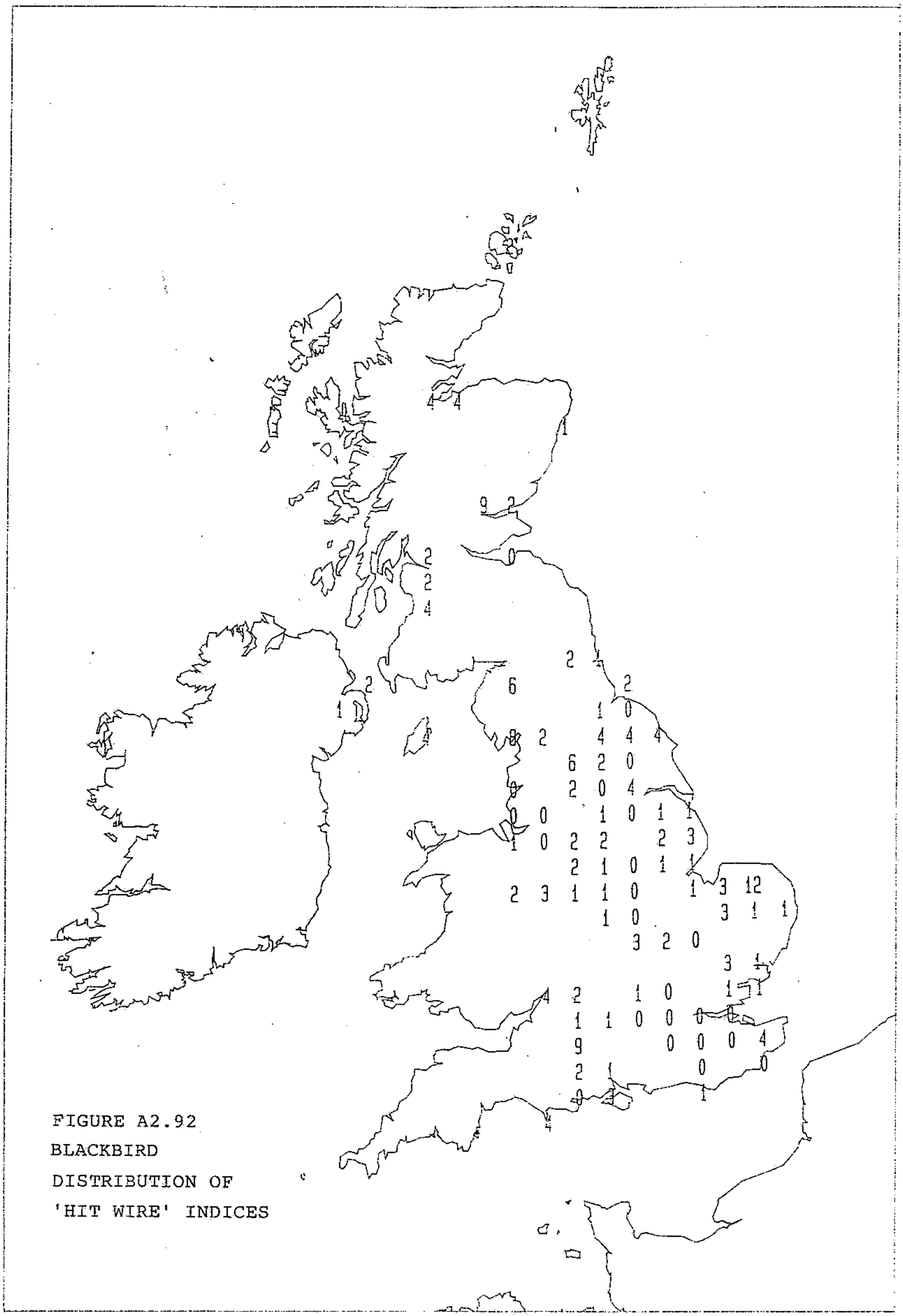

FIGURE A2.92
BLACKBIRD
DISTRIBUTION OF
'HIT WIRE' INDICES

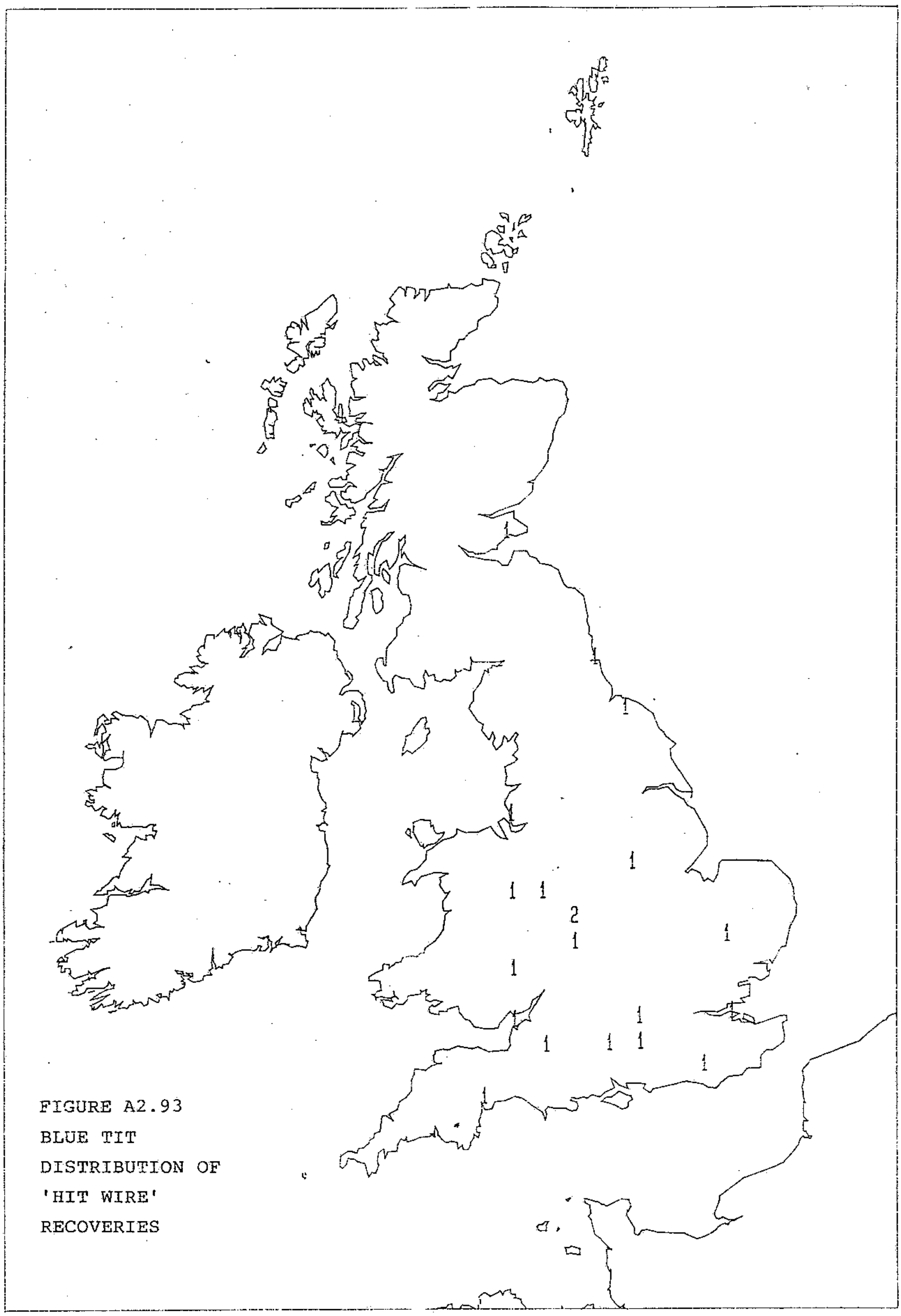


FIGURE A2.93
BLUE TIT
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

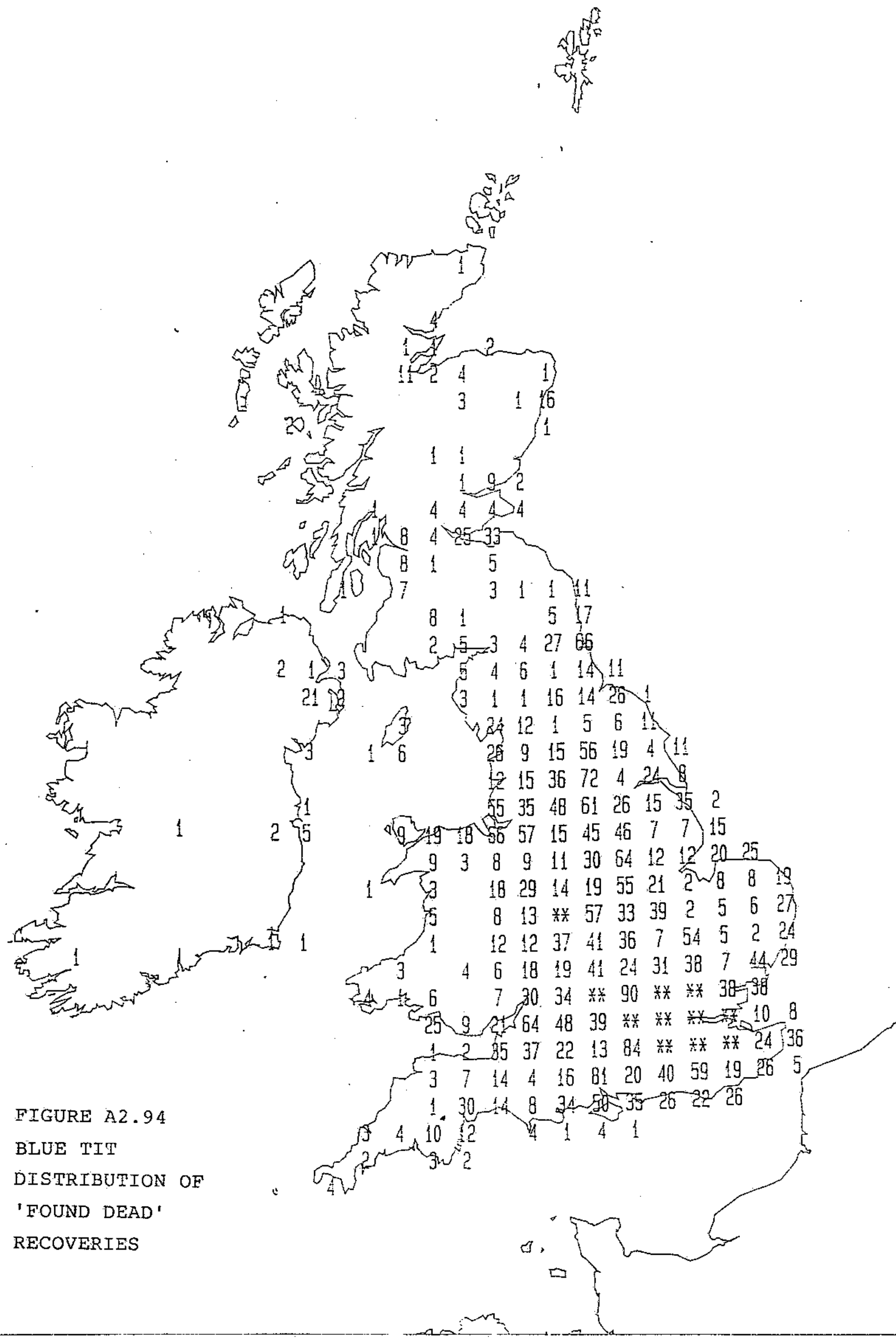

FIGURE A2.94
BLUE TIT
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

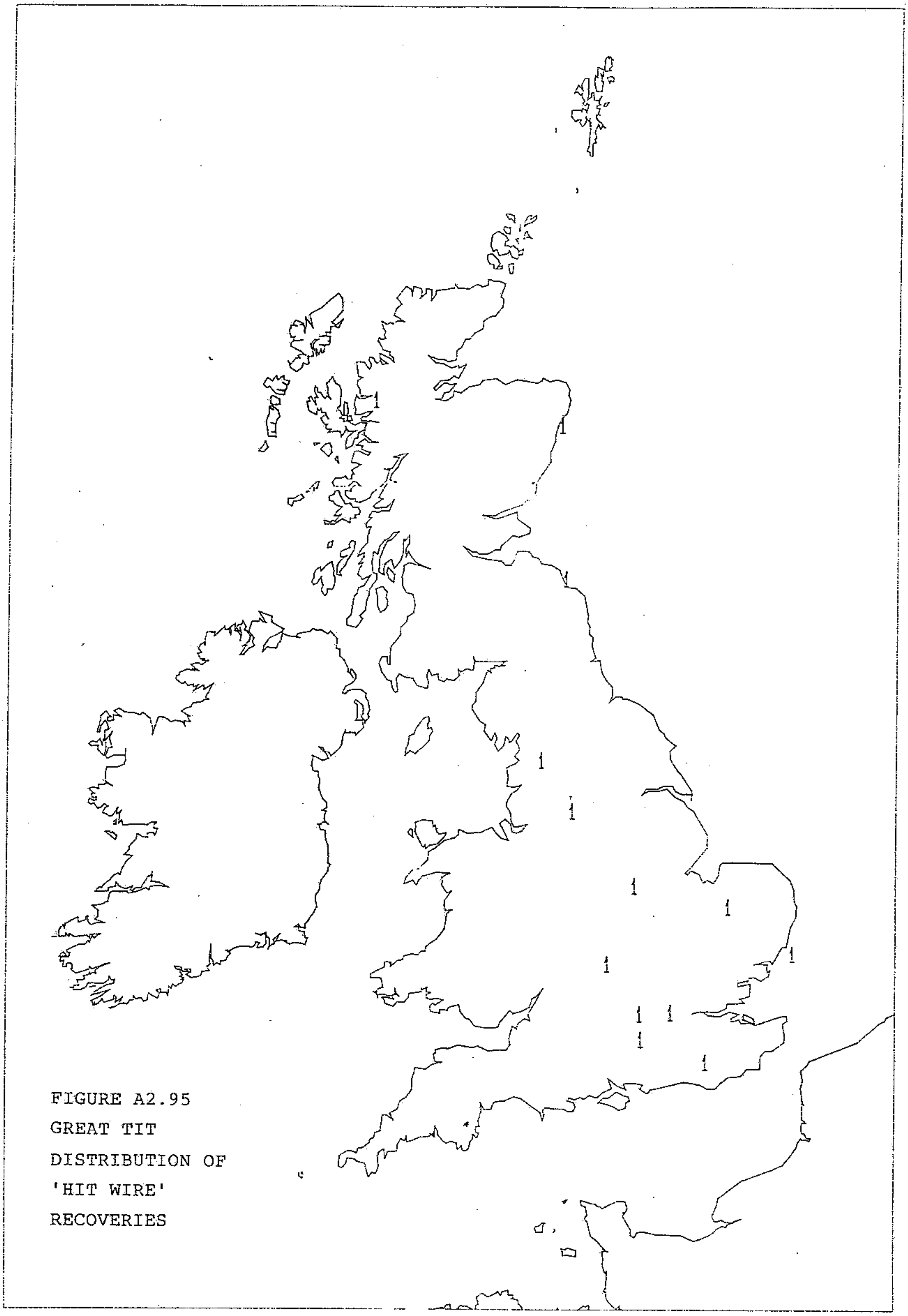

FIGURE A2.95
GREAT TIT
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

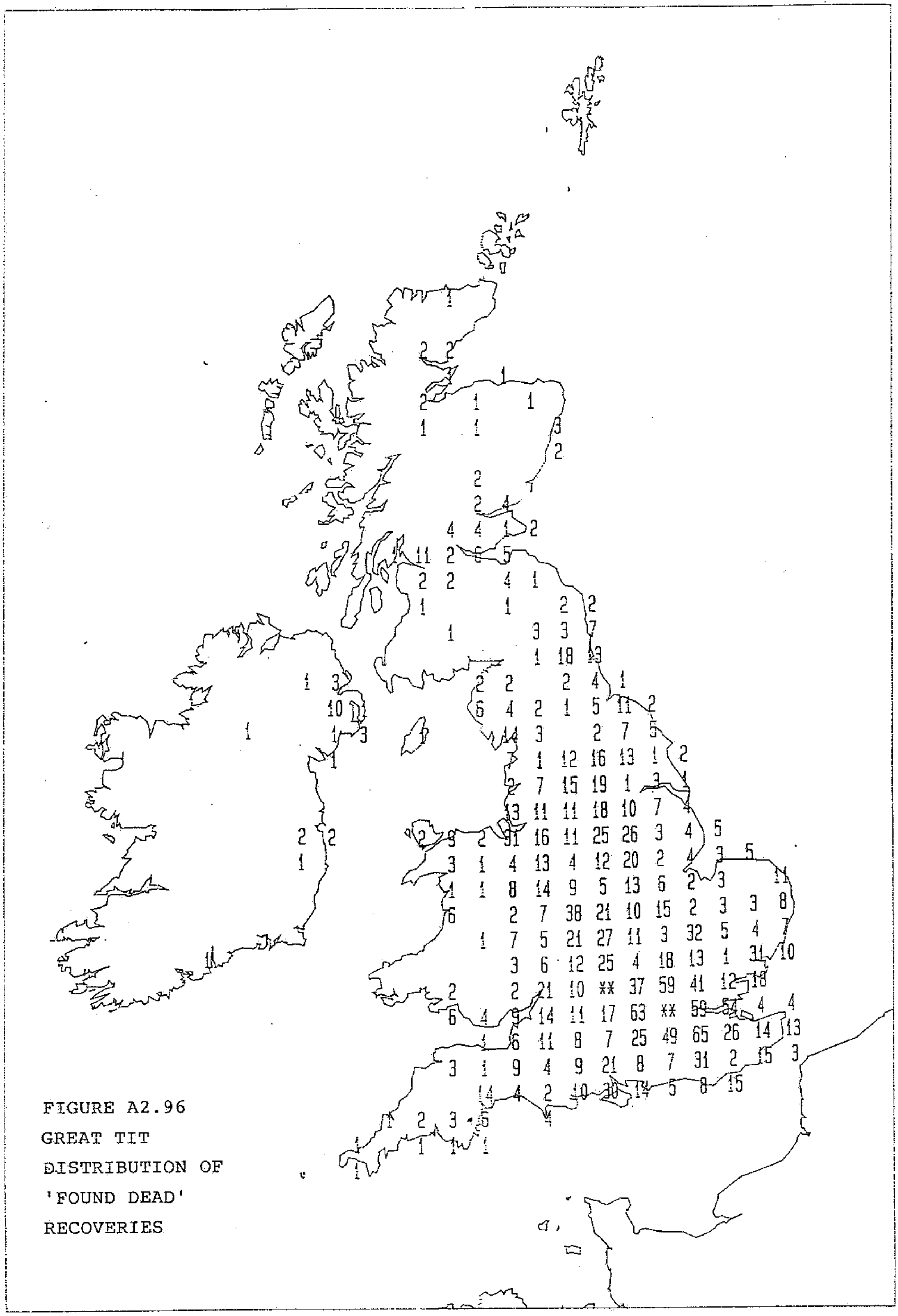

FIGURE A2.96
GREAT TIT
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

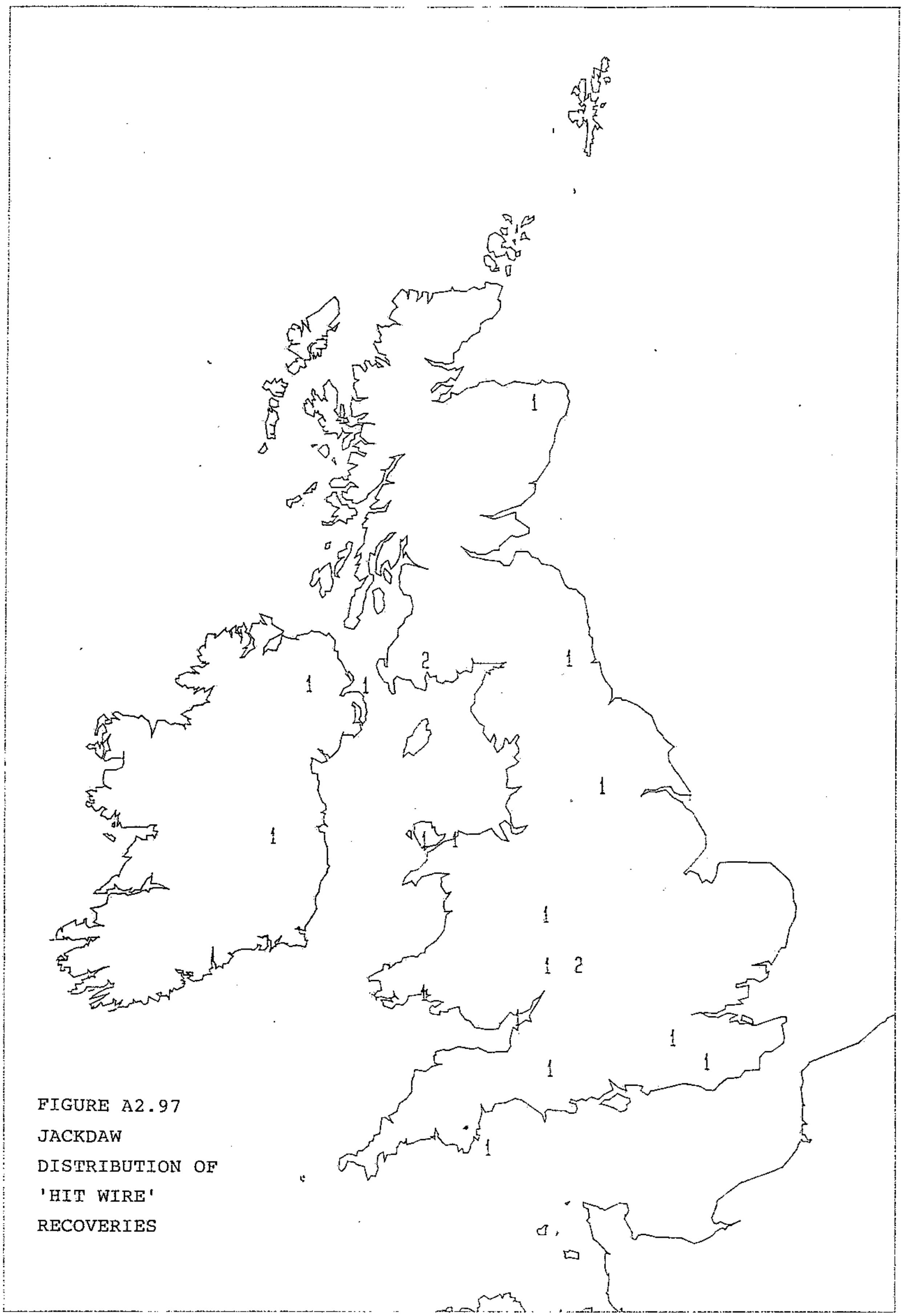


FIGURE A2.97
JACKDAW
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

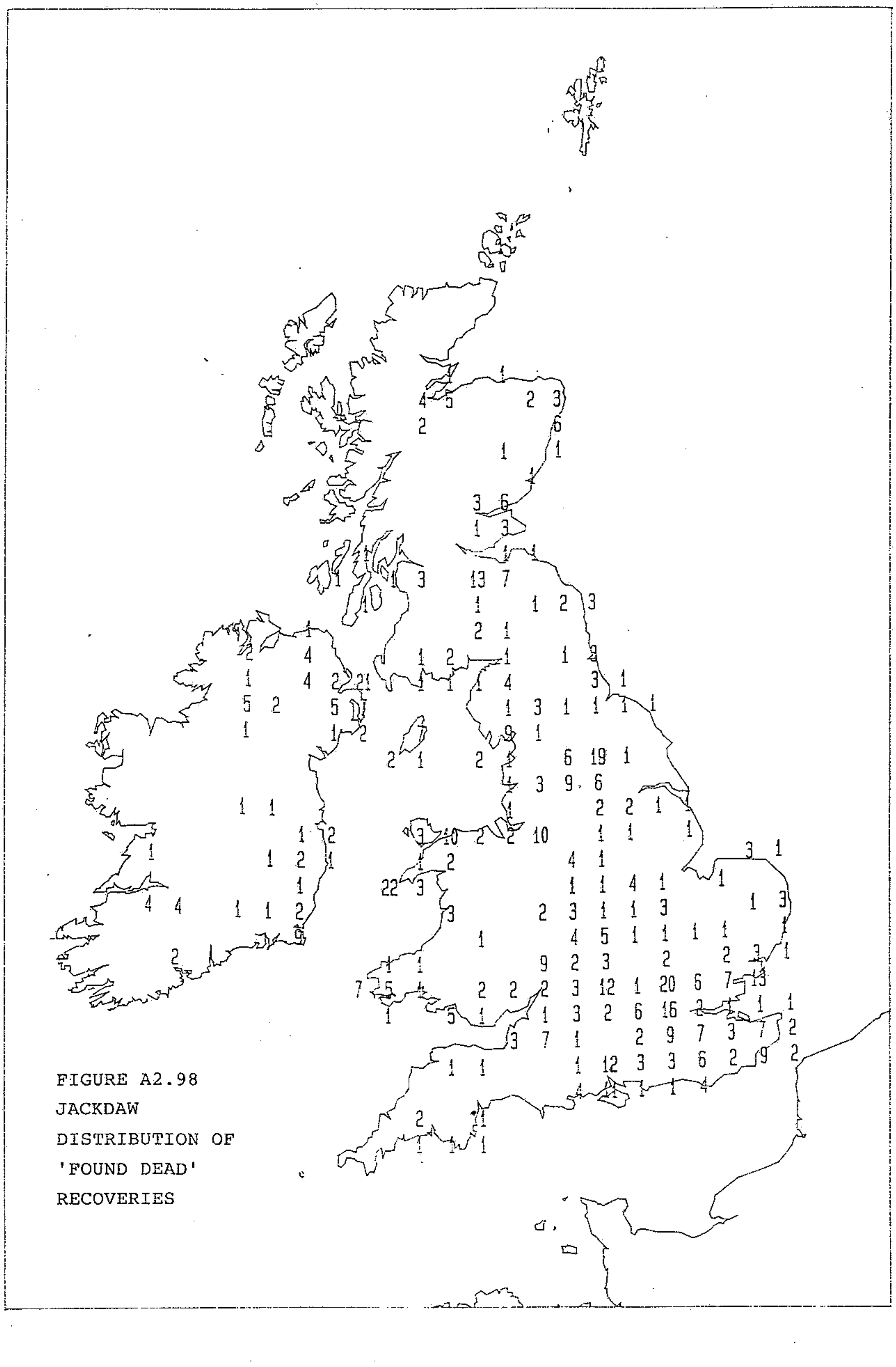

FIGURE A2.98
JACKDAW
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

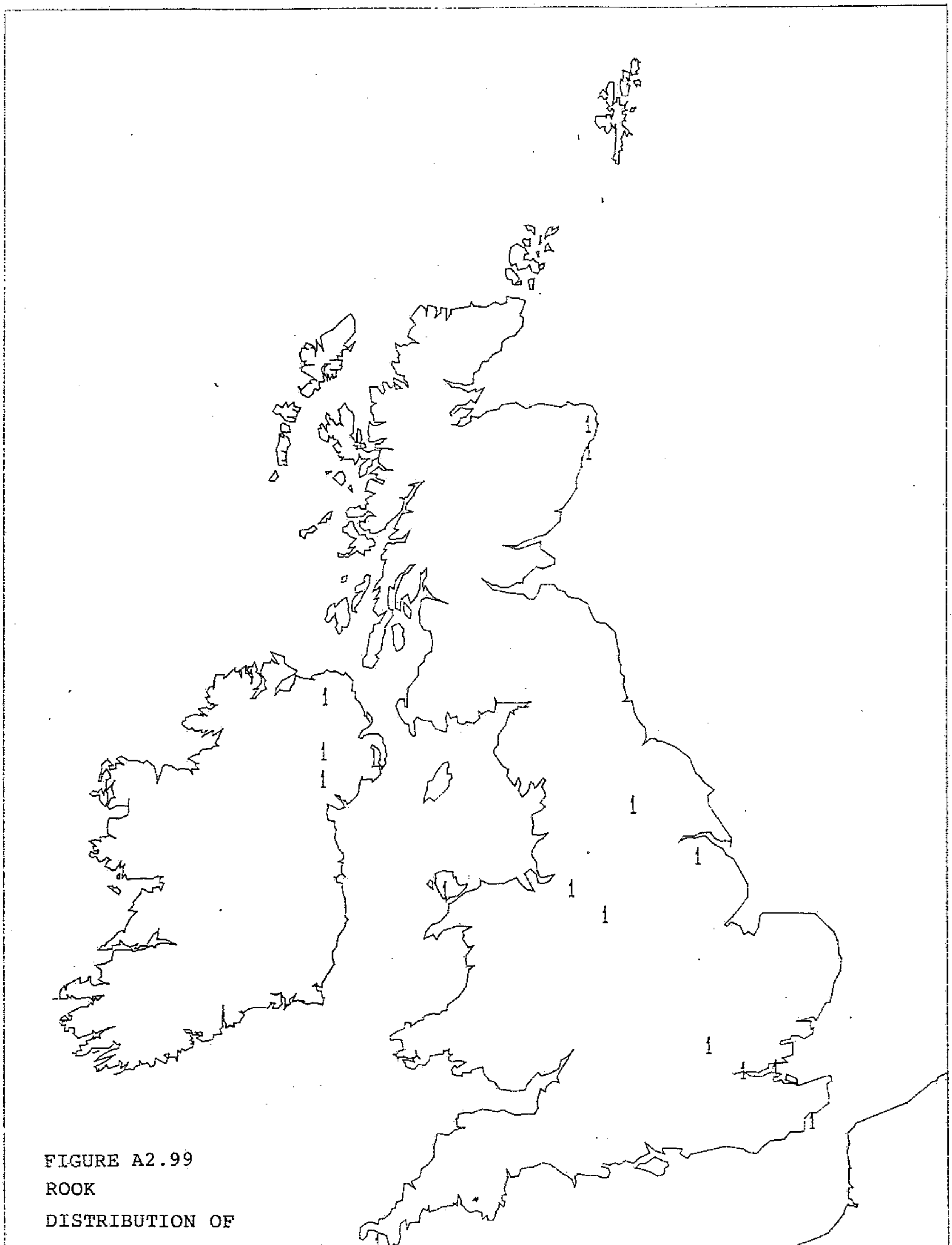

FIGURE A2.99
ROOK
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

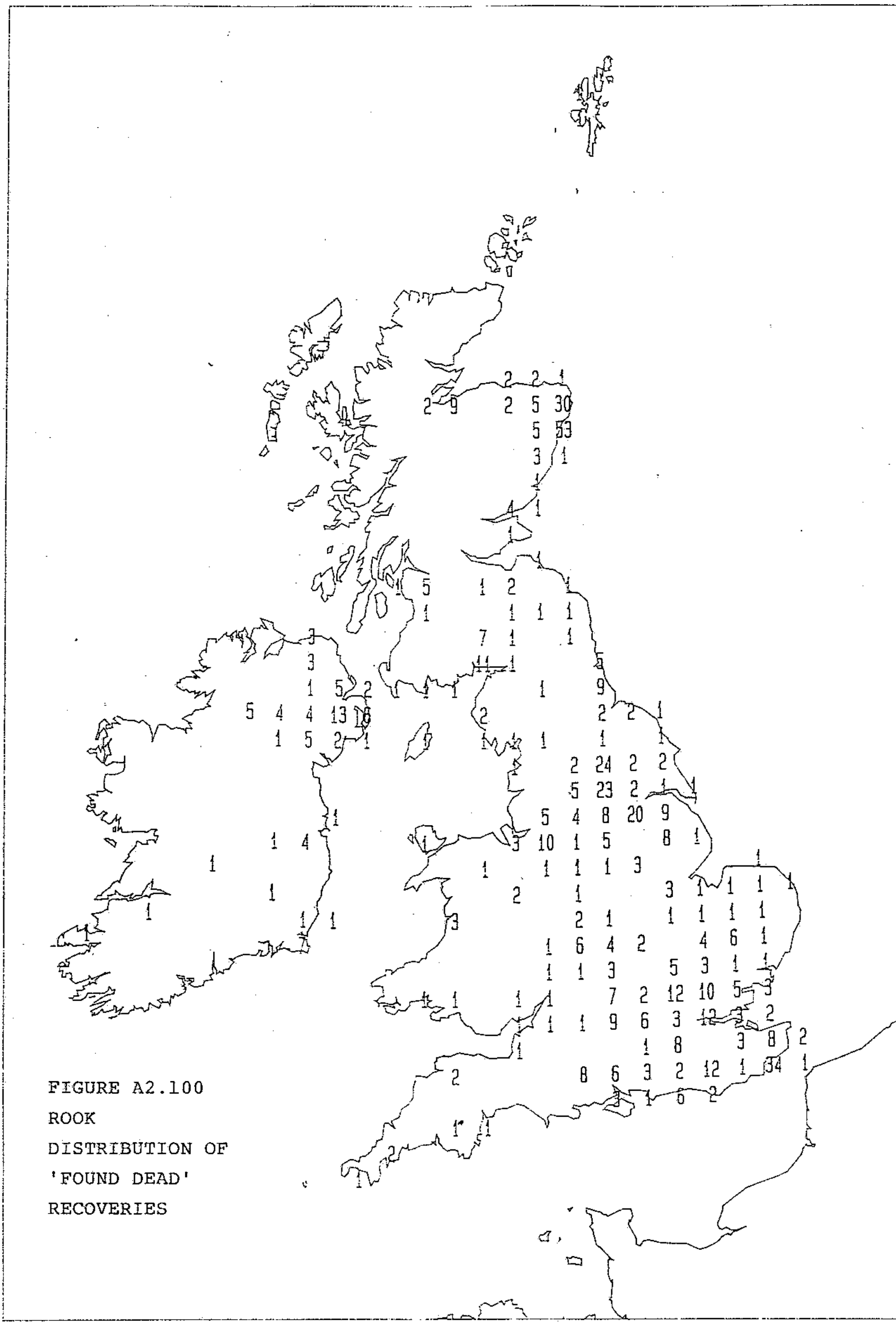

FIGURE A2.100
ROOK
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

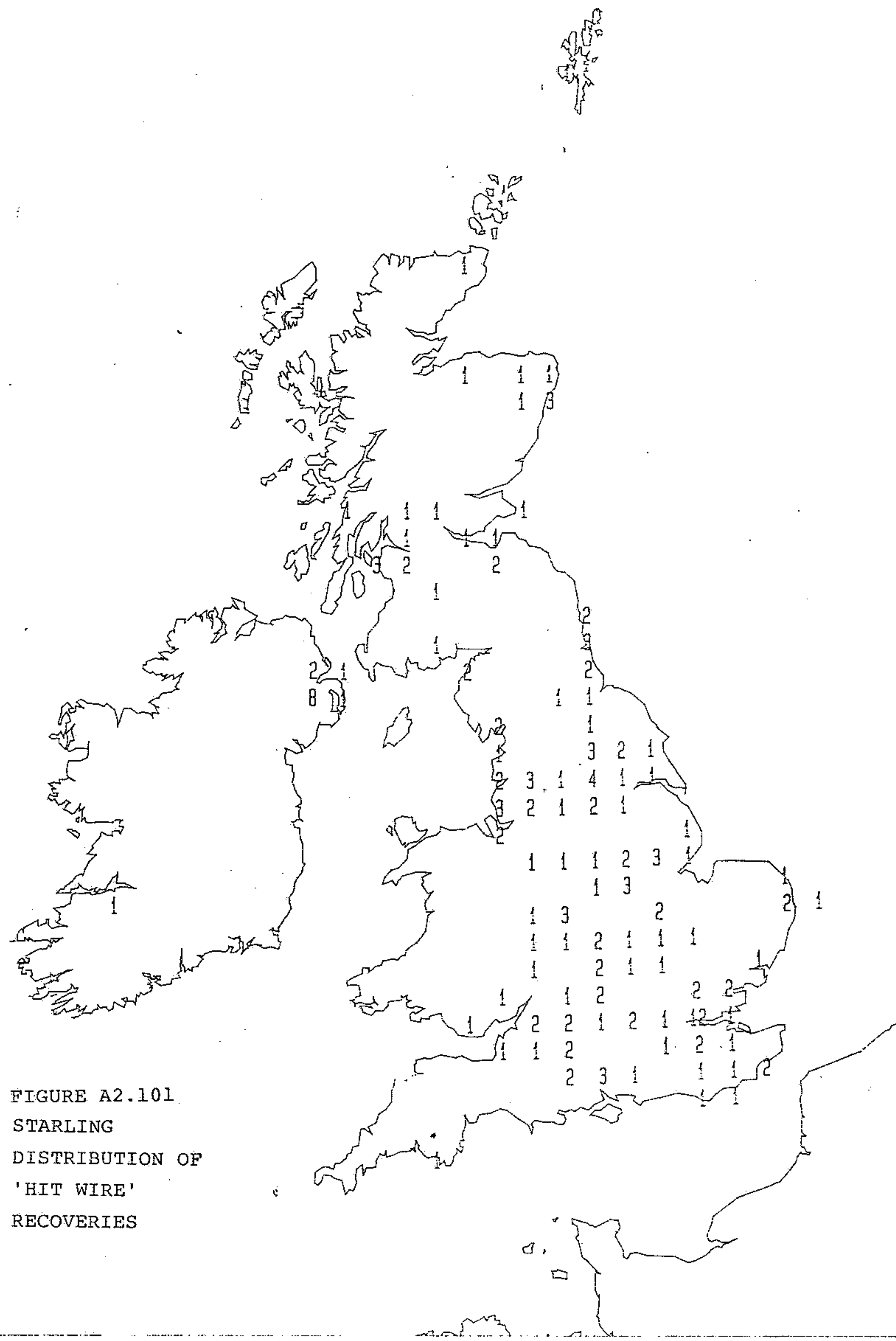

FIGURE A2.101
STARLING
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

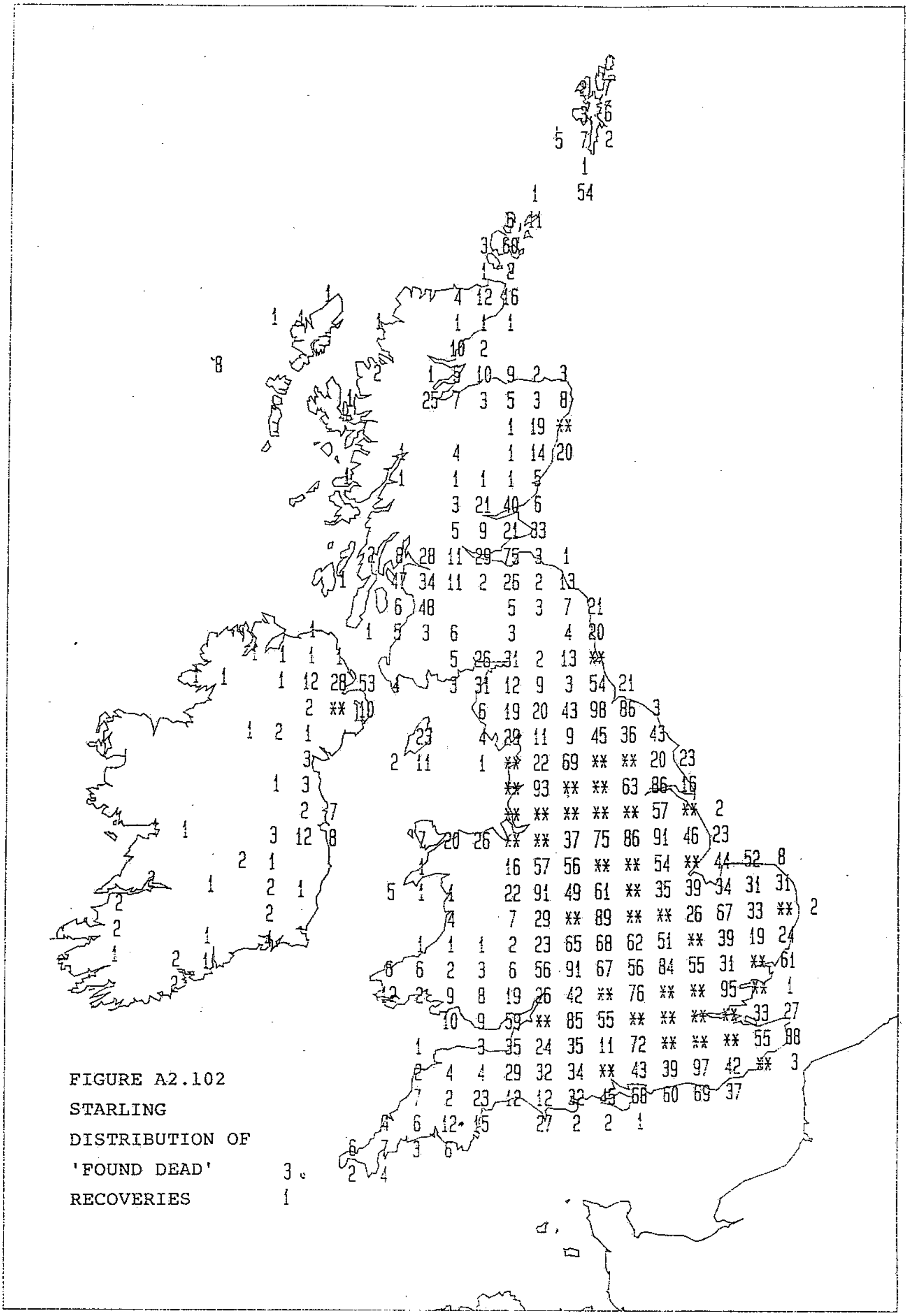

FIGURE A2.102
STARLING
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

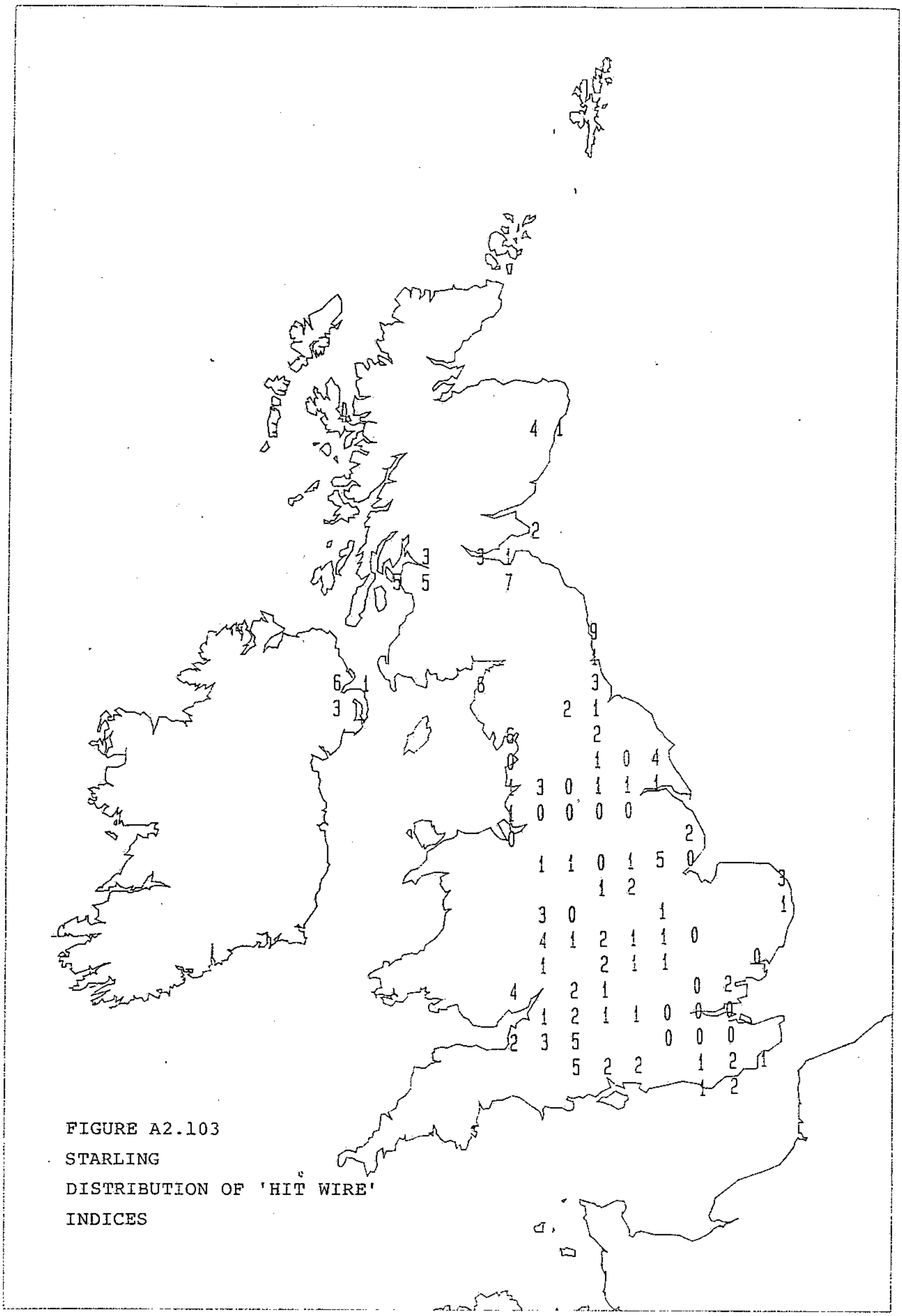

FIGURE A2.103
STARLING
DISTRIBUTION OF 'HIT WIRE'
INDICES

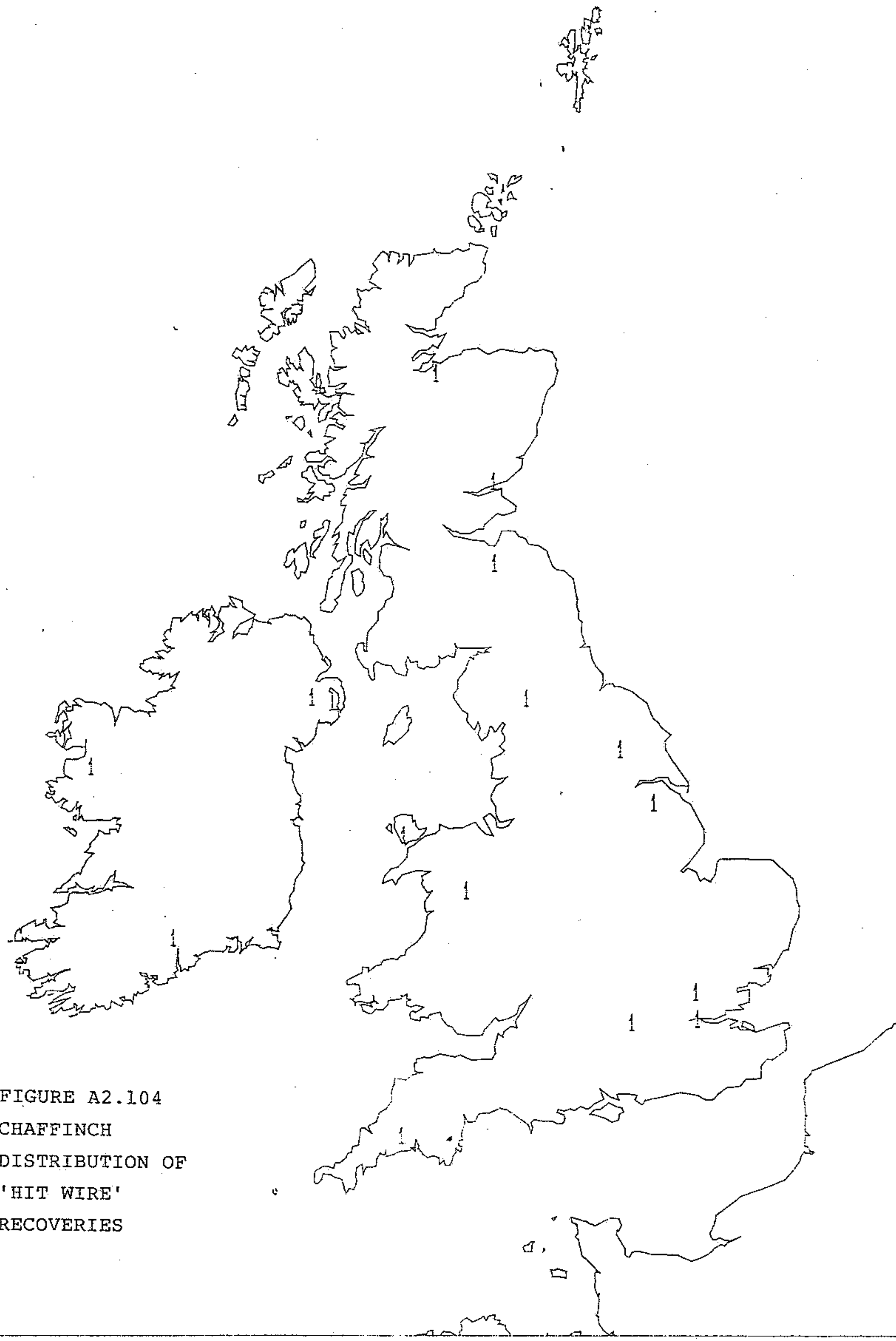

FIGURE A2.104
CHAFFINCH
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

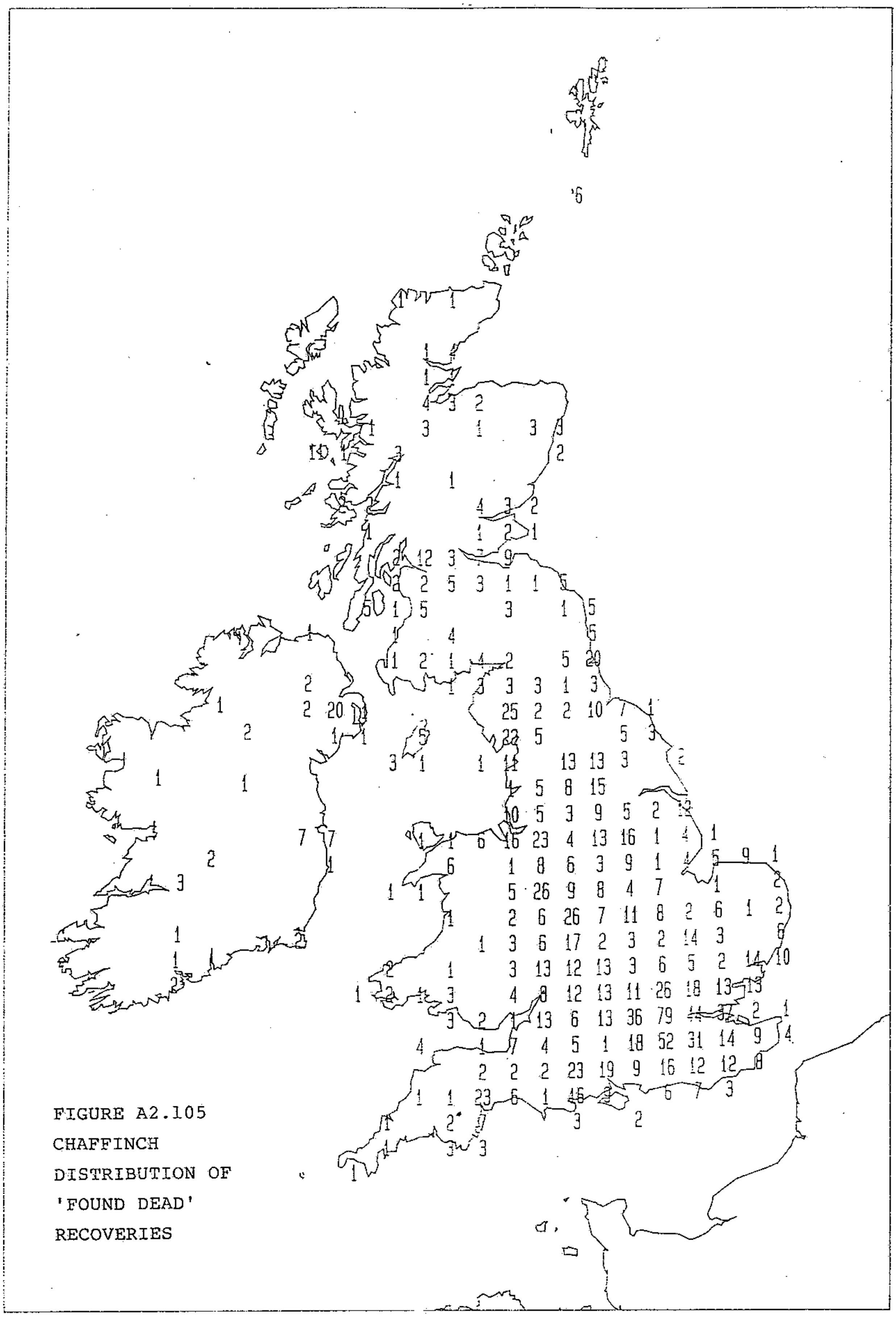

FIGURE A2.105
CHAFFINCH
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

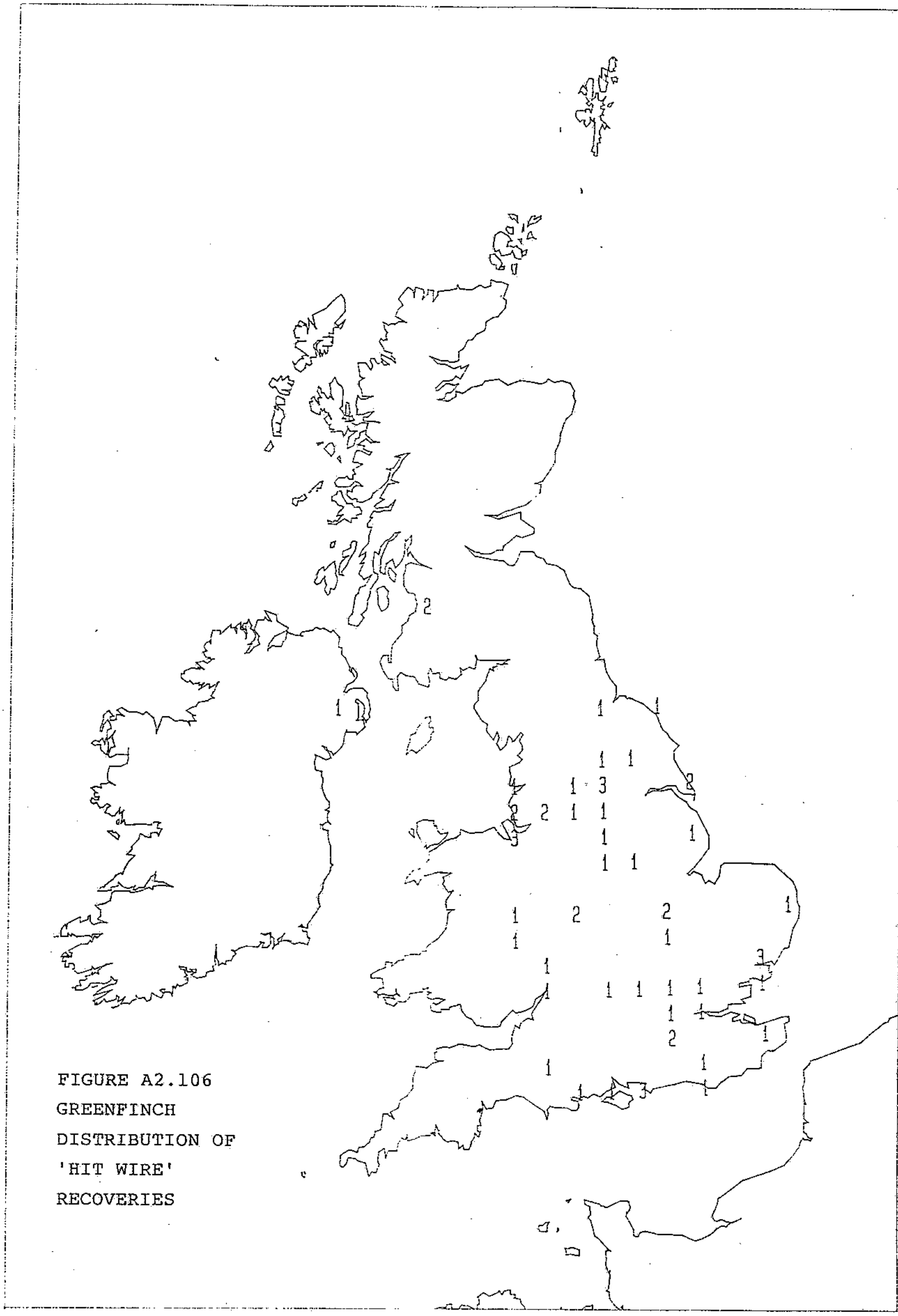

FIGURE A2.106
GREENFINCH
DISTRIBUTION OF
'HIT WIRE'
RECOVERIES

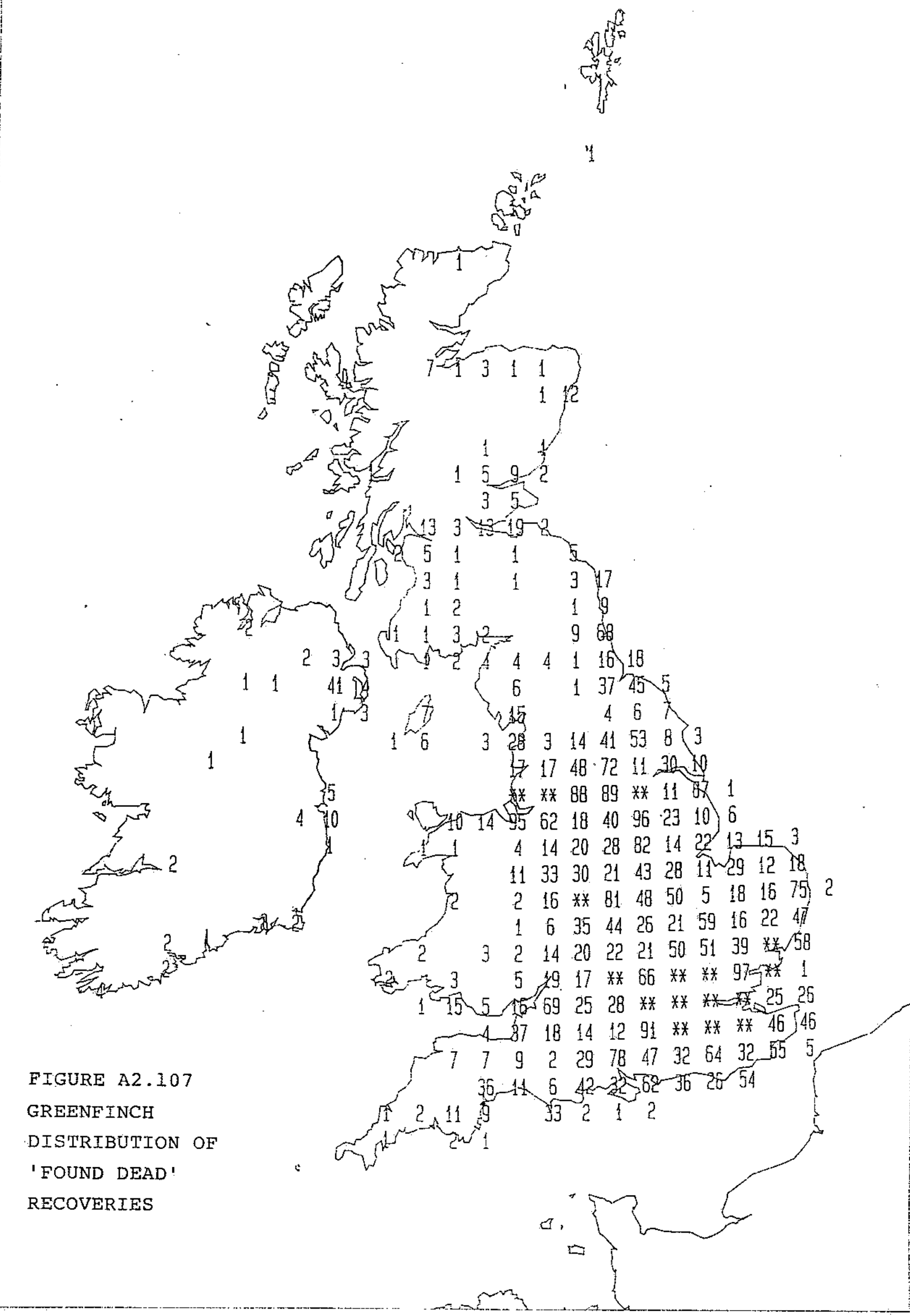


FIGURE A2.107
GREENFINCH
DISTRIBUTION OF
'FOUND DEAD'
RECOVERIES

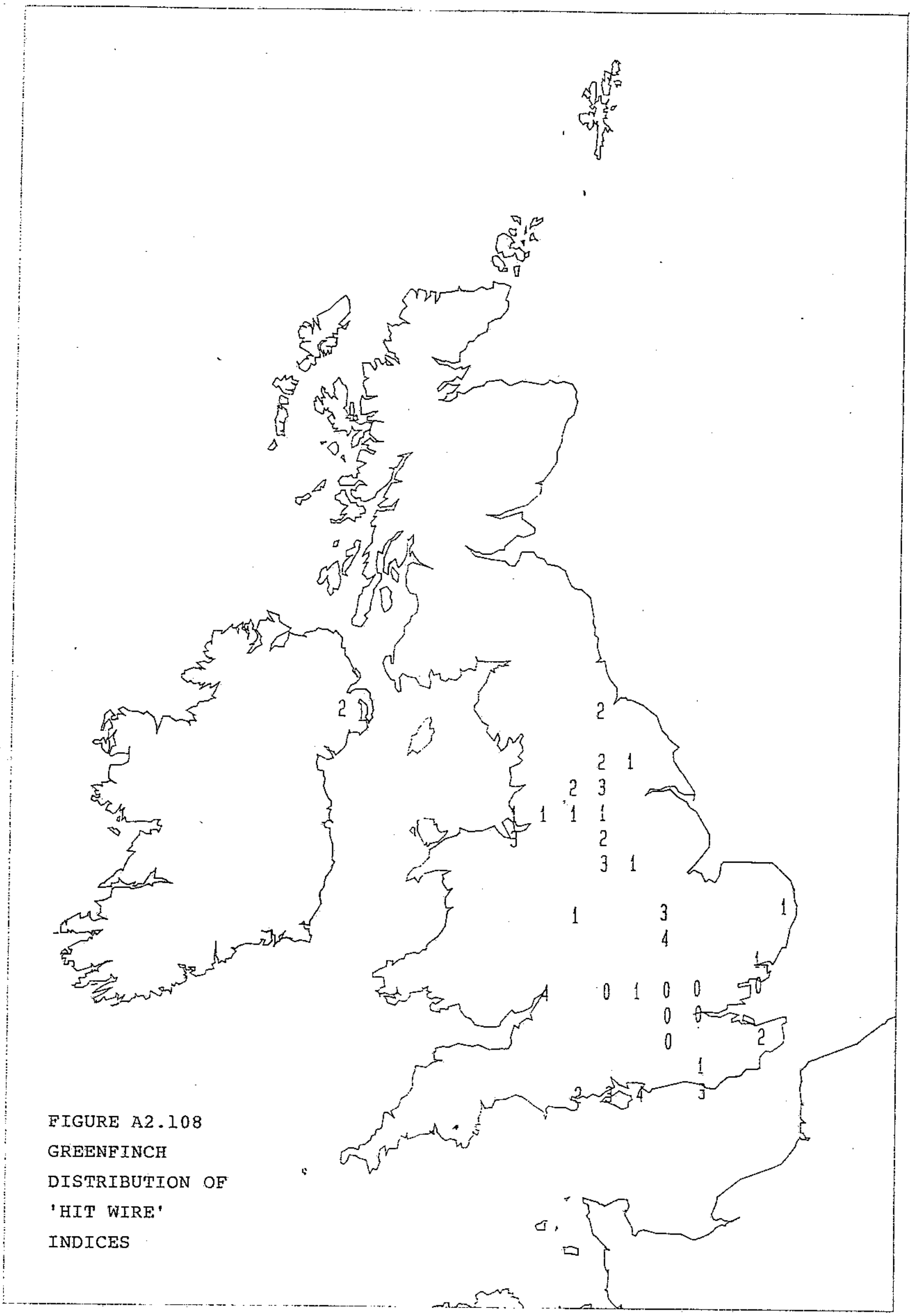


FIGURE A2.108
GREENFINCH
DISTRIBUTION OF
'HIT WIRE'
INDICES

# APPENDIX 3

## Scientific names of bird species referred to in the Report

| | |
|---|---|
| Little Grebe | *Tachybaptus ruficollis* |
| Great Crested Grebe | *Podiceps cristatus* |
| Fulmar | *Fulmarus glacialis* |
| Manx Shearwater | *Puffinus puffinus* |
| Storm Petrel | *Hydrobates pelagicus* |
| Gannet | *Sula bassana* |
| Cormorant | *Phalacrocorax carbo* |
| Shag | *Phalacrocorax aristotelis* |
| Bittern | *Botaurus stellaris* |
| Grey Heron | *Ardea cinerea* |
| Mute Swan | *Cygnus olor* |
| Bewick's Swan | *Cygnus bewickii* |
| Whooper Swan | *Cygnus cygnus* |
| Bean Goose | *Anser fabalis* |
| Pink-footed Goose | *Anser brachyrhynchus* |
| White-fronted Goose | *Anser albifrons* |
| Greylag Goose | *Anser anser* |
| Canada Goose | *Branta canadensis* |
| Barnacle Goose | *Branta leucopsis* |
| Brent Goose | *Branta bernicla* |
| Shelduck | *Tadorna tadorna* |
| Spur-winged Goose | *Plectropterus gambensis* |
| Wigeon | *Anas penelope* |
| Teal | *Anas crecca* |
| Mallard | *Anas platyrhynchos* |
| Shoveler | *Anas clypeata* |
| Tufted Duck | *Aythya fuligula* |
| Eider | *Somateria mollissima* |
| Ruddy Duck | *Oxyura jamaicensis* |
| Red Kite | *Milvus milvus* |
| White-tailed Eagle | *Haliaeetus albicilla* |
| Marsh Harrier | *Circus aeruginosus* |
| Hen Harrier | *Circus cyaneus* |
| Montagu's Harrier | *Circus pygargus* |
| Goshawk | *Accipiter gentilis* |
| Sparrowhawk | *Accipiter nisus* |
| Buzzard | *Buteo buteo* |
| Golden Eagle | *Aquila chrysaetos* |
| Osprey | *Pandion haliaetus* |
| Kestrel | *Falco tinnunculus* |
| Merlin | *Falco columbarius* |
| Hobby | *Falco subbuteo* |
| Peregrine | *Falco peregrinus* |
| Red Grouse | *Lagopus lagopus* |
| Black Grouse | *Tetrao tetrix* |
| Sage Grouse | *Centrocercus urophasianus* |
| Grey Partridge | *Perdix perdix* |
| Moorhen | *Gallinula chloropus* |
| Coot | *Fulica atra* |
| Sandhill Crane | *Grus canadensis* |

| | |
|---|---|
| Oystercatcher | *Haematopus ostralegus* |
| Stone-curlew | *Burhinus oedicnemus* |
| Little Ringed Plover | *Charadrius dubius* |
| Ringed Plover | *Charadrius hiaticula* |
| Dotterel | *Charadrius morinellus* |
| Golden Plover | *Pluvialis apricaria* |
| Lapwing | *Vanellus vanellus* |
| Knot | *Calidris canutus* |
| Sanderling | *Calidris alba* |
| Dunlin | *Calidris alpina* |
| Ruff | *Philomachus pugnax* |
| Snipe | *Gallinago gallinago* |
| Curlew | *Numenius arquata* |
| Redshank | *Tringa totanus* |
| Greenshank | *Tringa nebularia* |
| Green Sandpiper | *Tringa ochropus* |
| Turnstone | *Arenaria interpres* |
| Great Skua | *Stercorarius skua* |
| Black-headed Gull | *Larus ridibundus* |
| Common Gull | *Larus canus* |
| Lesser Black-backed Gull | *Larus fuscus* |
| Herring Gull | *Larus argentatus* |
| Great Black-backed Gull | *Larus marinus* |
| Kittiwake | *Rissa tridactyla* |
| Roseate Tern | *Sterna dougallii* |
| Common Tern | *Sterna hirundo* |
| Arctic Tern | *Sterna paradisaea* |
| Guillemot | *Uria aalge* |
| Puffin | *Fratercula arctica* |
| Stock Dove | *Columba oenas* |
| Woodpigeon | *Columba palumbus* |
| Collared Dove | *Streptopelia decaocto* |
| Turtle Dove | *Streptopelia turtur* |
| Cuckoo | *Cuculus canorus* |
| Barn Owl | *Tyto alba* |
| Little Owl | *Athene noctua* |
| Tawny Owl | *Strix aluco* |
| Long-eared Owl | *Asio otus* |
| Short-eared Owl | *Asio flammeus* |
| Swift | *Apus apus* |
| Kingfisher | *Alcedo atthis* |
| Great Spotted Woodpecker | *Dendrocopos major* |
| Skylark | *Alauda arvensis* |
| Sand Martin | *Riparia riparia* |
| Swallow | *Hirundo rustica* |
| House Martin | *Delichon urbica* |
| Tree Pipit | *Anthus trivialis* |
| Meadow Pipit | *Anthus pratensis* |
| Rock Pipit | *Anthus petrosus* |
| Yellow Wagtail | *Motacilla flava* |
| Pied Wagtail | *Motacilla alba* |
| Dipper | *Cinclus cinclus* |
| Wren | *Troglodytes troglodytes* |
| Dunnock | *Prunella modularis* |
| Robin | *Erithacus rubecula* |
| Bluethroat | *Luscinia svecica* |
| Whinchat | *Saxicola rubetra* |

| | |
|---|---|
| Stonechat | *Saxicola torquata* |
| Wheatear | *Oenanthe oenanthe* |
| Ring Ouzel | *Turdus torquatus* |
| Blackbird | *Turdus merula* |
| Song Thrush | *Turdus philomelos* |
| Redwing | *Turdus iliacus* |
| Mistle Thrush | *Turdus viscivorus* |
| Sedge Warbler | *Acrocephalus schoenobaenus* |
| Marsh Warbler | *Acrocephalus palustris* |
| Reed Warbler | *Acrocephalus scirpaceus* |
| Dartford Warbler | *Sylvia undata* |
| Lesser Whitethroat | *Sylvia curruca* |
| Whitethroat | *Sylvia communis* |
| Blackcap | *Sylvia atricapilla* |
| Chiffchaff | *Phylloscopus collybita* |
| Willow Warbler | *Phylloscopus trochilus* |
| Spotted Flycatcher | *Muscicapa striata* |
| Blue Tit | *Parus caeruleus* |
| Great Tit | *Parus major* |
| Nuthatch | *Sitta europaea* |
| Jay | *Garrulus glandarius* |
| Magpie | *Pica pica* |
| Chough | *Pyrrhocorax pyrrhocorax* |
| Jackdaw | *Corvus monedula* |
| Rook | *Corvus frugilegus* |
| Carrion Crow | *Corvus corone* |
| Raven | *Corvus corax* |
| Starling | *Sturnus vulgaris* |
| House Sparrow | *Passer domesticus* |
| Tree Sparrow | *Passer montanus* |
| Chaffinch | *Fringilla coelebs* |
| Brambling | *Fringilla montifringilla* |
| Greenfinch | *Carduelis chloris* |
| Goldfinch | *Carduelis carduelis* |
| Siskin | *Carduelis spinus* |
| Redpoll | *Carduelis flammea* |
| Crossbill | *Loxia curvirostra* |
| Bullfinch | *Pyrrhula pyrrhula* |
| Hawfinch | *Coccothraustes coccothraustes* |
| Snow Bunting | *Plectrophenax nivalis* |
| Yellowhammer | *Emberiza citrinella* |
| Reed Bunting | *Emberiza schoeniclus* |
| Corn Bunting | *Miliaria calandra* |