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South West Water Services Ltd
and
National Rivers Authority
South West Region

ROADFORD OPERATIONAL AND ENVIRONMENTAL STUDY

Draft Final Report

Volume 3 - Annex D Ecology
Annex E Recreation

November 1991

HALCROW

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Annex D

ECOLOGY

HALCROW

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FINAL REPORT

ANNEX D - ECOLOGY

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ANNEX D - ECOLOGY

D1 INTRODUCTION: DATA COLLECTION, AVAILABILITY AND ASSESSMENT

D1.1 General Introduction to the Ecological EIA

The manner in which Roadford is operated in relation to other water resource within Devon has the potential to affect (both beneficially or adversely in all cases) the ecology of six estuaries (Dart, Plym, Tavy, Tamar, Torridge and Taw), Devonport Leat, the freshwater reaches of the Meavy/Plym, Wolf/Thrushel/Lyd/Tamar and Okement/Torridge, as well as Burrator, Meldon and Roadford Reservoirs.

The areas affected are shown in Figure D1a. The extent to which each of the areas shown will be affected varies greatly; for this reason discrete units have been treated separately in the data collection and assessment process. Sixteen 'units' have been identified and these are numbered 2-17 in the Figure. Subsequently this Annex details the known data/interest of each of the unit areas and then assesses the potential impacts of the Halcrow Operating Case (ie D2 Dart Estuary, D3 Meavy/Plym system etc).

The data collection has combined the information collected by the old Water Authority over the past fifteen years with any relevant information found in the literature and made available through the consultation process with the local and national conservation agencies. For details see Annex C. The aim of the data collection exercise is to enable an assessment of ecological impact to be made for each of the affected 'units'.

The Interim Report detailed the majority of the information known about habitats and biota potentially impacted by Roadford's operation. these were then considered in the consultation process which involved conservation bodies who appraised both the negative and positive aspects of various operational scenarios.

In this Annex the potential impact of the proposed operation of Roadford is considered in the sixteen 'units' of river, estuary or reservoir which have been highlighted in Figure D1a. Each is treated in a standard manner. First the extent of available data for habitats and biota in the defined area is identified. From this the interest, whether typical or special, is highlighted (providing there is sufficient data to do this). Once the level of information, and its ecological significance has been considered, the potential impact of Roadford's operation is then assessed.

D1.2 Data Availability

Through the data-gathering process, and consultation, it became clear that a detailed freshwater ecological 'data base' exists only for the Wolf and Lyd sub-catchments. Data of relevance to the investigation is therefore somewhat disparate. For some aspects of biota for the Wolf there are tomes whereas for the rest of the river systems there is virtually nothing. For the

Lyd sub-catchment and Tamar there are more data of relevance than for the rest.

Where surveys, or information presented in the literature, are specifically related to only one of the single 'units' identified in Figure D1a, these data are referred to in the section of this Annex which deals with that unit alone. Where surveys, or the literature, have wide applicability, these are described in this section of the Annex and referred to, when appropriate, in the individual 'unit' assessments. Data introduced in this Section are presented as an Appendix to facilitate easier reading.

As a general rule, information on fish and river invertebrates is almost entirely confined to work done by the old Water Authority and some very recent surveys of the newly formed NRA (plus specific investigations undertaken specifically in relation to Roadford). For terrestrial habitats and general biota of rivers - ie bankside vegetation, mammals, birds, macrophytes etc virtually all the relevant data comes from external sources.

For the estuaries and the Lyd sub-catchment there is a wealth of information. All the estuaries have had both a sub-tidal and inter-tidal survey, together with a review of recent and historical literature; within the past five years. As part of the Roadford investigation a number of extensive and intensive investigations have been executed on the Wolf/Thrushel/Lyd/Tamar downstream of Roadford. As a result a database of almost unparrallel quality is available for assessment of impact here.

D1.3 Estuaries

For the six estuaries there is quite extensive information. All have been surveyed, and a literature review undertaken, by the Field Studies Council's Oil Pollution Research Unit. These were commissioned by the Nature Conservancy Council. Detailed information is also available for the birds of the six estuaries. All are counted monthly for winter wildfowl, details of which are held by the Wildfowl and Wetland Trust at Slimbridge. However summaries of each month's counts for the estuaries is given in the Annual Report of the Devon Bird Watching and Preservation Society. Waders in the estuaries are also counted monthly from August to May. These counts are carried out as part of the British Trust for Ornithology's Birds of the Estuaries Enquiry. Summary data are again given annually in the Devon Bird Report of the DBWPS with details held at the BTO.

From data provided, it is clear that the bird interest of some of the estuaries affected by Roadford is considerable. This interest relates to waders and wildfowl in winter; the breeding interest is not of major significance. Since some data are relevant to all the estuaries, illustrative features of the relative interest is given in Figure D1b. This Figure shows the national winter distribution of 12 waders and six wildfowl species (from Lack; 1986) which are of either local or national significance in one or more of the estuaries affected. The same Figure also shows the location of oystercatcher and shelduck breeding sites in Devon (from Sitter, 1988). These are the only birds of significance which breed on the estuaries

affected. The term 'significant' is a subjective term but implies that common birds such as mallard which nest in small numbers would not be included; similarly neither would less common or rare birds that bred only occasionally.

D1.4 Mammals

The south west of England is well known for remaining a stronghold for otters. It is known that virtually all the rivers and estuaries affected by Roadford are used by otters some for breeding.

Consultation with Mary Rose-Lane from the Tarka Project confirms that **ALL** rivers affected are utilized by otters. It is not policy to make public precise location of either breeding or resting holes. In the context of this study it is deemed unnecessary since risk to them is not regarded as an issue. It is important to note that the otter is a Schedule 1 animal under the Wildlife and Countryside Act 1981; this requires not only protection of the animal itself but its feeding, breeding and resting habitats.

Water voles and water shrews are the only other mammals of note which are closely associated with rivers. Data for both are sparse. It is noteworthy that in the detailed survey of Heath (1989) on the Lyd sub-catchment traces of neither of these river mammals were found. Since we do not understand fully the habitat requirements of the water vole and water shrew it is impossible to assess whether or not they will be impacted. No further reference will be made to them since the only potential adverse affects perceived are confined to the Lyd sub-catchment where they appear not to be present.

Although some bat species are closely associated with rivers, providing structures and trees are not removed or damaged, they will be unaffected. For this reason they are not considered further in the study.

D1.5 Amphibia

Frogs and toads are both amphibia which are associated with river valleys. As Heath (1989) found on the Wolf, frogs are associated with pools and ponds and rarely with rivers. It is not uncommon on the other hand for toads to breed in rivers. Apart from the data compiled by Health for the Lyd sub-catchment no data on amphibia has been obtained. Thus, no comment of scheme impact on this group will be made except for the Lyd sub-catchment.

D1.6 Birds of the Rivers

Birds most associated with rivers are dipper, grey wagtail, kingfisher, heron and sand martin. The first three are the ones most associated with the rivers affected by Roadford and have been surveyed in some detail in Devon during 1988. The results of these surveys should be available soon through the Devon Bird Watching and Preservation Society (John pers comm). The breeding distribution of the above birds in Devon is shown in

Figure D1c, taken from Sitters (1988). Minimal further reference will be made to sand martin since these birds are associated with rivers where there are soft earth cliffs; these habitats will not be affected by Roadford. Their food is entirely aerial insects so this too will be unaffected by Roadford's operation. Little reference will also be made to herons. These birds nest in discrete 'heronries' which are normally woodlands near water. The rivers are thus only important as a feeding ground. For such birds the important aspect of Roadford's operation is to consider its impact on their diet of fish.

For dipper, grey wagtail and kingfisher there are many aspects of the operation of Roadford which could affect them. Examples include direct effects such as increased or decreased risk of predation, drowning of nests, or improved or reduced feeding areas. The more serious indirect effects are centred around how changes in regime will affect their staple diet of river invertebrates and fish.

D1.7 Macrophytes of the Rivers

There is reasonable coverage of macrophyte data provided through the surveys of Holmes; these have been executed as part of his national programme for the Nature Conservancy Council and as specific commissions from the old Water Authority and the NRA as part of their drought monitoring exercise. Through these sources there is some information for the Tamar, Lyd, Thrushel, Wolf, Torridge, Okement and Meavy. In contrast Heath (1989) has provided a clear picture of the macrophytes of the Lyd sub-catchment, including a more detailed appraisal of the specialised liverworts and mosses. Holmes (1991) also provides details of habitat associations of macrophytes and bryophytes for a number of sites on the Lyd. Figure D1d shows the location of sites covered on the Tamar and Lyd catchments by Homes in 1986 and the plant data are presented in Table D1i. Table D1ii gives the location of sites surveyed on the Torridge and Okement in the same year with the data presented in Table D1iii.

The surveys highlighted that few rare species are found in the rivers. Figure D1e shows the distribution of two plants which are locally rare. The hybrid *Potamogeton* x *nitens* has been known to occur in the Torridge at Beaford since the 1940s. As shown in the figure, it was the only known locality in south-west England. The 1979 NCC surveys of Holmes found further plants at Torrington and Weare Gifford. The former record was confirmed during the drought monitoring surveys of 1989. *Potamogeton berchtoldii* (Small Pondweed) was found in both the 1980 and 1986 surveys in the Tamar whilst a new locality on the Torridge (downstream of the Torrington intake) was discovered during the drought monitoring of 1989.

Information for river bank plants is very sparse. The Devon Wildlife Trust highlighted the presence of *Hymenophyllum* (Filmy Fern) on the banks of the Meavy and data are available for the Lyd sub-catchment through the surveys of Heath (1989) and Holmes (1991). The recorders for the Botanical Society for the British Isles have been included in the consultation process.

However it is very unlikely that bank plants will be affected most in rivers by the operation of Roadford. Edge plants may be affected on the Wolf, Thrushel and, perhaps, the Lyd due to the effects of large augmentation releases in summer and HEP generation in winter. Changes in drawdown of Burrator might also affect its 'edge' plants here.

The possible impact on aquatic and marginal plants is considered for all river 'units' affected by Roadford.

D1.8 Freshwater Fish

Quantitative and qualitative information have been collected on the freshwater fish populations of the major rivers in the South West. The majority of the data have been documented by experienced staff of SWW and the NRA using standard electrofishing techniques, and as such records can be considered authentic.

A total of fourteen, species have been recorded in the six river catchments affected by Roadford in surveys from 1982-1989. Table D1iv shows the species recorded in each of the rivers. This may not be a comprehensive list but it will include the most abundant fish species. Any omissions are due to either the very localised distribution of a particular species or the species is present at an extremely low density.

The list of species for the Dart, Taw and Tavy are for sites above the intakes, no sites having been surveyed downstream. However, most are expected to occur either in the ponded section above the intake or immediately downstream. The list for the Tamar is derived also from sites not lying between Lydfoot and Gunnislake.

An idea of the spatial distribution of the fish species in the Tamar catchment (including the Lyd sub-catchment) and the Tavy and Meavy/Plym is shown in Figure D1f in the Appendix. This not only gives an idea of how commonly they occur in these rivers but also indicates their distribution in other rivers in Cornwall and West Devon. Details of the Salmonid fishery interest is dealt within in Annex F.

Although quantitative information is reported for most non-salmonid species, its value and accuracy is questionable. A better use of the data is as an index of the dominant species and the relative abundance.

The six rivers can be divided into two equal groups based on the most abundant non-salmonid species. The rivers of the first group are the Rivers Tavy, Plym and Dart. Overall these rivers can be characterised as being spate rivers with steep gradients, draining moorland and of consistently high water quality (1A). The most abundant non-salmonid species in each catchment are the eel and bullhead. The rivers of the second group are the Rivers Tamar, Torridge and Taw. These rivers represent the larger, less flashy and slow-flowing rivers that drain various geological formations and are of variable water quality (1B & 2). In addition, to the eel and bullhead, the most abundant non-salmonid species include the stoneloach and

minnow. In both river groups, other species are present but at low density and abundance levels. The greater species diversity reflects the greater habitat diversity of the larger rivers.

The indigenous salmon and trout stocks are the dominant species in the region and as such the management of these stocks receive priority. The importance of these species is in the fact that the six rivers support important sport and commercial fisheries.

The grayling is limited in its regional distribution to only two or three rivers. The River Tamar and its tributaries supports a small grayling population. The cleaner well oxygenated tributaries such as the Lyd and Tavy are favoured.

It is considered that there will be no significant effect on the freshwater fish stocks located downstream of Gunnislake on the Tamar, Lopwell on the Tavy, Newbridge on the Taw, Torrington on the Torridge and Littlehempston on the Dart.

The importance of the estuaries to fish species not listed in Table D1iv cannot be ignored. Many are important spawning, nursery and feeding grounds to both valuable commercial species and species of high conservation value. The proposed operation of Roadford proposes to improve lowest flows and therefore have no impact. The operation of Roadford provides opportunities for improvements in conditions for fish the Tamar below the Lyd. This will result from augmentations from Roadford which will improve water quality and increase the wetted area of the river under drought and low-flow conditions.

The effect of supply releases on the in-river flows will be most marked in the River Wolf. Maximum daily supply releases will increase the volume by 19 fold, increase the water velocity by 0.45 m/sec and increase the depth by a maximum of 30 cm. These effects will become progressively reduced downstream as channel width increases. The supply releases will have a small effect on the wetted surface area when compared to the significant increase due to the compensation release alone.

The absence/reduction of destructive spates and the greater seasonal flow constancy, on the Wolf will lead to greater bank and bed stability and hence enhanced plant growth. This may be considered a benefit to certain species but the elimination of spates will result in decreased fluvial geomorphological activities which redistribute bed materials and washout fines. The potential impact of siltation on the river bed is considered a temporary phenomenon which should be minimised and contained by subtle manipulation of river flows.

The supply releases will benefit the river environment for fish by enhancing the natural flow regime, increasing wetted surface area of river bed and increasing the area and diversity of physical habitat available. Any adverse effect of flow regulation would result from large and rapid flow variations. It is, however, now proposed that no rapid change in flow will be

associated with either water supply or HEP releases. Although there will be no diurnal fluctuations associated with supply releases, diurnal fluctuations in flow will occur if specific HEP releases are made in the winter. These daily pulses may have an impact on the spawning behaviour of salmonids which will need further investigation. However, in general the higher mean daily flows and greater seasonal flow constancy will compensate for the adverse effect of any daily fluctuations.

Under conditions of maximum supply release there should be a marked improvement in water quality of the main stream Tamar downstream of Lydfoot (see Annex B). The reduced temperatures will be beneficial to salmonid fish when temperatures in the river can reach a daily peak of 23-24°C. Conversely, long periods of constant releases of lower than ambient water temperature may have some effect on the growth rate and recruitment of species such as dace, bream and minnow.

In summary, fish species will benefit from the improved water quality and increased wetted surface area and depth associated with supply releases. Possible impacts are the lower water temperature and higher current velocity, (mainly associated with HEP releases). The velocity changes are unlikely to induce scour so species associated with the bed of the river are unlikely to be affected. The increased flows may result in flushing of the silts which will reduce the habitat available for larvae of lamprey. The more stable flow regime will benefit the minnow populations but any dramatic increase in summer flow or temperature reduction would be detrimental to non-salmonids.

D1.9 Invertebrates of the River

The database thus far is almost entirely based on information gathered by the NRA, South West Water, and its successor bodies. The only exception is information concerning odonata from the Lyd sub-catchment reported by Heath (1988).

There is a most comprehensive set of data from the Lyd sub-catchment, including separate sampling within habitats such as tree roots and vegetation. There are no data for the Dart, Tavy, Taw or Torridge between the points of abstraction and their estuaries. Some quantative data are available from the Meavy, Devonport Leat, Tamar, Okement and Torridge; however much is of limited value in assessing the impacts on specific species which might be affected.

All invertebrate data that are available are considered separately when assessing the known biota, and potential impacts, in each of the separate 'units'. The extent and type of available data for stretches of river affected other than the Lyd sub-catchment has meant that little could be gained from detailed appraisal.

D1.10 Water Quality Issues

During consultation it become clear that water quality issues were the major concern of the conservation agencies. Problems in warm summers in the Taw/Torridge and Tamar estuaries were well known and reported to us (RSPB reported problems in the Taw/Torridge for 1975, 76, 83, 84 and 89). However the concerns were not ones of having a direct affect on birds but an indirect one by impacting upon the breeding of the invertebrates on which they feed. This aspect is being investigated for both estuaries and the initial assessment is that the operation of Roadford will not add to the present problems; indeed it has the potential to give slight improvements (see Annex B).

There is also concern, especially from the Devon Wildlife Trust, for water quality in the rivers Wolf, Thrushel, Lyd and Tamar downstream of Roadford Reservoir. There was particular concern for nutrient levels, oxygen demand and temperature changes and how these might affect invertebrates, and then birds dependent on them (and fish) for food. For the Tamar estuary, further still downstream, the greatest concern was that no deterioration of water quality should occur to affect the invertebrates of the mudflats, the feeding ground of the nationally important population of avocets.

As part of the Roadford EIA, NRA SW Region undertook water quality modelling of the Tamar. This is reported in Annex B. A discussion document produced during the study gives a good indication of likely water quality changes in the Wolf, Thrushel, Lyd and Tamar. By inference any changes in freshwater quality will affect estuarine water quality. Since the water quality is so important when considering the potential effects of Roadford's operation on biota, a brief resume of the key findings is given here.

When Roadford is providing a constant 9 Ml/d compensation flow the following is likely to occur:

> **Temperature** differences will be marked in the Wolf and very little altered in the Tamar. From September to May the average temperatures in the Wolf will be about 2°C higher than now; in very cold winters it will be higher still. On the Lyd there will be minimal changes in this period and changes will be undetectable on the Tamar in winter. In summer (June, July and August) the water will be much colder in the Wolf. In an average year this will vary from 1-5°C but in hot summers the temperature difference from the natural will be even greater. Changes in temperature will still be apparent on the Lyd (about 2°C reduction in temperature from that upstream) and a very slight cooling (0.5-1°C) will be detectable on the Tamar. Temperature changes could affect both plant and animal productivity.
>
> **Dissolved Oxygen** will generally be lower in the Wolf (by about 2mg/l) in the winter but be higher (by the same amount) in summer. There will thus be a very stable DO regime which is healthier in the summer when organisms might be most stressed when temperatures

are higher. There is minimal difference detectable on the Lyd or Tamar although there is a hint of improved DO in the Tamar.

Biological Oxygen demand is predicted by water quality studies to be unchanged from the natural state but the demand will be lower in the Tamar than at present.

Nitrogen levels will be lower from May to September in all the river reaches below the reservoir; there are no significant differences in winter levels.

When Roadford is augmenting river flows to the maximum the following effect on water quality has been predicted through the model:

Flow in the river Wolf will be more or less at mean winter levels through this summer period; there will not be the natural 'peaks' or 'troughs' associated with a natural regime. There will be a significant increase in flows in the Lyd but these will not approach the mean winter flows. On the Tamar the summer levels will be also dramatically increased but the flows will be small when compared even with the winter base flows.

Temperature changes will be marked, 5°C reductions for the Wolf, Lyd and Tamar at Gunnislake not being uncommon. Such major reductions in temperature at Gunnislake would be limited to hot and dry summers.

Dissolved Oxygen levels will be increased in all the rivers downstream of the reservoir during such augmentations. The improved levels are very evident for the Tamar from May to August.

Biological Oxygen Demand does not change in the Wolf, becomes slightly reduced in the Lyd, and is dramatically lower in the Tamar.

Nitrate levels become lower in the Wolf from May to September and massively lower in the Tamar. There is little change in the Lyd; trends are for lower levels but in a dry period it is possible to have slightly elevated levels for short periods.

During HEP releases in winter the following effects are likely:

Temperature will increase by an average of more than 2°C in the Wolf and to some extent (c0.5°C) in the Lyd. There would be no detectable changes in the Tamar.

Dissolved Oxygen will slightly increase in the Wolf, Thrushel and Lyd.

Biological Oxygen Demand is generally reduced. However the reductions during the Monday to Friday operation is followed by a

distinct, but short, rise during the weekends when there are no special HEP releases.

Nitrate changes insignificantly.

The above information suggests that Roadford, either providing compensation flow or major augmentation, will be beneficial to the whole of the Tamar downstream of the Lyd. This applies to the estuary too. It is likely that the greater the need for abstraction at Gunnislake, the greater the benefit will be to the Tamar Upstream.

The impact on the Lyd is likely to be small and probably not affect its biota. Improvements resulting from a healthier summer DO might be offset by the potential influence of changes in temperature which might affect the breeding cycles of temperature-sensitive invertebrates.

Major changes will occur on the Wolf. The water quality will be generally much better and show less seasonal variations. Temperature changes will be significant and may have a major influence on invertebrate breeding.

D2 DART ESTUARY

The operation of Roadford will influence the Dart by affecting the amount of water which can be reliability taken from the Dart at Littlehempston and the neighbouring radial gates. There is only a very short stretch of freshwater between the intake and Totnes Weir, the upper limit of the estuary. The freshwater section is so short that consideration of potential impacts will be confined to the estuary.

A survey and literature review of the Dart estuary was undertaken in 1987, and reported on in 1988, by the Field Studies Council Oil Pollution Research Unit (OPRU; 1988). This report highlights that the estuary is long and narrow, some 18km from Totnes to its mouth below Dartmouth. The estuary has steep sides and the freshwater flow is comparatively greater than in most other inlets on the south Devon coast, such that full marine conditions are not experienced until its mouth. In the upper and middle estuary (c10km to Dittisham) the shores are predominantly of mud. The popularity of the estuary near Dartmouth for sailing has led to high concentrations of the antifouling paint TBT in the Dart.

In describing the habitats and species of the Dart estuary, the OPRU report concludes that neither are diverse and best described as 'typical'. The upper and middle zones, potentially at risk from river abstraction, are considered to be 'natural', lacking 'diversity', not 'fragile' (naturally a stressed community due to daily and seasonal fluctuations in conditions), not 'vulnerable' and with no urgency to protect anything. This said, it was noted that the presence of *Balanus improvisus* (brackish water barnacle) is of particular interest. However it is not thought to be vulnerable to the changes likely to occur as a result of the operation of Roadford. In conclusion, the Report states that 'The Dart does not compare well, in terms of diversity of marine habitats, communities or species, with many marine inlets further west. The intrinsic appeal of the estuary is its greater asset' but the 'reduction in concentrations of TBT in the water is likely to help the larval growth of many marine species'.

Reference to Sitters (1988) and Prater (1981) - see Figure D1b shows that the Dart estuary has poor populations of breeding birds, wader and wildfowl. Breeding birds have been reported by Sitters (1988), which shows that very few birds characteristic of estuaries breed on the Dart. The lack of reedbed and marsh means that only the odd pair of reed warblers nest there whilst the moorhen, more common inland, also finds a few suitable nest locations. Heronries are common on the steep wooded slopes of the Dart estuary, giving the area significant interest in the county. The only other common breeders are mute swan and shelduck, both species being typical of most Devon estuaries. The possibility of water rail being a breeder has also been indicated. The Dart estuary at Totnes gained great interest in 1979/80 when gadwell were recorded breeding for the first time in Devon (Sitters, 1988). Since then the breeding population has moved to Slapton and Beesands.

Wildfowl and waders are regularly counted and data are held by the BTO and the WWT. Recent data have not been obtained since there has been no indication that a major change has occurred in recent years. The total number of waders and wildfowl using the Dart is surprisingly small, according to Prater (1981). Dabbling ducks predominate, with maximum numbers of mallard (190), curlew (120) and redshank (100) occurring in the winter on the western mud flats of the upper and middle estuary. Soper (1986) reports this to be the best part of the Dart estuary for birds. The site is not of regional or national importance for birds although mute swan, shelduck, wigeon, teal, pochard, tufted duck, oystercatcher, ringed plover, lapwing, dunlin and turnstone are regularly recorded. Owen *et al* (1986) have reported reasonable numbers of tufted duck above swallowfields weir.

There are no data for invertebrates or fish below the intake.

Neither the estuary nor the lower reaches of the Dart itself have statutory or local nature conservation designations. Two Sites of Special Scientific Interest are present on the banks of the estuary above the high water mark.

The effect of Roadford's operation is to improve freshwater flows to the Dart estuary during low flows. Considerable improvement to the historic situation occur in both 'normal' and 'dry' years. Slight decreases in flow occur when river levels are high; however the proportional decrease is miniscule compared with the almost doubling of the existing residual flows. As such the operation of Roadford is deemed to be potentially beneficial to the Dart.

D3 MEAVY AND PLYM DOWNSTREAM OF BURRATOR

Roadford's operation has the potential to affect the Meavy and Plym systems by altering the nature and timing of Burrator supplies. Through this it will affect when, and how frequently, Burrator spills.

Burrator was built almost a century ago and has thus had a major affect on the Meavy system. To some extent it has also influenced the Plym. Because the impoundment can either eliminate totally, or at the very least attenuate the effect of, large floods, wetland habitats dependent on regular inundation are not important in the valley. Those dependent on water table related to the river may still be present. No important wetlands in the river corridor have been identified through the consultation process. However, roadford's influence could not impact upon terrestrial habitats on the valley floor in the future. The only possible affect on interests of the river valley is to the oceanic lower plants in the wooded slopes abutting the river. DWT have reported the presence of Filmy-fern (*Hymenophyllum*) in woodlands close to the Meavy downstream of the dam. Spilling of the reservoir during the summer is likely to increase moisture content here and be beneficial to this fern. As spilling in summer is not the most efficient use of water resources this is likely to be reduced. However in several years this does not occur anyway (most frequently in years when they would be under greatest stress because of a hot dry period). This suggests that they should not be adversely affected to any degree. For the benefit of salmon fishing, spilling will aim to take place by late autumn in all years. Failing this enhanced flows will be achieved through controlled releases.

The Meavy/Plym system is, for some as yet unknown reason, established as an important breeding area for the feral exotic introduction mandarin (see Figure D3a). According to Turner (in Sitters; 1988) the mandarin has been present on the Plym for several years and breeding is now confirmed from several localities. Mandarin are an uncommon bird in Britain and Turner has indicated that they are in a 'precarious state' in their homelands of Asia. The Plym community is therefore important since the British population is now of international importance. However, the impact of Roadford is likely to be minuscule.

Reference to Figure D1c (Appendix A) shows that dipper breed very successfully down the whole of the Meavy and Plym (downstream of the Meavy). The same Figure also shows kingfisher breeding in the lower reaches of the Plym and grey wagtail throughout the whole system. Sand martin does not breed on the river but there is a heronry sited a short distance downstream of Burrator.

Reference to Devon Bird Reports for the 1980s indicates that the diversity of wildfowl in winter is low in the Plym estuary. Mallard are always counted in reasonable numbers but the only other bird that is encountered regularly is shelduck. The same Reports indicate that the wader population is of greater interest. Dunlin are often counted in large numbers but are at other times totally absent. Oystercatcher, ringed plover, curlew and redshank are

encountered regularly. The speciality of the Tamar, black-tailed godwit, is also occasionally counted.

Some quantative and qualitative invertebrate information is available for the Plym and Meavy. These data show a fauna indicative of very high water quality in the Meavy; this improves the fauna in the Plym below its inflow.

The Meavy has been shown to be a very important salmonid fishery (see Annex F). Non-salmonid fish are few (see Table D1iv), confined to eels and three-spined stickleback. The Plym has slightly more, including bullhead, eel and brook lamprey in the non-tidal reaches.

A feature of the Meavy is the luxuriant macrophyte growths that occur in the river. No formal surveys of more than isolated locations appear to have been undertaken. Figures D3b and D3c give information gathered during the drought monitoring of 1989. The same site was also resurveyed in 1990 and showed little change due to the impact of the drought. The site surveyed is located at Gratton, about 4km downstream of Burrator. Data gathered during that survey, and previous casual observations at other locations down the Meavy, suggest that the community is unusual, in having a very high standing crop, but with no rare species present. It is unusual to find such a luxuriant growth of higher plants associated with oligotrophic rivers.

No rare plants were recorded but some species warrant comment. For instance, the submerged alternate-flowered water-milfoil (*Myriophyllum*) and spanner-leaved water-starwort (*Callirichte*) were both present at abundance levels exceeding 25%. Both the ivy-leaved and round-leaved crowfoot (*R. hederaceus* and *R. omiophyllus*) were present growing side by side. It is also highly unusual to find water-cress (*Rorippa officinalis*) growing alongside lesser spearwort (*Ranunculus flammula*). The former is most associated with chalk rivers where water chemistry is vastly different from that of the Meavy. The one common factor of the Meavy and chalk streams is the stable flow regime.

There is great ecological interest in the Meavy. The reason why there is such botanical and invertebrate interest is the stability of bed resulting from reduction of spates and enhanced low flows through compensation discharges. The present regime is near perfect. Summer flows in droughts are higher than they would be under natural conditions, spilling of the reservoir always occurs, and water quality is good. Although the timing of spilling is important for salmonid fisheries, it is not for ecological interests. Thus the critical point is that it periodically does spill, but when through the winter is unimportant. Spilling ensures that the bed does not become clogged with silts but the attenuation of flows by Burrator ensures that the floods with the force to move the bed and remove vegetation are very rare indeed.

The operation pf Roadford could change the Meavy very subtly through reduced winter scour only. This should be monitored through plant and invertebrate monitoring.

D4 TAVY DOWNSTREAM OF LOPWELL

The Tavy, estuarine below Lopwell, could be impacted by the operation of Roadford because water abstractions here can be used in conjunction with Burrator and Roadford Storage.

The Tavy estuary is a tributary of the Tamar estuary which was subjected to a detailed survey and literature review by the Field Studies Council Oil Poliution Research Unit (OPRU; 1986). Although present within the large study area, no intertidal or sub-tidal sites within the Tavy estuary were sampled. Previous surveys of the Tavy were however considered. The Tavy is described in the Report as part of the 'Central Estuarine' zone where fucoids dominate. Nothing of particular interest was noted for the Tavy, but it must be considered that it forms part of what the report describes as one of the most extensive marine inlets studied which shows better developed responses to salinity changes than any other surveyed. Nineteen plants and animals were listed as being of conservation importance in the estuary, but none were present in the Tavy.

The birds of the Tamar estuary are of great significance (NCC, RSPB pers comm), warranting national recognition (see D9 for details). Unlike the Taw/Torridge estuary, it has not be notified as an SSSI. However it is being considered, and the Tavy below Lopwell is included within the provisional boundary. Reay (pers comm), organiser of the Tamar estuary count for the BTO Birds of Estuaries Enquiry, reports that the Tavy estuary is counted separately from the rest of the Tamar (which is split into 12 areas which have synchronised counts). These data are held by the BTO. Records for waders during the 1980s (from Devon Bird Reports) suggest that the Tavy has reasonable numbers of oystercatcher, curlew and redshank recorded through the winter with intermittent records for dunlin (one of the specialities of the Tamar complex), snipe, lapwing etc. Black-tailed godwit, one of the most important birds of the Tamar, is rarely recorded. The estuary is poor in comparison with many of the smaller estuaries for wildfowl (Devon Birds Reports through the 1980s). As with all the estuaries in Devon (with the exception of the Exe), waders and wildfowl fail to find many suitable nest sites on the Tavy.

Reay (1988) has shown that the Tavy does contribute to the importance of the Tamar Estuary generally in respect of the avocets (see Figure D9b). However the 1987/8 counts indicate that it is 'relatively unimportant'. In certain periods of the year, and particularly under adverse weather conditions (very cold or very strong winds) the Tavy is thought to play an important role. Reay also reports that in the 1970s (Figure D9c) the Tavy was used much more than now, on some occasions being more important than the famed Tamar itself.

There is no consideration of the freshwater sections of the Tavy since the intake is situated at Lopwell, the retaining weir being built where the river was previously tidal.

Despite the Tavy below Lopwell being considered for SSSI notification, it is difficult to see how the proposed operation of Roadford could adversely affect its present interest. The hydrographs clearly show that very little freshwater reaches the Tavy estuary for long periods during the summers of most years because of the transfer of water to Morwellham for generation of HEP and present abstractions. In periods of low flow these are very significant takes of water. Since the interest of the estuary has been maintained whilst this has continued it is not possible that water taken for public supply in the way proposed, could adversely affect present conditions.

The proposals enable low flows to the estuary to be enhanced, and as such, must be considered potentially beneficial. On the other hand there is a trade-off whereby more water is taken from the river during much higher flows. Apart from the impact upon migratory animals (ie salmonids) the potential adverse impacts must be regarded as less than the potential improvements from the increased low flows. As the reduction in high flows is proportionally greater than in other rivers, some limited monitoring should be undertaken to determine if there are any adverse impacts.

D5 DEVONPORT LEAT

The Leat will be affected by the operation of Roadford by having reduced flows passing down it in some periods to enable more water to be retained in the Dart system. This element of the scheme has already been implemented.

During the construction process it became clear that little attention has been paid to this artificial, but ancient, open water conduit. Observations made by the authors, and rapid inspections made by Liverpool University's Environmental Advisory Unit (Halcrow; 1988), suggests that vegetation is sparse. The Halcrow report states:

> "The vegetation of the Leat is susceptible to considerable changes in water flow as the rest of the system, and it is sparsely vegetated for most of its length. Macrophytic species include *Callitriche stagnalis, Potamogeton polygonifolius, P.berchtoldii, Jucus bulbosus*, as well as aquatic mosses. At various sections of the leat visited brown trout were observed".

Observations made by the author indicate that the dominant species are the macrophytes *Juncus bulbosus* (Bulbous Rush) and *Callitriche hamulata [intermedia]* (Spanner-leaved) [Intermediate] Starwort) with *Potamogeton polygonifolius* (Bog Pondweed) locally common. *Myriophyllum alterniflorum* (Alternate-flowered Water-milfoil) is also present. The most common bryophytes are the liverworts *Scapania, Solenostoma* and *Chiloscyphus* and the mosses *Fontinalis antipyretica, F.squamosa, Hygrophypnum ochraceum* and *Rhynchostegium riparioides*.

There are few data on invertebrates.

A W G John (pers comm) has indicated that the odd pair of dipper and grey wagtail nest on the Leat; apart from this there is little known about its birds. It is unlikely that it has any major interest.

No information exists on the fish stocks of the leat. However brown trout do reside in the leat (visual observations) together with possibly eels and bullheads. Despite higher prescribed flows to the Dart, the sweetening flow required to maintain water supplies and protect the aquatic environment generally will be sufficient to ensure existing fish are not affected.

Since flows down the Leat have to be maintained at all times to supply isolated homesteads with water, there is no threat to it becoming dry. On the known interest of the Leat, there is nothing which is likely to be significantly and adversely affected by the operation of Roadford. However some monitoring would be required to ensure that reduced flows did not cause sections to become unacceptably shallow; if this was apparent, local engineering works should be considered to alleviate the problem.

D6 RIVER LYD SUB-CATCHMENT (WOLF, LOWER THRUSHEL, LOWER LYD)

The Wolf, Thrushel below the Wolf, and Lyd below the Thrushel, are the sections of freshwater river most likely to be impacted by the operation of Roadford. Impacts will be imparted through several distinct paths, all resulting from the affects of having a large part of the Wolf valley impounded. The main ways in which this will influence biota are:

- Elevated summer levels due to the compensation releases being about nine times higher than drought flow.

- Decrease incidence, and possibly elimination of major floods in the Wolf.

- Very low winter flows in the upper Wolf except when HEP and scour releases are being made.

- Reduction in erosion and increased stabilisation of the river bed; this is likely to be confined to the Wolf.

- Potential to increase clogging of gravel interstices through a combination of physical and chemical changes.

- Changes in water quality, including temperature. It is likely that water quality will improve and the river will become more homothermal; winter temperatures will increase more with greater HEP generation and summer temperature fall more when augmentation flows are greatest.

There are other subtle changes which will occur too. However the ones outlined above are the ones which will most affect river plants and animals. Different aspects are more important for some groups (or individuals with differing requirements within the same group) than others.

The previous Water Authority instigated many detailed investigations in the 1980s to obtain a comprehensive database of the Lyd sub-catchments before impoundment. Many of these (eg fisheries and invertebrates) were undertaken in house whilst others were contracted. These surveys provide a particularly good basis for assessing the potential impact of Roadford's operation. Indeed, the fishery and invertebrate studies continued through the construction and filling phases so that some of the predictions of impact can be tested.

The adoption of HEP generation rules does not form part of the TOR of this study. However it is an area of interest for ecology. During the early rounds of consultation there was great concern for the impacts that rapid diurnal fluctuation might cause (these were proposed as they maximised tariffs). However the recent adoption of policies for generation of 'green energy' has resulted in the need for such fluctuations to be dropped from consideration. Present proposals suggest generation at a steady state in the winter months when water is available; the flows resulting in the Wolf

will be small compared with natural high flows in the pre-impoundment condition.

D6.1 Invertebrates

The majority of invertebrate surveys were executed by the Roadford Project team, managed by Hugh Sambrook. Data have been collected before, during and after construction of the reservoir. These data have been primarily quantitative and to species level. During 1989, 1990 and 1991 special surveys were undertaken to establish if there were major differences in invertebrate communities within different habitats (ie pools, riffles, tree roots, vegetation). Apart from the data provided from surveys of the Project Team, little else has come to light. Heath (1989) surveyed the Lyd catchment in great detail and made visual observations of adult odonata (dragonflies and damselflies). His findings are reproduced in Table D61z overleaf. These data are of little value in assessing the impact of Roadford's operation since it is not known where the species are breeding.

Because of the most comprehensive nature of the invertebrate database produced from the Project Team, a detailed appraisal has been made. This includes a major review of the literature which considers the affects of impoundment, regulation, and of HEP generation on stream invertebrates. Because this is more complete than anything which could be attempted for any of the other interests, it is presented as a 'stand alone document' as Appendix B. This has been produced by Marc Ingeirest and Hugh Sambrook of the Roadford Project Team with critical appraisal by Patrick Armitage of the Institute of Freshwater Ecology. This EIA of Roadford Reservoir on the downstream invertebrates first synthesises the effects of regulation on downstream aquatic environments. It then gives details of the invertebrates present in the Lyd sub-catchment before predicting how Roadford's operation may affect them. It was written during the filling phase of Roadford (1990) and does not take account of more recent invertebrate data collected nor the new proposals for HEP generation.

A brief summary of the key findings are given here.

In conjunction with the proposed HEP operation, higher daily main flows and greater seasonal flow constancy will occur downstream of Roadford reservoir. The latter has been shown to compensate for the adverse effects of daily flow fluctuations.

A reduction in the severity and frequency of spates could be favourable to the mosses, algae and macrophytes downstream of the dam due to greater bed stability. This would in general be beneficial to the invertebrates.

Roadford reservoir is provided with multilevel draw-offs which should minimise the release of poor quality water. Aerators will be in use during the summer to prevent stratification and deoxygenation of the deeper layers of the reservoir, ensuring that the reservoir is always mixed.

The invertebrates will be less adversely affected by surface-water releases than deep-releases. They will probably benefit from the use of surface water, at least in terms of increased abundance/biomass. The use of the mixed reservoir water drawn from the best water quality level will also benefit the invertebrate communities.

The use of the scour draw-off should be strictly regulated as the discharge of large quantities of silt in the river will be highly detrimental to the benthic fauna. These deep releases may also include anoxic water and unacceptably high levels of metals. To minimise the impact on river fauna, releases from the scour draw-off should be made in conjunction with spate/flood conditions in adjacent river catchments.

Plankton from reservoirs usually settle rapidly in receiving waters; therefore the enriching effect on a fast-flowing river such as the Wolf should not persist very far downstream of the dam. Overall the greatest impact of the operation of Roadford will be on the River Wolf immediately downstream of the embankment. The addition of water from the unregulated Rivers Thrushel and Lyd could rapidly mitigate any adverse effects of regulation.

The invertebrates from the cylinder samples or those collected during the special habitats - pools, tree roots and submerged macrophytes - surveyed in the spring of 1989 are typical of similar rivers in the South West.

Two species however are of regional importance: a stonefly *Amphinemura standfussi* and a caddis *Athripsodes bilineatus*. Both are not nationally rare but have not been commonly recorded in SW England. The reasons for this are not entirely clear; however the infrequent surveys to species level and identification difficulties contribute to ? of records.

Low flows (9 Ml/d) and silty conditions will characterise the early years of operation of Roadford Reservoir. This will generally be detrimental to the existing benthic invertebrates. As the habitat and flow requirements are not known for the two regionally rare species, no prediction of impact is possible.

However, several taxa appear to be largely unaffected or even thrive under such conditions. The most notable example is the mayfly *Caenis rivulorum* whose density in the spring of 1989 reached 1280 individuals/m^2 at the most heavily silted site immediately downstream of the dam. The caddis *Polycentropus flavomaculatus* and the water-mites (Hydracarina) also showed a significant increase in abundance at this site. Sphaeriidae (bivalves) are another taxon characteristic of areas with a reduced flow and silty stone surfaces, although they have not increased downstream of the dam.

The mayfly *Ecdyonurus sp.* (Heptageniidae) appear unaffected by the changes. The closely related *Rhithrogena semicolorata* however decreased in abundance immediately downstream from the reservoir.

Stoneflies are in general very sensitive to introduced sediments and low flows. They have already decreased in abundance and diversity downstream of the dam. *Leuctra geniculata* and *L fusca* are however unaffected and will be the dominant stoneflies during the early years of operation of the reservoir. *L nigra* is another species usually found in slow-flowing, silty reaches but it is rare in the Lyd catchment and has not increased downstream of the dam.

The filling years of Roadford Reservoir are likely to be detrimental to taxa requiring fast flows and/or clean stone surfaces such as the caddis Hydropsychidae and the blackflies (Simuliidae).

Higher maintained flows and HEP releases made in the years of operation should flush out the accumulated sand and silt from riffle areas. Siltation of the substrata and associated problems can therefore be considered temporary.

Some invertebrates are better adapted to withstand pulsed HEP releases during the winter months and have been seen to be unaffected or to increase downstream of HEP reservoirs. Some are able to burrow into the substrate during adverse conditions, such as the mayfly *Paraleptophlebia submarginata* and the stoneflies *Chloroperla torrentium* and *Leuctra fusca*. Others are summer-growing species which overwinter in the egg stage or as small nymphs buried deep in the strata, such as the mayflies *Caenis rivulorum* and *Ephemerella ignita* and the stoneflies *Leuctra fusca* and *L geniculata*. On the other hand, winter-growing species such as *L hippopus* will be adversely affected.

Leuctridae (stoneflies) and Elminthidae (riffle beetles) are characteristic of irregular hydraulic conditions and should not be adversely affected.

Large cased caddis (Limnephilidae) that were collected mainly from tree roots and submerged vegetation (eg *Potamophylax*) are expected to decrease in abundance or even be eliminated downstream of the dam. Those species that were also regular found in pools such as *Halesus* and *Chaetopteryx villosa* may remain unaffected.

HEP releases during the winter months will probably reduce the diversity of species downstream of the dam, but the overall abundance is expected to increase. Autumn and winter spates associated with the unregulated River Wolf, would, under extreme conditions, significantly reduce the total abundance and diversity of the invertebrates. The dam will stabilise the flow regime during the autumn and winter and it is thought that HEP releases will probably be less detrimental to the benthic invertebrate biomass than natural winter spates. Peak flows will not exceed 320 Ml/d and water velocity will be less than 0.7m/sec. Under the harshest conditions the maximum change in water height will be 40 cm but for the majority of times the change will be approximately 25 cm.

Higher daily mean flows and greater seasonal flow constancy will occur downstream of the dam when the reservoir will be fully operational. If

surface water is released this will generally be favourable to the filter-feeders such as the caddis Hydropsychidae, Polycentropodidae and Brachycentridae. The benefits to all filter-feeders is not certain. Blackflies, preferring high velocities, will thrive, whereas high velocities can be sub-optimal for many caddis. The young larvae may be impaired by summer augmentation flows but benefit from autumn and winter HEP releases when they are larger.

The expected increased standing crop of benthic mosses, algae and macrophytes downstream of the dam due to the stabilised flow regime will generally be favourable to the invertebrates. This will however be detrimental to the filter-feeding Simuliidae (blackflies) and to the mayflies Heptageniidae. Conditions will be favourable in those suitable areas not colonised by macrophytes.

Tolerant and ubiquitous taxa such as the chironomid midges are expected to increase in density.

The increased abundance will be at the expense of a reduction in species diversity if habitat diversity is lessened through flow regulation.

The Wolf alone is likely to be impacted in any significant way in the section between the dam and the Kellacott Stream. In this stretch intensively surveyed from 1985-1989 only two species, the caddis *Cyrnus trimaculatus* and *Silo nigricornis*, were found confined to this area. They were rare however and both captured on only one occasion. During the first years of operation of the reservoir (compensation flow only), *Cyrnus* is expected to increase downstream of the dam.

The probable reduction in species diversity immediately below the dam appears acceptable when weighed against the expected increase in abundance of taxa and enhanced conditions for others in the lower parts of the Lyd-subcatchemnt. This view is taken because no regionally rare species are confined to the Wolf system where greatest changes will take place. Major changes in the Thrushel and lower Lyd are not expected; indeed the lack of drought stress, better water quality and some small reduction in the magnitude of large spates is considered to be beneficial, when considered in the long term rather than on a year to year basis. Overall diversity of aquatic invertebrates in the Lyd catchment as a whole will not be adversely affected since much of it is unaffected by Roadford.

Careful chemical and biological surveillance of the coming years is imperative as changes to the community are bound to occur.

D6.2 Adjacent Land

The most comprehensive survey of the habitats adjacent to the Lyd, Thrushel and Wolf was undertaken by Heath (1989) on behalf of the DWT as part of the Roadford Investigations. His river corridor survey not only included the 9.5km of these rivers between Roadford and the Tamar, but also 14.5km of control river comprising 8km of Thrushel above the Wolf and

6.5km of Lyd above Thrushel foot (Figure D6.2a). A detailed investigation of the same area, plus a section of the Tamar downstream of Lyd foot, was undertaken by Exeter University (Maltby & Hughes; 1987, Maltby & Hogan; 1989). This investigation aimed to identify all wetland areas within the valley floor of the study area and ascertain whether they were 'river' or 'water-table' dependent.

Both studies highlighted that the valley floor of the Wolf, Thrushel and Lyd were predominantly agricultural, mainly improved pasture with small amounts of arable land, damp/marshy grassland and fragments of woodland. Reference to Figure D6.2b shows that agricultural improvements since 1963 have led to 50% of the broadleaved woodlands of the Wolf being destroyed whilst many small percentages of loss were found for the other rivers. In contrast, the Thrushel has suffered the most catastrophic losses of wetlands and rough ground - about 85% loss. However the most important point shown by Figure D6.2b is that the extant area of broadleaved woodland and wetland adjacent to the Lyd, Thrushel and Wolf downstream of Roadford is very limited indeed.

Figure D6.2b shows that in the Wolf downstream of Roadford dam, less than 15ha of broadleaved woodland and 4ha of wetland/rough ground exists adjacent to the river. The habitats are thus very limited in extent. Heath (1989) also highlights that the most extensive, and highest quality, areas of wet grassland used to occur in the valley within the reservoir site and thus have now been destroyed. An indication of the extent of 'quality' habitats is given in Table D6.2i and Figure D6.2c. These both show the 'Key Sites' identified by the DWT and Exeter University surveys. The former identified 45 such sites in their study area (including the Lew catchment of the Torridge) which were the best examples of habitats found. From the Figure it can be seen that seven sites were found by DWT between the Tamar and Roadford dam; three on the Wolf and four on the Lyd. The wetland surveys of Exeter University identified four sites; a tiny area of wet grassland (Z) not described further, a wet scrub clearing (Y) containing reed and sedge and also not further described, 1.5ha of marshy grassland (X) within DWT site W2 and wet grassland (W) near Rexon. The Exeter University survey thus identified just two wetland sites downstream of Roadford, one of which (W) is adjacent to a tributary stream. Maltby and Hogan (1989) describe the detailed investigations which have been undertaken at these sites and confirm that the wetland interest appears to be totally related to water table; river regime and affects of inundation are not regarded as significant determinants. Table D6.2i summarises the interests of the 'key sites' as given by Heath (1989); this too shows that the seven key sites identified by the DWT survey are not dependent on the river.

Observations made during visits to the area highlighted the presence of a small area of *Carex paniculata* (Great Tussock-sedge) marsh on the west bank of the Wolf immediately below Rexon Cross bridge. This is obviously of some note but may have been excluded from the DWT survey because it is about 60m away from the bank of the river; it is also probably just outside the floodplain.

Reference to Table D6.2l indicates that two of the seven 'key sites' are heronries. A small one exists on the Wolf at Milford Quarry and a larger one is at Lifton Park on the Lyd. Neither is dependent on the regime of the river to maintain its interest.

The potential for the operation of Roadford to affect changes in adjacent habitats of the Lyd sub-catchment is very limited. Heath (1989) has highlighted that none of the best sites in the floodplain are river-dependent; he has also shown how agricultural improvements have led to major declines in valued habitat resources over the past 25 years. A total absence of future affects cannot, however, be predicted. Although flooding of the valley floor will still continue in the Lyd, Thrushel and lower Wolf (below the Kellacott Stream), the extent, duration and depth are all bound to be reduced to some degree. In the case of the Lyd there will be minimal differences but progressively the affect will be more acute up the Thrushel and Wolf. Since no habitats (or permanent communities or transient feeding birds) of any significance have been identified which are dependent on periodic inundation, the impact on existing ecological interest has to be assessed as negligible or non-existent.

D6.3 Mammals

Heath (1989) undertook investigations of mammals present within the river corridors of the Lyd sub-catchment. He reported the presence of badger, rabbit, hare, grey squirrel, fox, mole, deer, bank vole, short-tailed vole, common shrew, daubenton's bat, mink and otter. Only the latter is of significance in relation to the operation of Roadford. Because of the importance of this mammal, surveys to identify stretches of river utilised by otters were undertaken in both 1987 and 1988; results are shown in Figure D6.3a. It is important to note that the other two 'aquatic' mammals (water vole and water shrew) were not found.

Otters have declined dramatically in Britain since the war and they, and their habitats, are now protected by provisions in the 1981 Wildlife and Countryside Act. Some recovery in their numbers and distribution has taken place in recent years and the populations in Devon and Cornwall are of great significance in S-W England (especially now since declines have continued in Somerset and Dorset; Heath, 1989). Reference to Figure D6.3a shows that otters regularly use the Wolf, Thrushel and Lyd and Heath (1989) comments that usage is particularly high in the lower reaches of the Lyd.

It is difficult to see how the operation of Roadford reservoir for water supply could do any harm to the otter populations of the Lyd sub-catchment. Bankside habitats (particularly tree cover creating safe holts), food supply, adjacent habitats forming cover and lack of disturbance are the most critical factors affecting their distribution. As other sections of this Annex have indicated, there is little likelihood of Roadford operation affecting adjacent habitats; bankside trees will be unaffected; disturbance in the open farmland should not increase and food is more likely to increase than decrease in abundance. HEP generation might pose a threat of potential reduction in food available for otters. However this loss may be partially,

wholly or more-than off set by the creation of new feeding and resting areas associated with Roadford Reservoir itself. These latter benefits are dependent on deliberate efforts to create suitable features and are unlikely to accrue if left to form on their own.

A recent survey of the Wolf and neighbouring catchments by Mary Rose-Lane (pers.comm) for the Tarka Project confirmed regularly used holt sites on the river. There are no concerns that operations will damage otter populations here but a requirement to monitor responses to releases for HEP and water supply are deemed desirable. The existing data are regarded as a reasonable database since control sites are available within the catchment.

D6.4 Amphibia and Reptiles

In his surveys of the Lyd sub-catchment Heath (1989) recorded the presence of both amphibia and reptiles for the rivers and their adjacent lands. Although Grass Snake and Common Lizard were recorded, the presence of these species now, and in the future, are unrelated to the Wolf and the operation of Roadford.

Common Frog and Common Toad are both dependent on water for breeding. The distribution of these two amphibia in the survey area of Heath is shown in Figure D6.4a. The former was only recorded from adjacent ponds and temporary water bodies and thus cannot be considered to be affected by the future operation of Roadford. The latter, on the otherhand, breeds in the Wolf. Heath reports that spawn is attached to submerged plants and later swarms of tadpoles occur in the shallows, and large numbers of juveniles feed on the marginal shingles.

It is highly likely that the overall impact of Roadford on the Toads of the Wolf will be beneficial. In normal and wet summers it is probable that they will breed in huge numbers, given protection from being washed through the system by the lack of spates and the shelter available in the increased plant growths. The compensation flow, over three times greater than the dry-weather flow, will also ensure that a much larger area is available at all times; this will reduce competition for space as well as ensure predation is reduced as tadpoles swarm into shallow alcoves. Under 'typical' year operation the amount of water augmented to the Wolf will be significant compared with the compensation releases and some washout from the system is inevitable.

Under drought conditions the potential for reduced Toad populations in the Wolf is a real threat. Augmentation of the order of magnitude proposed is highly likely to remove the majority of tadpoles from the Wolf. The greatest impact would be if large amounts of augmentation have to be made early in the summer; conversely a late summer drought would have much less impact. However there is the potential that under drought conditions the loss of tadpoles from the Wolf would lead to improved populations in the Thrushel, Lyd and Tamar due to them being washed into these rivers when flows are low and conditions are much better than in 'typical' years.

HEP generation is unlikely to have any effect since Toads are unlikely to be using the river during the period of most releases.

D6.5 Birds

Heath (1989) surveyed the Lyd sub-catchment for birds. He recorded dipper, kingfisher and grey wagtail breeding on the rivers below the influence of Roadford (see Figure D6.5a). He also reported that two heronries are present within the area and mallard breed commonly throughout the stretches investigated. The survey by Heath represents the most detailed information available for birds in the Lyd sub-catchment and have been put into a county perspective by 1988 surveys of dipper, grey wagtail and kingfisher by Devon Bird Watching and Preservation Society surveys reported by A W G John, (pers comm).

Breeding dippers were confirmed for the Wolf, Thrushel and Lyd below the influence of Roadford; however this bird was absent from the upper half of the Wolf. In comparison with ideal dipper habitats (Sitters 1988), densities in the study area were just slightly lower. Actual nest sites were located, four in all, which showed that none were within one metre of the water level. Grey wagtails were numerous in the study area and breeding sites were confirmed for all three rivers below Roadford. The density of one nest site for each kilometre of river is typical for good sites in Devon (Sitters; 1988). A nest was found which was 1.3m above river level. Kingfishers were found to occupy four territories on the Roadford-affected reaches of the Lyd sub-catchment.

The potential impacts on the three key breeding birds of the Lyd sub-catchment focus primarily of food availability and risk of predation or drowning of nest sites. Figure D1c, Appendix A, shows the distribution of the three species in Devon (from Sitters; 1988). It shows that grey wagtail is the most numerous and kingfisher the most scarce.

It is perceived that the most common species, grey wagtail, is most threatened. Its major habitat requirements in streams is the combination of riffles and shingles, with Tyler 1987) reporting that deciduous trees adjacent to rivers favour them. Aquatic insects form only about 25% of their food whilst a variety of flies and other insects of terrestrial origin (many from shingle or wooded margins) form the bulk of the diet for adults and young (Ormerod and Tyler; 1987). Under normal or wet summers the amount of augmentation from Roadford will be small and the impact on the feeding grounds of the shingle banks will be small. In dry summers augmentation will be very significant and many of the shingle margins will be drowned out and food will not be available from these sources. It is unlikely that nest sites will become more vulnerable to drowning or predation although birds may be tempted to nest lower down the banks in the Wolf if there are several years when the reservoir never over-tops. HEP generation should not affect the birds since this will occur out of the breeding season. In the Lyd sub-catchment as a whole Roadford may exert some benefit. The notes written alongside the distribution maps in Figure 6.1c indicate that grey wagtails are very susceptible to hard winters, when streams become frozen.

The Wolf is less likely to become frozen because of the compensation flow from the Reservoir; HEP releases would also ensure lack of freezing. In such weather conditions birds which might breed elsewhere in the catchment could feed here in increased numbers.

Dippers are highly correlated with fast-flowing streams, very rarely breeding far from the stream itself. In summer the staple diet of both adults and young are mayflies and caddisflies. Since both these groups are not expected to decline when Roadford is operational, and the dipper feeds predominantly under water, no adverse impact is likely. Indeed, if invertebrate densities increase, and the taxa are the ones which are predated on by dipper, there is every reason to suggest that the bird may be favoured. There is the potential that breeding sites may become more prone to flooding following several seasons without over-topping which might possibly induce sites to be located lower down the banks than they are at present. However few sites are ever located within 40cm of the low-flow level so protection from summer floods is more likely.

The kingfisher is the rarest of the river birds breeding on the Lyd sub-catchment (Figure D6.1c); like the dipper, it is very highly correlated with rivers and streams. Although widespread in Devon, the bird is scarce in Devon (Heath; 1989). Kingfishers, like grey wagtails, are very vulnerable to severe winters when food becomes unavailable to them as rivers and streams freeze. Thus, the potential benefits of the Wolf for the catchment as a whole in cold winters is the same as for the wagtails. For breeding success the kingfisher requires small fish, tadpoles and large invertebrates. On the whole it is predicted that small fish will not be adversely affected by the operation of Roadford for water supply although in severe droughts they may be more difficult to catch due to the much larger stream area available to them for cover and the extra water depth. In normal summers they may be more numerous and more readily available to be predated. Tadpoles are likely to be numerous in wet summers but be washed out the system in dry summers. HEP generation is likely to have only an indirect affect on kingfishers in the summer because of its potential to decrease the biomass of food available during the winter. A direct benefit might result in severe winters by keeping a long stretch of river free from ice.

D6.6 Non Salmonid Fish

Relatively detailed information is available concerning these fish (see D1.8 and Appendix A). Minnow, stoneloach, eel, bullhead and brook lamprey occur in the Wolf, and in the Thrushel downstream of the Wolf. In addition, to these, grayling occurs in the Lyd.

General aspects of how Roadford will affect river fish has been considered in D1.8. Specific affects, more or less confined to the Lyd sub-catchment, relate to compensation flows from Roadford, HEP generation and summer augmentation releases.

A compensation release of 9 Ml/d is being made continuously from Roadford Reservoir. The impact of this flow will be most apparent during

low flow periods and will be reduced progressively downstream as natural base flows increase. In dry summers, the natural flow of the River Wolf drops to 1 Ml/d and 3 Ml/d in an average summer. Compensation flows alone will have the effect of increasing flows in the River Wolf nine and three fold in dry and average summers respectively. These increases in flow, elimination of spates, increase seasonal flow constancy, enhanced plant growth and discharges of good water quality will provide substantial benefit to the aquatic environment downstream of the reservoir for fish.

HEP generation should not affect the breeding success of non-salmonids since all have their main spawning season outside the period of HEP releases.

Summer augmentation is likely to have greater impact in drought years than in normal or wet years. The decrease in temperature could adversely affect minnow in these years but may considerably benefit grayling, stoneloach and bullhead (as well as salmonids). However the more stable regime which will result in the long term is likely to have beneficial affects on all the fish cited despite some seasons having adverse affects.

D6.7 River and Bankside Flora

The most comprehensive survey of the catchment was undertaken as part of the river corridor survey of DWT (Heath; 1989). This survey recorded habitat features and flora down the whole length of the Wolf, Thrushel and Lyd downstream of Roadford and an even larger length of 'control' river upstream in the Thrushel and Lyd (Figure D6.2a). Macrophyte recording was also undertaken by Holmes (1987) who surveyed two sites on the Lyd and one on the Wolf downstream of the dam and two sites on the Thrushel and four on the Lyd upstream of the influence of Roadford. The sites on the Lyd had been surveyed ten years earlier during an NCC survey. A baseline survey of selected habitats for bryophytes and habitats was undertaken on the Wolf in 1990 (Holmes 1991).

Some of the results of plant surveys are given in Table D1ii and D6.7i. The former lists all species recorded by Holmes in his survey of 1987 (including those of the Tamar), and the latter bryophytes recorded by Heath in an intensive investigation of good habitats for this group of lower plants. Both Holmes and Heath noted the importance of the bankside trees in all the rivers, not only of interest in themselves but also of importance in their role of stabilising river banks, providing habitats for animals, creating moist conditions necessary for oceanic bryophytes to thrive, and an allochthonous food source to animals in the streams. Both surveys also indicated that rooted aquatics are very limited in all the rivers due primarily to the unstable nature of the gravel/pebble/ boulder bed. Where stable rocks occur the presence of richer bryophyte communities, with much greater biomass, were noted. Even here, the flora is often naturally impoverished by the extent of shading.

Reference to Table D1ii shows that only two species were recorded solely from the Wolf - *Callitriche hamulata* (Intermediate Water-starwort) and *Carex*

pendula (Pendulous Sedge). Heath (1989) made reference to the former, stating that it is widely distributed in Devon and is the only characteristic submerged higher plant of the rivers locally. He also noted that the Pendulous Sedge is a local species of shaded wet woodlands. Only two other species were found which are confined to the Lyd sub-catchment below Roadford - *Mimuus guttatus* (Monkey Flower) and *Rorippa nasturtium-aquaticum [Nasturtium officinalis]* (Water-cress). The former was noted by Heath in the same location with a comment that it is an introduced species whilst the latter was not recorded (nationally it is widespread and, although local in distribution, it is not uncommon in Devon). Heath recorded the presence of a county rarity on the banks of the Wolf (*Scirpus sylvaticus* - Wood Club-rush) but noted that it was 'fairly frequent' on the Thrushel (see Figure D6.7a). Holmes also recorded this plant from the Tamar. Truly submerged higher plants are exceedingly rare, both Holmes and Heath highlighting that the only other aquatic plant found in the area was *Myriophyllum alterniflorum* (Alternate-flowered Water-milfoil); and this confined to a small patch in the Lyd at Lifton. It is, however, common in the Tamar (Table D1ii).

In an intensive investigation of aquatic and bankside bryophytes at 14 sites on the Lyd sub-catchment and the Lew (Table D6.7i), Heath (1989) recorded a total of 36 species. Eleven mosses and two liverworts were confined to the Wolf and a further one liverwort (*Pellia epiphylla*) was exclusive to the Lyd below the influence of Roadford. The other 22 species were present within the catchment upstream of the influence of Roadford. The majority of the species recorded are common nationally, and locally often quite abundant in damp places and along stream sides. *Riccardia* and *Plagiochilla* are not common species, the former being more typical of rocks in clean streams and the latter in damp locations where water is enriched to some degree. The only two species of any note recorded are *Atrichum crispum* and *Thuidium delicatulum*. Both are oceanic western species; although the former is locally abundant in north western Britain, it is much rare in Devon and Cornwall.

Regulation of the Wolf through Roadford reservoir is bound to exert some influence on this stream as well as some effect on the lower Thrushel and lower Lyd. Heath (1989) has debated the potential effects and concluded an influence will be exerted through reduced flows during the filling phase; changes in depth, width and velocity resulting from the elevated dry-weather flows, the augmentation for water supply, infrequent and less severe spates, and releases made for HEP generation; water 'quality' differences due to changes in temperature regime and nutrients; and potential physical changes due to the change of regime. Petts (1981) has indicated from other studies that morphological changes to river channels in the Lyd sub-catchment due to the headwater impoundment of the Wolf, should be confined to the Wolf itself.

Personal observations made for streams and rivers downstream of impoundments (River Tees below Cow Green, Haddeo below Wimbleball, St Neot River below Colliford, River Fowey below Siblyback and Meavy below Burrator all indicate massive increases in aquatic plants. The Meavy is

perhaps the best example to consider since it has been impounded for about a century. Truly aquatic mosses still thrive, a community very similar to the one described for the Wolf exists there but it is far more diverse and the biomass is much greater. No comparable data have been collected for the splash zone species but there is nothing to suggest these have suffered due to impoundment. Indeed, the presence of Filmy Fern (*Hymenophyllum*) which demands the same moist conditions as many of the oceanic bryophytes, suggests they have not suffered to any marked degree. Two truly aquatic plants thrive in the Meavy, Alternate-flowered Water-milfoil and Intermediate Water-starwort, and cover large areas of the river bed. Holmes and Whitton (1977) have suggested that the building of Cow Green Reservoir led to a considerable upstream invasion of truly aquatic plants (Pondweed, Milfoil, Crowfoot and Starwort) into the river in response to the more stable substrates which had developed due to the higher 'low flows' and lower 'high flows'.

In assessing the impact that Roadford will have on the plants of the Lyd sub-catchment it is probable that the following will occur. Such predictions are made in the absence of any quantitative evidence from other sites but from extrapolations from previously impounded catchments and their vegetative characters today.

i Mosses such as *Fontinalis, Rhynchostegium, Amblystegium, Hygrohypnum* and *Acrocladium* will increase due to greater stability of rocks, reduced winter scour, and less summer desiccation.

ii The liverworts *Chiloscyphus, Riccardia* and *Plagiochilla* will increase due to the same reasons.

iii The increased bed stability and reduced scour will lead to an eventual massive increase in the submergent *Callitriche hamulata; Myriophyllum alterniflorum* is likely to invade from downstream in the Lyd and Tamar whilst new species likely to colonise the Wolf are *Ranunculus* (river sp[p] as well as edge *R omiophyllus*), *Sparganium* (Bur-reed), *Lemna* (Duckweed) and *Potamogeton crispus* (Curly Pondweed).

iv Some edge bryophytes may diminish, not through any direct effects but by increased (and more stable) edge growths of ruderals and grasses.

v Effects will be marked in the Wolf, be much less evident in the Thrushel and be barely detectable in the Lyd. In the very long term effects in the lowest reaches will become more evident as the rich and luxuriant community upstream constantly replenishes lost stocks downstream through spates.

vi The increased abundance and higher plant diversity in the Wolf is dependent on periodic flushing through over-topping to ensure gravels are cleaned etc. This is only relevant for the c3km upstream of the Kellacott Stream since natural spates from here will be

sufficient to cleanse the lower reaches of the Wolf above the Thrushel.

The above predictions are based on the utilisation of Roadford for water supply only. Generation of HEP is unlikely to impact upon plant communities. The present proposals will result in much smaller releases being made than would naturally occur. 'Bleeding' water from the reservoir for such generation will also reduce the impact of scouring floods since the reservoir will rarely be 'over-full'.

D7 TAMAR FROM LYDFOOT TO ABSTRACTION POINT AT GUNNISLAKE NEWBRIDGE

This section of river will be affected by the operation of Roadford in three ways:

- Compensation releases from Roadford of 9Ml/d at all times, increasing the summer base flows when there are no augmentation releases and minimally reducing winter flows.

- HEP releases in winter which will slightly enhance flows.

- Augmentation releases in summer when river flows are low and prescribed residual flows do not allow unsupported abstractions at Gunnislake.

The three points above have implications for both water quality and the obvious volume differences. Annex B (see summary in D1.10) indicates that water quality will be materially improved through the entire length of the Tamar from Lydfoot to Gunnislake. In summer BOD will be reduced and DO increased substantially whenever augmentation releases are made. Temperatures are reduced during low flows in the summer, especially so under drought conditions when major releases are made from Roadford for subsequent abstraction at Gunnislake.

Surprisingly there are few data for non-salmonid fish in the Tamar between Lydfoot and Gunnislake. Reference to Table D1iv (Appendix A) shows that grayling, bream, minnow, dace, stoneloach, eel, bullhead and brook lamprey all occur in the main river. However there have been no recent surveys which have taken in sites downstream of the Lyd. The population is more diverse than some of the other rivers because of the size of the river and the variety of habitats. None are rare species.

Some macro-invertebrate data have been collected from the river. However these have not been assessed at this stage; a full appraisal will be made for the final report.

Reference to Figure D1c (Appendix A) shows that both kingfisher and sand martin breed in small numbers down the river. Dipper are more successful and grey wagtails breed commonly down the Tamar. There is also a heronry on the banks of the river.

Macrophytes of the river have been surveyed twice by Holmes. The first surveys were undertaken in 1980 whilst the last were executed in 1986 (Homes; 1987). In contrast to the Lyd catchment and the Torridge, the Tamar has a much richer plant community and many more aquatic higher plants. This, in the main, is due to the much greater stability of the bed. Filamentous algae dominate the submerged habitats of the river but several other plants are not uncommon. Aquatic mosses such as *Fontinalis squamosa*, *F antipyretica* and *Rhynchostegium* are locally abundant on submerged rocks whilst the splash zones of boulders or man-made

structures are colonised by *Schistidium* and *Cinclidotus*. Submerged higher plants include *Callitriche* (Starwort), *Ranunculus* (Crowfoot), *Myriophyllum* (Milfoil) and *Potamogeton* (Pondweeds). Plants rarely recorded locally included *Scirpus sylvaticus* (Wood Club-rush), but this has been found on most of the rivers investigated. The finding of *Potamogeton berchtoldii* (See Figure D1e, Appendix A) is noteworthy, as is the rare algae *Cladophora aegagropila*. However this algae has also been recorded from the Torridge (see D11).

The operation of Roadford is predicted to have a beneficial affect on the ecology of the main stem Tamar. At present any known interest is more at risk from deteriorating water quality, and the way in which this gives competitive advantage to filamentous algae, than they are from the operation of Roadford. It is predicted that:

- HEP generation in the winter will be too insignificant in its physical and temperature affects to have any influence on river biota.

- Winter compensation flows from Roadford will have absolutely no affects whilst benefits during the summer will be insignificant.

- Summer augmentation will improve water quality, increase wetted area and decrease temperatures to the benefit of most plants and animals. Decreases in temperature will be less in normal summers and most in hot dry summers. Those potentially at risk are the few coarse fish which have their best recruitment years when summers are hot and river levels low. Marginal plant communities will benefit because they will not be exposed for long periods in any summer whilst plants of riffles (ie Crowfoot and Milfoil) will also benefit because they will not become exposed. Grey wagtail is the only bird likely to have reduced feeding areas in very hot summers; however better than average conditions would occur on all the tributaries except the Wolf.

D8 TAMAR FROM GUNNISLAKE NEWBRIDGE TO GUNNISLAKE WEIR

This is the section of Tamar downstream of the abstraction but above the tidal influence. It is thus affected by how much water is left in the river after abstraction. Depending on river flows, the residual flow will either be 'natural' river water or a mixture of this and water released from Roadford to support the pmf downstream of the abstraction.

There are few data for this short stretch of river.

The 1980 macrophyte survey of Holmes for the NCC included 0.5km downstream of Gunnislake bridge. The flora recorded there appears to be typical of the rest of this short ponded section. Rooted macrophytes are very rare indeed, just the odd plant of *Potamogeton berchtoldii* (Small Pondweed) and *Ranunculus* (Crowfoot) being found. The few large boulders that are present often have the mosses *Fontinalis antipyretica, Fissidens* and *Amblystegium fluviatile* in submerged locations whilst rock surfaces intermittently drowned (and the weir) have *Cinclidotus* and *Schistidium*. The dense shade from flanking trees ensures that the marginal flora is also sparse; *Phalaris* (Reed Canary-grass) occurs in the few open areas.

The flora is poor because the section is ponded and the bed is predominately rock and gravel, not clay or firm silts. There is no evidence that it is impoverished because of abstraction of water from upstream. Visual observations over many years by the author indicates that ponding does result in discolouration of the water through the abundance of planktonic algae and fine suspended matter. This has been confirmed by Brian Elvin (pers comm). During the drought of 1989 it was clearer than observed before, a feature confirmed by a resident living adjacent to the river for a decade. The longer retention time in this ponded section had enabled a large population of zooplankton to develop which predated the phyto-plankton which normally discoloured the water.

The presence of Small Pondweed is noteworthy in a Devon context (see Figure D1e, Appendix A).

This section of the river is unsuitable habitat for grey wagtail and dipper although the fast flows over the weir, and immediately downstream, do provide some feeding areas. Breeding in the area is confirmed for the former but not the latter (Figure D1c, Appendix A). The same figure shows that kingfisher are not known to breed here whilst there is a heronry immediately adjacent to the river. Sitters (1988) reports that nine nests were present in 1985 at the heronry at Hatch Wood.

The impact of Roadford's operation is minimal in this section of river. However, if it is accepted that the augmentation releases, and to a very small degree the increased compensation flows, from Roadford are beneficial for the main stem Tamar, by inference they must give benefit downstream too. These benefits relate solely to improved water quality since Roadford does not affect residual flows, but the amount abstracted. The proposed reduction in compensation flow from Roadford during releases for abstraction is not regarded as significant.

D9 TAMAR ESTUARY DOWNSTREAM OF GUNNISLAKE WEIR

The estuary will be affected by the operation of Roadford in several ways. Firstly there will be an effect from the amount of abstraction which takes place without augmentation releases from the reservoir; this will happen when flows are not low. Secondly it will be affected by the augmentation releases made during low flows so that sufficient water can be abstracted at Gunnislake but still allow an acceptable minimum flow to pass downstream. The water quality aspects of the released water is thus of paramount importance.

There is a considerable amount of data concerning the marine and estuarine biota of the Tamar estuary complex, primarily due to the presence of the Marine Biological Association being based in Plymouth. The estuary was also the subject of a survey and literature review by the Oil Pollution Research Unit of the Field Studies Council (OPRU; 1986). This report comments on how extensive the Tamar estuary is and that it is about 30km long. Because it is long, and in places quite narrow, the report states that 'salinity of surface and subsurface waters of marine inlets is highly variable in relation to freshwater input and tidal movements'..... Data for the Tamar indicate 'relatively low and strongly fluctuating salinity values from October to March and a period of higher more stable salinities from April to September'.

The survey and literature assessment identified nine 'major ecological zones' in the Tamar estuary (these are shown in Figure D9a). Even in the Upper Estuarine Zone (7) marine organisms dominate. It is here where the intertidal mudflats stop. Because of the very soft nature of the mud, the flats have a species-poor invertebrate fauna; liquid mud also impoverishes the shore communities. Further upstream the salinity is always less than 20% in Zone 8, irrespective of how low the summer flows are. Under winter flooding conditions it can be 0%. There is a marked change in this short length of estuary as it narrows. Although Fucoids still dominate, Common Reed (*Phragmites*) appears as a fringing plant on the northern (upstream) shores. The upper (Zone 9 - Riverine) still contains Fucoids and there are no records of freshwater species colonising the channel.

The OPRU report lists 19 algae and animals from the Tamar estuary which are of conservation interest, several with national status. However none are from the section of estuary (Zones 7-9) which are materially affected by freshwater inputs from the Tamar. Edwards, commenting as the Marine Conservation Officer of the Devon Wildlife Trust (Pers comm), has indicated that there has been extensive research undertaken on some species. She undertook to assess whether any of this is relevant to the present EIA and also to check the distribution of key rare species. Nothing of significance has been reported.

In assessing the 'conservation value' of the Tamar Estuary the OPRU report refers to the ornithological interest which they have not included in their assessment (see later for details of this interest). The report highlights that the most outstanding feature of the estuary is the change in composition,

and decrease in species richness, which occurs on passing up the estuary as salinity becomes increasingly more variable and lower. It also suggests that the reaches above Tamar Bridge have few polluting influences 'so that communities are unlikely to be stressed by factors created by man'. This comment is made despite the reported isolated occurrence of low DO associated with fine sediment suspension when flows are very low at summer neap tides. The estuary is reported to have rarity value for its gradient of communities which reflect the high inputs of freshwater to the system. It is also regarded as diverse because of the presence of both 'soft' and 'hard' substrates. In relation to the present investigation, it is most relevant to highlight their assessment of the 'fragility' of the identified interests - 'The communities and species present in this area are subject to a high degree of natural stress resulting from variation in salinity and **turbidity** in particular. They are therefore resilient to large changes in conditions. Changes in water flow or freshwater input would be likely to result in a relocation of zonal boundaries but only major construction works or shore reclamation seems likely to cause damage'.

During the consultation process it was clear that the main nature conservation interest of the Tamar Estuary is centred on ornithology. As with the majority of estuaries in Devon, few waders or wildfowl breed there (Reay; pers comm). Only shellduck and mallard are known to breed in any numbers at all (Figure D1b). Reference to the same figure shows that regionally, or nationally, the Tamar estuary is important for: avocet, black-tailed godwit, dunlin, water rail, shovelor, shellduck, common sandpiper, green sandpiper, greenshank, and redshank. The Annual Reports of the Devon Bird Watching and Preservation Society do not have summary statistics for the estuary because it is bound on the west by Cornwall and the east by Devon.

Discussion with EN (previously NCC) and RSPB indicate that the wader interest is most significant on the mudflats above Tamar Bridge. Avocet and black-tailed godwits are the most important species. Reay (1988;89) has reported on the close and special relationship that the Tamar Estuary and avocets have. Others, including Penhallurick (1969), Cadbury & Olney (1978), Prater (1981) and Lack (1986), have acknowledged the exceptional importance of the Tamar to avocets.

After an absence of more than a century, avocets began breeding on the east coast of Britain in the late 1940s. Since that time the national breeding success has increased (see Figure D1b) with Spencer (1988) reporting a continuous expanse to around 270 pairs rearing about 250 young in 1985. In the late 1940s the Tamar supported **ALL (ie 100%)** of the British over-wintering avocets, including those that bred in Suffolk (Reay; 1988). Gradually as avocets have increased in Britain the numbers on the Tamar have also increased with the estuary supporting the only significant numbers of the birds for a full three decades. However their proportion of the British over-wintering total has declined in the past decade as other areas have improved. Thus by 1985/6 (Salmon, Moser & Kirby; 1986) the Exe estuary and Halvergate complex of estuaries had replaced the Tamar as the most important sites. Salmon, Prys-Jones & Kirby (1987) noted the

following year that the Tamar probably supported significant numbers of avocets but there had been no systematic counting done on the estuary for the Birds of Estuaries Enquiry in the past five years. It was the lack of data which prompted Reay to undertake an assessment of existing data and embark upon a survey which would highlight the present status of the bird on the Tamar (Reay; 1988).

From Reay (1988) it has become clear that the avocets preferentially use (for feeding or roosting) parts of the Tamar more regularly than others. This is shown in Figure D9b. This equates roughly to the Central and Upper Zones identified by OPRU (1986) where the saline and freshwater fluctuations are greatest and where the mudflats are most prevalent. In considering what affects the areas used within this zone by avocets, Reay concluded that strong winds and very high river flows appear to be most influential. The high river flows in 1989/90 appear to have pushed the birds further down the estuary where salinity is greatest and where their food might be most available in these conditions (Reay; pers, comm).

Detailed counts in 1987/8 and 1988/9 indicate that peaks of over 100 birds is not unusual. The present status of the avocet is thus good (see Figure D9c) which contradicts the suggested decline reported in Birds of Cornwall (1984). The same figure also shows how, in recent years, that the Exe has eclipsed the Tamar; fortunately this is not at the expense of the Tamar population. Figure D9c shows two periods of slight decline: 'Tavy years' is when birds tended to use the Tavy more than the Tamar whilst 'Saltash' indicates a more recent move to use Saltash.

In assessing the importance of the Tamar, Reay (1988) indicates that for more than thirty consecutive years the minimum number (50) of birds required to make the site nationally important have been exceeded. In the past three years the figure has exceeded 100. There appears to be no unique features of the Tamar Estuary which resulted in it being the most important site for avocets in the British Isles for three decades. It is suggested that a combination of geographical location (giving mild climates), topography (provision of shelter in adverse conditions), lack of disturbance and an abundance of food are important. Reay (1988) concluded that the importance of the Tamar cannot be disputed because of the numbers of avocets recorded and the historical link with the re-establishment of the species in Britain.

Prater (1981) listed six species in the Tamar complex (including the Tavy, Plym and Lynher) which achieved national importance in the period 1969 to 1975 -avocet, wigeon, golden plover, dunlin, black-tailed godwit and redshank. Using the latest qualifying levels for national importance (Salmon, Prys-Jones & Kirby; 1987), and data in the CFNHC Annual Reports (1985; 1986) Reay (1988) concluded that the Tamar Estuary complex as a whole now only has two birds of national significance - avocet and black-tailed godwit. Both are only important in the Tamar estuary itself (summary data during the 1980s in Devon Bird Reports shows only rarely do these birds get counted in any numbers in the Tavy, Plym or Yealm). Reay (1988) also reports that the rare spotted redshank and the greenshank are increasing.

Primarily because of the ornithological interest, part of the Tamar Estuary is being considered for notification as an SSSI by EN. The approximate area of the site is indicated in Figure D9d.

The impact of Roadford's operation is deemed minimal or beneficial. This conclusion is based on the interest being mainly based on winter birds when flows will be materially unaffected. As potential adverse impacts on birds are likely due to reductions in invertebrates within the muds, summer flows to the estuary will not be reduced, and during long hot summers the quality of the water discharging over Gunnislake weir should be improved, no adverse impact can be perceived.

D10 OKEMENT DOWNSTREAM OF MELDON

This section of river has the potential to be affected by Roadford operation through modifications to the utilisation of Meldon Reservoir; this might involve greater releases of water being made to the Okement for subsequent abstraction from the Torridge at Torrington.

Much is known about the macrophytic vegetation of the Okement and Torridge through surveys undertaken by Haslam in 1969 and 1975 (Haslam; 1982) and Holmes in 1978, 82, 86 and 1989. The surveys by Haslam were less detailed than those by Holmes and provide no additional information to that presented by Holmes (1987).

The grid references of the sites surveyed by Holmes are given in Table D1i and the species recorded from these sites in 1986 given in Table D1iii. For both the Okement and the Torridge, the survey data from both Holmes and Haslam indicate that no significant changes in macrophyte distribution have occurred over the past twenty years.

Because the Okement rises high on Dartmoor it has a predominantly nutrient and base-poor water chemistry. It also flows rapidly over bed rock, boulders, cobbles and pebbles. Its margins are often wooded which casts considerable shade over the river. The physical characteristics, together with the water chemistry, of the river determines its flora. Reference to Table D1iii shows that the submerged flora is dominated by bryophytes and algae. There is a transition downstream from the liverwort zones of *Scapania*, *Nardia* and *Marsupella* in the upper reaches to the moss communities of *Hygrophypnum* and *Fontinalis squamosa* in the middle and lower reaches. Where the bed is stable in the middle reaches the biomass of moss can be very high. Above its confluence with the Torridge the bed is very unstable and vegetation within the channel is minimal. No truly aquatic higher plants (ie *Potamogeton*, *Ranunculus*, *Myriophyllum* or *Callitriche*) have been recorded from the Okement.

Despite the lack of any aquatic higher plants, the species-richness of the Okement is reasonably high due to the relatively frequent occurrence of a wide range of mosses and liverworts. In comparison with other tributaries of the Torridge, the Okement has a diverse plant community (Holmes; 1987). Holmes also reviewed previous work on the Okement system as well as botanical records given in Imery-Cook (1984) and Walters and Perring (1976). His conclusion was that there was no evidence to suggest that the Okement had ever contained many truly aquatic higher plants and no locally or nationally rare species have been recorded from the channel. The same author also made visual observations of the Okement during, and after, the drought of 1989. Bryophyte communities remained healthy during the very low flows. They were also unaffected by the metalliferous acid flush which caused major fish mortalities following that drought, and previous ones in 1984 and 1976.

Grey wagtail and dipper are commonly found breeding on the Okement system above Okehampton and less commonly downstream also. Kingfisher

on the otherhand rarely breed on the river, preferring when they do the lower reaches (see Figure D1c).

The main influence on the plants of the Okement is the rocky bed and scouring spates; a secondary influence is the predominantly oligotrophic water which exerts its effect throughout the year. Transiently low pH and high metal levels will have little or no affect. Since the flow regime and physical character have such an influence on the flora of the channel it is inconceivable that changes of the magnitude envisaged in the future will have any affect at all. The same lack of affect on birds is also predicted. However, unlike the plants, they are potentially affected by the transient pulses of acid waters which have been shown to kill many invertebrates and small fish on which the birds prey. Because grey wagtail are less dependent on aquatic insects, they are less likely to be affected by this.

Factors other than releases from Meldon are therefore important in determining the floral and faunal communities of the Okement; as such changes proposed as part of Roadford's operation will have no significant impact.

D11 RIVER TORRIDGE FROM THE OKEMENT TO TADDIPORT BRIDGE

This section of the river is potentially impacted by the operation of Roadford because of releases down the Okement for subsequent abstraction below Taddiport Bridge. However the amount released is so small that no significant changes to the flow regime of the Torridge is likely.

As stated in D10, the Torridge system has been intensively surveyed for macrophytes over the past 20 years. The most recent survey, and review, was undertaken by Holmes (1987) because water from Roadford was initially intended to be transferred to north Devon via the Lew and Torridge.

The sites surveyed for macrophytes, and the data obtained, are given in Tables D1i and D1iii. In his assessment of the data collected in the light of previous records, Holmes (1987) concluded that the Torridge had not suffered a reduction in the distribution of macrophytes. Indeed, a few new records for some species were made (see Figure D1e). He states "The inescapable conclusion from the 1986 survey of the macrophytic flora of the Torridge system is that it is extremely impoverished. There is overwhelming evidence that this has always been the case, particularly for aquatic species. The macrophytes also have a very low productivity and standing crop. Since it has been shown that historically this has always been the case, there is considerable reason to suppose that the flora is constrained by physical parameters far more than chemical ones. The main constraining factors are degree of shade and bed stability".

Reference to Table D1iii shows that the bankside flora of the Torridge is totally dominated by the common *Phalaris arundinacea* (Reed Canary-grass), always covering more than 10% of the bank with trees also very common. The channel is dominated by a combination of River Crowfoot (*Ranunculus* hybrid?) and a mixture of algae. Where rock are embedded they are frequently covered in mosses, most notably *Fontinalis squamosa* and *F antipyretica*. The Alternate-flowered Water-milfoil (*Myriophyllum*) is present, but never common.

Figures D11a, b shows the species recorded at Town Mills (site 14 just upstream of Taddiport) during the drought of 1989. This indicates that major changes have not occurred recently but there is an indication of a reduction in the amount of Crowfoot. During the drought, as would be expected, filamentous algae were more common; a new record was made for *Scirpus sylvaticus* (Wood Clubrush).

A few locally rare species have been recorded from the Torridge. *Cladophora aegagropila* is a rare species in Britain (Holmes and Whitton; 1975) but is common throughout this section of the Torridge. *Scirpus sylvaticus* is a relatively uncommon plant in Devon and has been recorded from Town Mills Bridge and at Weare Gifford on the banks of the Torridge. Perhaps the most interesting plant present on the Torridge is the hybrid pondweed *P x nitens* (*Potamogeton gramineus x P perfoliatus*). This has been known to occur at Beaford on the Torridge since the 1940s but was

not known from anywhere else in Devon. The 1978 surveys on behalf of NCC found it also at other locations downstream (see Figure D1e).

Kingfisher, dipper and grey wagtail all regularly breed along this section of the Torridge. Sand martin also utilise the steep sandy banks where the river opens out from its wooded valley and flows through broad open farmland (see Figure D1c).

Otters are known to use regularly the Torridge and its tributaries for feeding and also breeding. Historically it is famous for this mammal (Tarka the otter at Torrington).

No change in the Torridge above Taddiport is likely to occur as a result of Roadford's Operation.

D12 RIVER TORRIDGE FROM TADDIPORT BRIDGE TO BEAM WEIR

This short section of river (less than 3km) is the most downstream stretch of the Torridge unaffected by tidal influences. Immediately downstream of the bridge is the abstraction point to Torrington Water Treatment Works and a short distance downstream of this is the sewage outfall. The stretch will be affected by Roadford because the operation of the reservoir provides water for North Devon (via a pipeline) and hence can influence the extent and timing of abstractions from the Torridge.

Table D1i indicates that a site (15) downstream of the abstraction and sewage outfall, has been surveyed for macrophytes in 1986 by Holmes (1987). Table D1iii shows that this site has far fewer species than found at the site only 3km upstream at Town Mills (site 14). Some idea can be gauged as to whether this is primarily in response to the effects of abstraction and/or the sewage outfall by reference to data collected by the NCC in 1978 from Weare Gifford (2km further downstream). The following species, absent from site 15, were present a little further downstream at Weare Gifford:

Ephydatia	Freshwater Sponge
Cinclidotus fontinaloides	Moss
Caltha palustris	Marsh Marigold
Eleocharis palustris	Common Spike-rush
Eupatorium cannibinum	Hemp Agrimony
Filipendula ulmaria	Meadowsweet
Lythrum salicaria	Purple Loosestrife
Myriophyllum alterniflorum	Alternate-flowered Water-milfoil
Potamogeton x nitens	Hybrid pondweed

On the otherhand, the following were not:

Cladophora aegagropila
Dermatocarpon fluviatilis
Verrucaria spp
Amblystegium fluviatile

Since the four species listed above are generally pollution-sensitive lower plants (two are aquatic lichens) it is suggested that the sewage outfall is having some affect, perhaps this influence being enhanced by abstraction. For marginal and bankside plants the effect is either very limited, or non-existent (local conditions precluding records for some species which find suitable habitats downstream).

Reference to data collected from the 1978 NCC survey also suggests that either, or both, the sewage outfall or the abstraction are having some influence in the lower freshwater reaches of the Torridge. Although the Weare Gifford site is influenced by tides, this is a back-up of freshwater from upstream and not an intrusion of brackish conditions. Despite all the sites surveyed below the Okement being classified into the same plant community type (Holmes; 1983), the lowest site at Weare Gifford was the

only site to have a large growth of the pollution-tolerant algae *Stigeoclonium*. This was confirmed by the drought monitoring work of the author in 1989 (see Figure D12a, b); filamentous algae were more than twice as abundant at Rothern Bridge than at Town Mills, and *Stigeoclonium* was only present at the former (Figure D12a). Thus it is concluded that the sewage outfall does exert an influence on the river, and this may be influenced by the amount of water abstracted just upstream of the outfall.

There is no specific information for birds within this section of river but data in Sitters (1988) suggests that dipper, grey wagtail and kingfisher breed here (Figure D1c).

There are no adjacent habitats of any note which could possibly be affected by changes resulting from the operation of Roadford.

The proposed operation of Roadford should lead to improved conditions for biota because existing flow conditions will be enhanced through reduced abstractions at all but moderately high flows. Although the amounts are small in comparison with the other rivers, even slightly reducing the abstractions at times of low flow leads to a significant percentage improvement in flows remaining. Conversely the slightly increased take at high flows has a negligible influence on the percentage decrease in flow compared with existing situations.

D13 TORRIDGE ESTUARY (DOWNSTREAM OF BEAM WEIR)

This section of tidal river and estuary will be affected by the operation of Roadford through its influence on the extent and timing of abstractions from the Torridge upstream. Since the stretch upstream also receives outfalls from sewage treatment works and a creamery, the main potential impacts arising from changes in water resource usage is most likely to be imparted through water quality changes rather than any physical effects of changes in amounts of water. This is critical in the Torridge since dry weather flows in the lower reaches of the river are exceptionally small when compared with mean discharges.

The principal interest of the tidal Torridge and its estuary is birds. Unlike the Tamar, the main interest centres on the mudflats of the lower estuary where significant numbers of waders are present each winter. In common with the Tamar, the estuary has little breeding-bird interest. Combined, the Taw-Torridge estuary has been notified as an SSSI downstream of Bideford Bridge (Figure D13a). The citation (Figure D13b) indicates that the bird interest is a most important element of its ecology which justifies its designation. The importance of the site for curlew, golden plover, redshank, dunlin and oystercatcher is indicated by the citation as well as the winter populations of these birds in south-west England as shown in Figure D1b. Both EN and the RSPB have indicated that the numbers of waders present on the estuary in hard winters frequently exceeds 20,000 birds. This gives the site both National and International status.

In the tide-affected river above the SSSI at Bideford, dipper do not breed but grey wagtail thrive and breed in good numbers (Sitters; 1988 - Figure D1c). The same sources of information indicate kingfisher breed at the head of the regular saline intrusion zone at Beaconside.

A survey and literature review of the Taw/Torridge estuary has been undertaken by the Fields Studies Council's Oil Pollution Research Unit. Nothing of exceptional interest is known save for the bird interest. The saltmarsh habitats around the edge of the mudflats were also noted as being important.

There are no data on the usage of the estuary by mammals; otters are known to use it however.

Botanical information is very limited for the upper estuary. A site at Weare Gifford was surveyed as part of the national NCC surveys of Holmes in 1978. Although below Beam Weir, the river is only affected by diurnal fluctuations in water level and not any intrusion of salinity. Due to this, the flora is little changed from that above. Filamentous algae, such as the pollution-tolerant *Cladophora* and *Stigeoclonium*, dominate the in-channel flora whilst the margins have abundant Reed Canary-grass (*Phalaris*), as upstream. The locally under-recorded Wood Club-rush was found here on the banks whilst in the channel the rare *Potamogeton nitens* was also found (confined in south-west England to the Torridge; see Figure D1e).

The lower estuary, within the SSSI, has a typical zonation of saltmarsh plant communities and some relatively rare plants too (see Figure D13b). The most interesting communities are associated with the various zones of saltmarsh rather than the river mouth which has the most variation in diurnal salinities related to river flows.

Greatest interest in the estuary is thus centred more than 10km downstream of Beam weir on the Torridge on the open mud flats and saltmarsh of the combined Taw/Torridge estuary. Subtle differences in the amount of freshwater flowing into the area of main interest during summer time cannot have any effect at all providing water quality does not deteriorate. This opinion is based on assumptions that the principal interests identified are not dependent on subtle changes in salinity at the river/sea interface during the summer. They are, on the other hand, dependent on the physical nature of the estuary which is shaped by the river flows during spates and the daily and seasonal affects of tides in creating mudflats, sand banks and saltmarsh. The only influence of low flows on the ecological interest of the key areas of interest centres on water quality and the affect that a catastrophic pollution incident might have on invertebrates on the mudflats (and thus food chain of important birds) and the vegetation furthest down the shoreline and closest to the Torridge itself.

As the proposals provide for reduced takes of Torridge water under low flows the conclusion has to be that there cannot be any adverse impacts of the operation on the Torridge. The reduced takes might be beneficial, but the amount of charge in relation to the dominant factors determining the main interests of the estuary suggests the changes will have no detectable influence.

D14 TAW ESTUARY DOWNSTREAM OF NEWBRIDGE

The operation of Roadford could affect the Taw estuary by influencing the extent and timing of head-of-tide abstractions at Newbridge.

Little information is available for this estuary. It is tidal from Newbridge and saline influences can extend this far up river. The Taw/Torridge SSSI (Figure D13a) does not extend as far upstream as Newbridge. Thus, like the Torridge and unlike the Tamar, the estuary interest is centred in the mainly marine section and not the area most affected by river flows.

The ornithological and plant interest, and their status, is as described for the Torridge estuary in D13. The effect of river flows on this interest during the summer, and the potential impact which changes in abstraction might have, are also the same.

Since the Taw has a much higher pmf, abstractions cease before a drought period begins. The proportion taken is so small in relation to the residual flow that no adverse impacts appear likely. As the proposal will result in a new permanent abstraction on the Taw, it will be important to monitor the situation to confirm this conclusion.

D15 BURRATOR RESERVOIR

Burrator will be affected by Roadford in being drawn down further, and more regularly, than at present. Because of the fishery interest of the Meavy (dependent on flushing floods in late autumn/early winter), water supply operations will aim to allow the reservoir to be full by early winter.

Devon has few large areas of open water; prior to the building of Roadford Reservoir, Burrator was the second largest (61ha) open water site in the country (Slapton Ley being the largest at 97ha). Just over ten years ago, the RSPB in conjunction with the Water Space Amenity Commission (WASC; 1979) produced a classification of reservoirs according to their bird interest. Those with any interest were classed into one of four 'grades' according to how many wildfowl they attracted. The lowest grade attract between 100-250 birds, and Burrator fell within this lowest grade. Smaldon (1982) reported in 'Devon Birds' that Burrator is the most ornithologically interesting of the Dartmoor reservoirs; despite this its depth and acidity and poor productivity precludes it becoming an important site for wildfowl. He reports that "wintering numbers of duck are low, breeding waders are non existent" and "passage birds are scarce". The vegetated margins, he reports, leave little exposed mud making it a very poor feeding ground. This has been confirmed by John (pers comm). Wildfowl counts during winters through the 1980s (Devon Bird Report summaries) indicate mallard are the only really common bird to occur although teal, pochard and tufted duck may be counted in reasonable numbers. Burrator's main ornithological interest is the recently developed Goosander roost (see Figure D15a). Sitters (1988) reports that this bird first bred in Devon in 1980 (on the Dart) but the favoured winter roost in the whole of Devon is Burrator.

Despite being a mature reservoir, Burrator also has a poor flora, supporting few aquatic or marginal species. Of principal interest is Quilwort (*Isoetes*) and Shoreweed (*Littorella*), the latter carpeting much of the draw-down shoreline. This, together with *Scirpus fluctaus* (Floating club-rush) and *Juncus bulbosus* (Bulbous Rush), gives rise to the unusually green exposed margin around the reservoir in summer and results in the poor feeding conditions for birds. The rapid changes in water level enable these plants to succeed in Burrator since they can withstand deep inundation and periodic desiccation through exposure.

No invertebrate data have been found for Burrator. However there is some concern regarding the potential for interesting species to be associated with the vegetated drawdown zones (information given through consultation meetings).

The greater utilisation of Burrator for water supply will obviously have some impact on its present biota. Thus far, however, nothing of major significance has been reported to occur there save for goosander in winter and Quilwort. The former is not expected to be adversely affected since the reservoir should be full by early winter. Because of this the locally important wildfowl interests should be maintained. Greater draw-down, and for longer, may results in the upper shoreline losing its Shoreweed community. This

would be detrimental to the visual amenity of the site but may provide better feeding conditions for waders and passage birds. However it may adversely affect specialised invertebrates (not investigated) if they are present.

The vertical distribution of Quillwort is not known. Searches by the author in 1990 around limited areas of the drawn-down shores (by c.4m) failed to find it. Greater drawdown could potentially adversely affect it if it is located at deeper localities to avoid desiccation. It is possible that it might not be able to migrate further down the reservoir to avoid future desiccation because of light limitations. Clearly a monitoring programme is required to assess how changes in water level affects the present floral assemblages. As there is inadequate knowledge of these at the present time, a base-line survey at the first available period of extended drawdown is required.

D16 MELDON RESERVOIR

Roadford could affect Meldon by enabling more releases to be made to the Okement as well as more water being taken for direct supply.

Meldon is a very steep-sided reservoir in the West Okement catchment high up on Dartmoor. It is an acid and very nutrient poor reservoir since its catchment is open moorland and health. The steep rocky edges preclude the growth of extensive communities of marginal plants. Between the rocks sparse clumps of rush (*Juncus effusus, J bulbosus*), Lesser Spearwort (*Ranunculus flammula*) and grass (*Nardia and Molinea*) together with mosses such as *Calliergon, Hyocomium* and *Drepanocladus* occur. On the rocks a few mosses, exemplified by *Racomitrium aciculare*, are present. Within the body of the reservoir there is only sparse growth and limited survey information is available. DWT have a reserve around part of the reservoir but little or no management occurs on it.

The birds of the reservoir are generally poor, the lack of food and exposed steep edges being the main reasons. Wildfowl counts reported during the 1980s in the Devon Report indicate that it is not unusual for no birds to be present at all. When they are present there are very few individuals. It is noteworthy that goosander have been recorded at some time in most years.

No records of invertebrates have been made available.

It is clear that Meldon has been poorly investigated, compounding the impression that it has minimal ecological interest. This said, it is difficult to see how any major interest could be affected when this reservoir works conjectively with Roadford. The drawdown curves produced suggest that the changes will be slight, some years showing slightly less drawdown and others showing slightly more.

D17 ROADFORD

The extent and quality of ecological interest at Roadford will depend on a combination of many factors. The principal ones are:

- The area set aside primarily for wildlife.
- Type and extent of active recreation and areas of public access.
- Form and location of habitats created on adjacent terrestrial land in addition to tree planting.
- Form, extent and success in creating marginal habitats to mitigate against the impacts of regular drawdown.

For some considerable time the potential for habitat creation has been recognised at Roadford. Conservation bodies sit on a consultative group which includes wildlife, recreation and local interests. The minutes of their meetings are not available to the public, however. In the recognition that the building of Roadford Reservoir would destroy existing valuable wildlife habitats in the Wolf valley, and provide opportunities for habitat creation, South West Water commissioned a survey of the site. This was undertaken by the Devon Wildlife Trust who produced a final report in December 1986 (Steel; 1986). This report described the habitats of the Wolf valley and assessed their quality. The report also made recommendations for future management. In 1989 (Watkins & Steel; 1989) a conservation management plan was commissioned by South West Water and produced by DWT. This latter document outlined the rationale for conservation management together with prescriptions and priorities for action.

The key findings of the first report was that some habitats of interest would be lost. Two woods would be destroyed, the most extensive one having little interest whilst the smaller one was better. Dry grasslands had little value whilst the damp/marshy grasslands had both floral and bird interest. Greatest value was placed on the extensive Culm Measure grasslands which would be destroyed. The report also highlighted that many spring lines were present, several just above the top level of the reservoir. The report also made 33 recommendations regarding measures to protect areas of interest before, during and after construction as well as the measures required to provide the means whereby the wildlife potential of the impounded valley could be realised.

Discussions with SWWSL have indicated that the majority of the recommendations could be accommodated; DWT have been given another commission to advise further and update their management plan to take account of new information and development of existing habitats. The consultation process suggests that conservation bodies have a satisfactory input through the consultative committee and can influence the management and creation of habitats and the monitoring of plant and animals on the site as it develops.

It is worth noting that wildfowl in reasonable numbers have already been counted on the site (A W G John, pers comm). However it is too early to begin to predict how operations will affect the plant and animal communities which will develop in the future. Monitoring of development and change is deemed desirable.

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APPENDIX D1

HALCROW

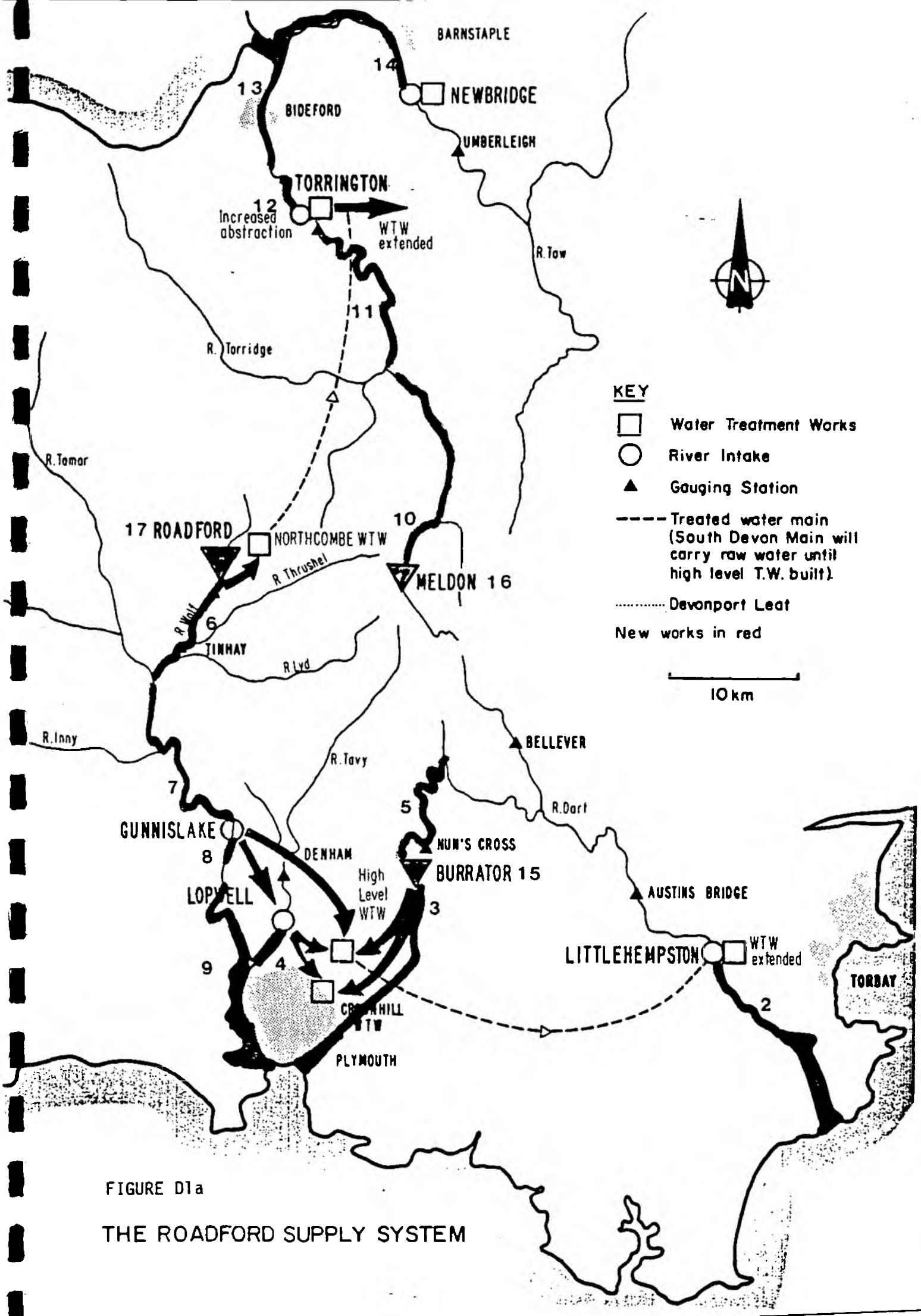

FIGURE D1a

THE ROADFORD SUPPLY SYSTEM

FIGURE D1b Important waders and wildfowl in the estuaries affected by Roadford's operation. The first 17 distribution maps illustrate the local or national importance of species in winter (taken from Lack; 1986). The last two, for breeding shelduck and oystercatcher are taken from Sitters (1988).

Oystercatcher

Haematopus ostralegus

THE high-pitched, strident calls and the strongly contrasting patterns of its black and white plumage place the Oystercatcher amongst the most noticeable inhabitants of the coasts of Devon, though mainly outside the breeding season. The wintering population of several thousand birds, concentrated on estuaries and scattered along coasts, dwindles in spring to a few hundred as the adults migrate to breed in Holland, Scandinavia, northern Britain and the Faeroes. Most of those remaining are immature (less than 5 years old). Only a few dozen pairs breed in Devon.

Breeding birds only occur along the coast, usually in rocky and inaccessible places, so more pairs may breed in Devon than have yet been discovered. None has been recorded inland. This is in marked contrast to other parts of the country where Oystercatchers breed far from the coast, particularly along river valleys. Most observers in Devon mention birds breeding at the foot of cliffs, amongst shingle, rocks and boulders. To avoid the high tides, some pairs even breed on the cliff face. One or two pairs breeding by the East Yelland Power Station, on the Taw estuary, make their scrape in a mixed area of grass, shingle and bare mud. Freedom from excessive disturbance is important, otherwise the parents do not have enough time to feed their young (the Oystercatcher and the Snipe are the only British breeding waders that do this regularly) and protect them from predators. Disturbance may be the reason why few Oystercatchers in Devon breed on sandy shores and marshes, as they do elsewhere in Britain. Widespread disturbance may partly explain the small numbers that breed in the county, though its position at the edge of the breeding range must also be involved: breeding Oystercatchers were rare, even in the last century, before disturbance along the coasts increased to present levels.

Only the Lundy Island population has been counted often enough for us to know how numbers have changed recently. According to Dymond (1980), the number of pairs has fluctuated between 8 and 22 pairs since the 1920's, without any obvious trend up or down. Dare (1970) estimated that 25-50 pairs bred in Devon in the early 1960's, including the Lundy birds. The present survey indicates 28-58 pairs, so there may have been a slight increase. This is hard to prove, because the coverage by birdwatchers in the county has increased. But it is clear that only a tiny fraction of the 36,000-46,000 pairs estimated by Reed (1985) to breed in the British Isles, do so in Devon.

Nothing is published on the wintering areas of Devon breeding birds, or of their breeding biology. Harris (1967) studied them on Skokholm Island, S Wales, where they probably behave similarly. Pairs arrive from the wintering areas during February and early March and take up territories almost immediately. Most laying occurs between mid-May and mid-June, with average clutch-size varying annually from 2.5 to 3.3. The proportion hatching varies from 44 to 82%, with predation, mainly from gulls, being the main cause of egg-loss. On average, each pair produced 0.9 fledged young during Harris' study. Birds leave for the wintering areas in July and August.

Evidence from Skokholm is that most adults winter within a short distance of the breeding area, many on the nearby mainland. A few go further afield, including one which was found on the Exe estuary, Devon (176km SSE). Many immatures from Skokholm move south to France, though some return to breed on the island when they reach maturity. A Devon ringing recovery which follows this pattern concerns a bird, ringed as a chick on Lundy in June 1966, and recovered near Quiberon in Brittany the following January.

Though few in number, breeding Oystercatchers do contribute to the interesting variety of the summer coast-line. Protection from disturbance could increase their numbers, as it has done in NW France. Unless this is provided, they are unlikely to be seen in any but the most inaccessible parts of Devon.

J. D. GOSS-CUSTARD

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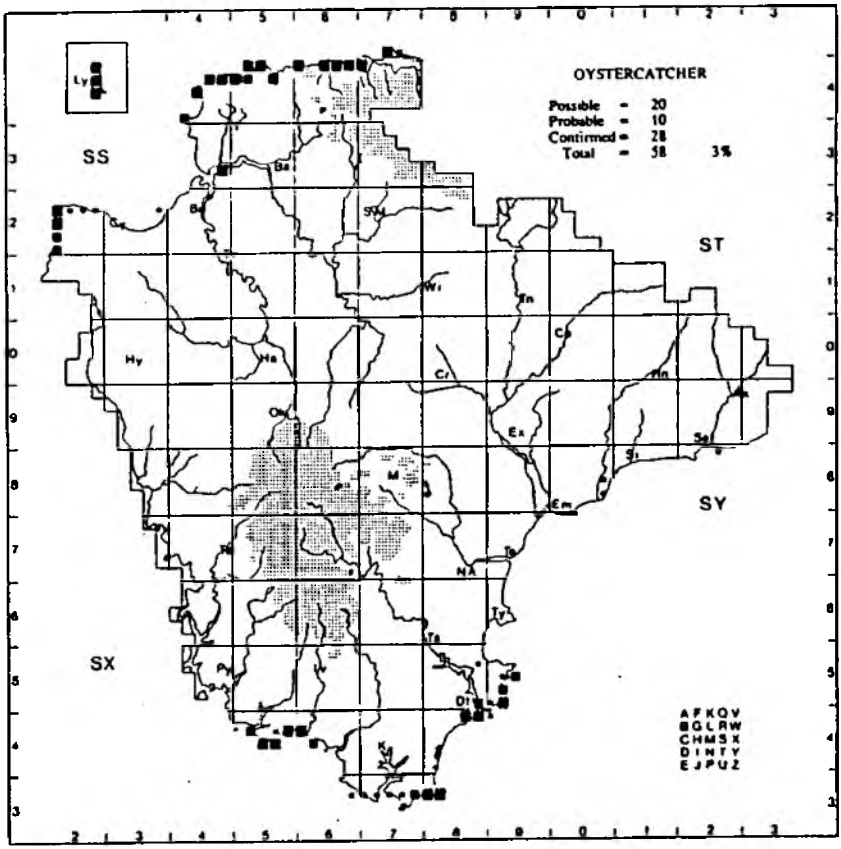
OYSTERCATCHER
Possible = 20
Probable = 10
Confirmed = 28
Total = 58 3%
SS
ST
SX
SY
A F K Q V
B G L R W
C H M S X
D I N T Y
E J P U Z

Dipper

Cinclus cinclus

THE Dipper is the only passerine to have mastered the art of feeding under water. It is common on fast-flowing rivers and streams throughout Devon and is usually seen perched on a rock in mid-stream or diving for food in the shallows. It is often first located by its penetrating *zit* call as it flies, low and direct, past the observer. Both male and female may be heard singing in almost any month of the year.

Dippers are found mainly on clean, fast-flowing streams and rivers in hilly areas, especially on the slopes of Dartmoor and Exmoor. They avoid open moorland and slow-flowing, lowland rivers. Occasionally they breed on streams close to lakes or reservoirs. On the N Devon coast, Dippers may breed within 100m of the sea. Provided that the nest sites remain undisturbed, they will nest in villages and even town centres, as they do in Okehampton, Tavistock and Newton Abbot.

The map shows Dippers to be widespread on all the main rivers and most of their tributaries, from sea level to over 450m a.s.l. They appear to be commonest on the Dart, Plym, Tavy and Okement flowing off Dartmoor, the East and West Lyn and the Bray on Exmoor and on the Otter. This may, however, be a result of better observer coverage. Except when they are feeding young, Dippers may be difficult to locate, particularly those using well-hidden natural sites, or in steep wooded river valleys. They are scarce or absent in the South Hams, on the low-lying Rivers Clyst and Culm between Topsham and Cullompton, on the Rivers Mole and Yeo near South Molton, on parts of the upper reaches of the Rivers Taw and Torridge, and between Okehampton and Holsworthy (where there are no rivers or large streams). They have never been seen on Lundy.

Although the majority of occupied tetrads (310 or 72%) lie between 50 and 200m a.s.l., the highest percentage occupation of available tetrads by Dippers was between 250 and 400m, perhaps indicating a preference for upland sites (see altitude chart).

In ideal habitat — large rivers with plenty of shallow riffles — there may be three pairs per 2km of river, but overall density is likely to be much lower. Given an average density of 1-2 pairs per occupied tetrad, the Devon population is probably 500-700 pairs. On some Welsh rivers there has been a decline in the number of breeding Dippers, apparently caused by a decline in invertebrates arising from an increase in river acidity (Ormerod *et al* 1985). Nationally, however, the Waterways Bird Survey index shows that the population is fairly stable and this also seems to be the case on the Rivers Tavy and Plym where A. W. G. John has studied Dippers since 1976. The large numbers of feral mink now present in Devon may give rise to increased predation on Dipper nests in future.

Dippers breed in most of western and northern Britain, in Ireland (where there is a separate race), and in much of Europe, but are absent from southeast England, northern France, the Low Countries and most of Germany and Poland. Their breeding range extends eastwards to the Himalayas, where they occur up to 3,600 m a.s.l., and beyond Lake Baikal to 120°E. Their large domed nests, placed 1-4 m above the water, are built mainly of moss and lined with leaves (often beech) and placed on ledges or in crevices in bridges, culverts, weirs or walls, on rock faces, in overhanging tree roots, and a few behind waterfalls or on old water wheels. The female alone incubates 4-5 eggs for 16 days, then both parents feed the nestlings for a further three weeks on invertebrate larvae (mainly caddisflies, mayflies and stoneflies) and a few fish. Males are sometimes bigamous, particularly where two suitable nest sites are close together. The average size of 110 broods in W Devon, mainly on the Tavy and Plym, during 1977-86 was 3.5 (A.W.G. John). This compares well with the range of brood sizes found elsewhere in Britain (Tyler and Ormerod 1985). The first young usually fledge in late April or early May and second broods are raised by 10-30% of pairs in W Devon.

In Britain, Dippers of the race *C. c. gularis* are very sedentary and ringing of birds in W Devon has shown that few move more than 5km from their birthplace. However, two nestling Dippers from E Cornwall have reached the River Tavy. One ringed in May 1970 on the River Fowey was trapped near Tavistock in September 1978, at the time the oldest Dipper recorded in Britain. A bird caught at Peter Tavy in August 1981 had been ringed three months earlier near Bodmin, 41km to the west. A few birds of the Continental race *C.c. cinclus*, known as the Black-bellied Dipper because they lack the chestnut breast-band, occur each winter on the east coast of Britain. The Dipper population is not affected by severe winters, and birds are known to feed under ice when necessary. Adults remain on the same territory throughout the year. Communal roosts of up to 6 or 7 Dippers may occur at suitable bridges in autumn and winter.

In a few instances, traditional nesting sites in bridges have been ruined by re-pointing of the bridge. Nestboxes have been used successfully with this species and could perhaps be useful on some of the new smooth concrete bridges now being erected.

A. W. G. JOHN

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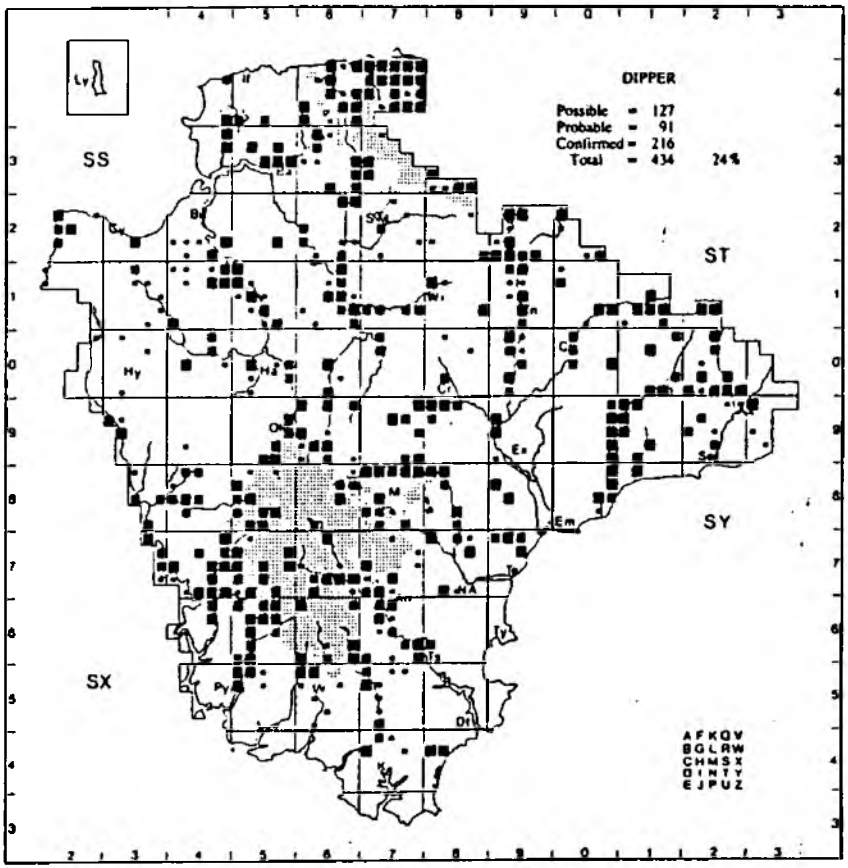
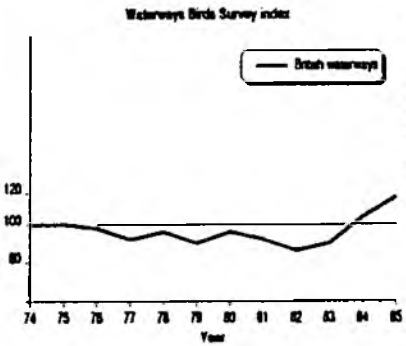
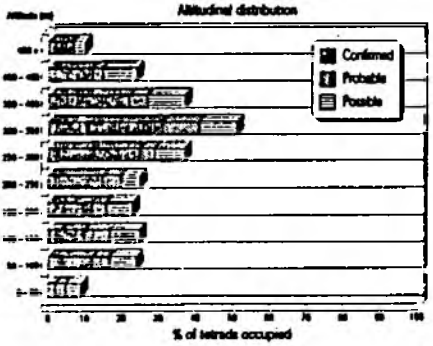

DIPPER
Possible = 127
Probable = 91
Confirmed = 216
Total = 434
24%
SS
ST
SX
SY
A F K Q V
B G L R W
C H M S X
D I N T Y
E J P U Z


Waterways Birds Survey index
British waterways
120
100
80
74 75 76 77 78 79 80 81 82 83 84 85
Year


Altitudinal distribution
Confirmed
Probable
Possible
% of tetrads occupied

Kingfisher

Alcedo atthis

IT is the high-pitched flight call which usually draws attention to a Kingfisher as, with a flash of dazzling blue, it dashes by along a stream or river. But an observer must be more patient to watch one perched on an overhanging branch waiting to plunge into the water after a fish.

During the breeding season, Kingfishers are birds of slow-flowing rivers, canals, lakes, ponds and flooded gravel-pits, though in the autumn and winter they tend to move downstream to tidal waters and estuaries. Devon is not well endowed with slow-flowing rivers and there are few suitable lakes and ponds, so it is not surprising that the county population of Kingfishers has never been particularly large. The map shows that breeding has been proved on all the main river systems, but the fast-flowing upper reaches where they tumble off Dartmoor and Exmoor, so beloved by the Dipper, are avoided by the Kingfisher. The Otter is particularly favoured, with breeding records along almost the entire length. There is also a good scattering of records along the Exe, Culm and Yeo. Rivers like the Dart and Teign, however, which are generally fast-flowing and for the most part pass through geological conditions which provide less suitable nesting banks, have relatively few breeding Kingfishers.

Obtaining confirmation of breeding for this species can be very time consuming, necessitating a search of all suitable sections of river in a tetrad. This would have been especially difficult for observers covering tetrads far from home. It is therefore not surprising that evidence of confirmed breeding was obtained for only 74 tetrads. Nevertheless, with probable and confirmed breeding in only 7% of tetrads in a seven-year period and with each tetrad registration almost certainly referring to just one pair, there is no doubt that the Kingfisher is a particularly scarce species in Devon.

Severe winter weather, causing rivers and ponds to become frozen over, usually results in heavy mortality. This is reflected in the Waterways Bird Survey index which shows sharp reductions following the cold winters of 1978/79 and 1981/82. In Devon, where Kingfishers can move to the estuaries in winter, these effects are probably not quite so severe as in inland counties. On the basis of the rather sketchy information which is available, it is estimated that the Devon population has fluctuated during the period of the survey in the range 50 to 150 pairs.

It is interesting that Dippers were recorded in nearly twice as many tetrads as Kingfishers. This reflects the higher proportion of fast-flowing rivers and streams in Devon.

The Kingfisher breeds from the British Isles to NW Africa and eastwards across the warmer parts of Eurasia as far as New Guinea. It is widely, but thinly, distributed in England, Wales and Ireland on all suitable river systems, but becomes much more local in Northern England and is very scarce in Scotland. Nests are generally excavated in steep banks of slow-flowing streams and rivers, but sometimes in banks and sandpits some distances from the nearest water. The breeding season lasts from late March to August and two broods are usually reared, a fact that greatly helps numbers to recover after the depletion caused by severe winters.

The majority of British Kingfishers are sedentary and two-thirds of ringing recoveries refer to distances of less than 9km. In autumn, there is a limited post-breeding dispersal mainly involving juveniles. The longest movement recorded for an adult in Devon was a male ringed at Fleet Mill marsh near Totnes on 27 July 1975 and found dead a month later at Buckfastleigh (11km N). Recoveries of juveniles include a young male ringed at Slapton on 12 August 1975 and retrapped on 11 September the same year at Fleet Mill marsh (15km N) and a young female ringed at Slapton on 22 August 1985 which was killed when it flew into a mirror on 14 December 1985 at Plymouth (38km W). Occasionally much greater movements have been recorded, including an immature male ringed at Slapton on 4 August 1973 and retrapped at Vlassenbroek in Belgium on 28 July 1974. This was only the second foreign recovery of a British-ringed Kingfisher.

Apart from the effects of severe winters, river pollution, causing fish kills, is probably the main hazard to the Kingfisher population of Devon. In an agricultural county, the source of river pollution is usually uncontrolled farm effluents, especially silage liquor and slurry. Fortunately the South West Water Authority is well aware of the problems caused by some farm enterprises and all incidents of pollution are investigated, with persistent offenders liable to prosecution. Although Devon cannot provide enough habitat for a large population of Kingfishers, we should strive to ensure that their existing haunts are not destroyed as a result of modern river management, disturbance or pollution.

K. C. TYSON

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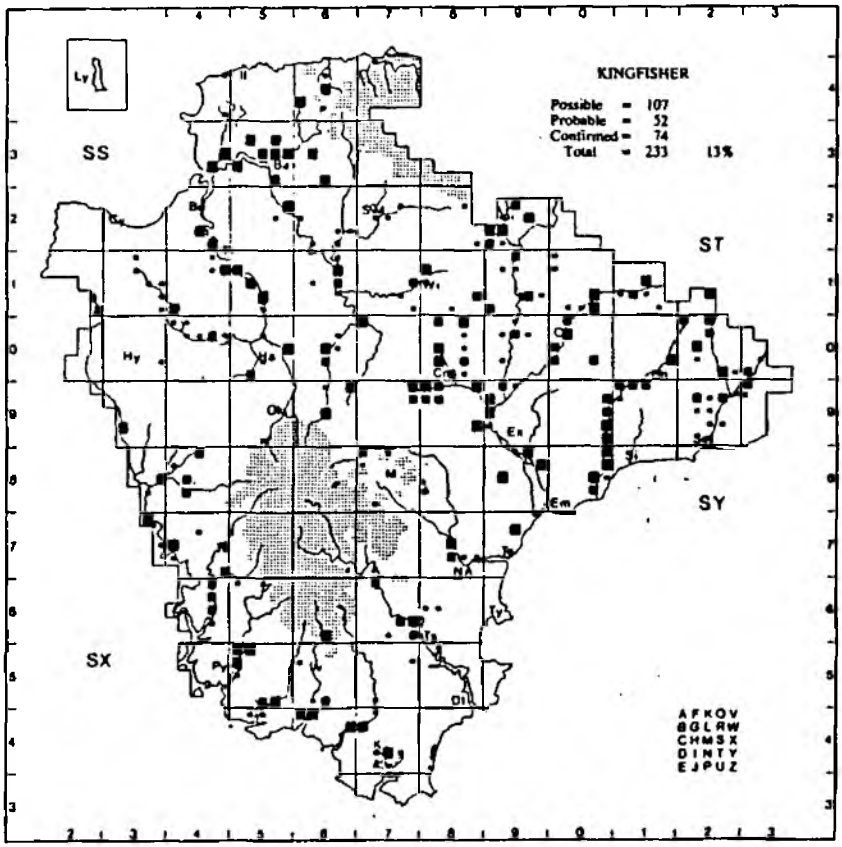
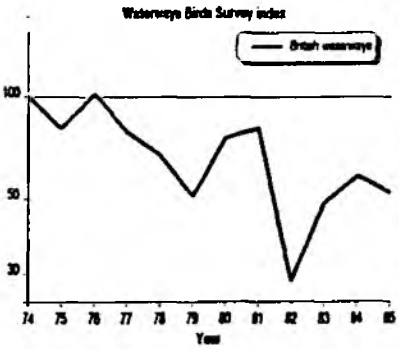
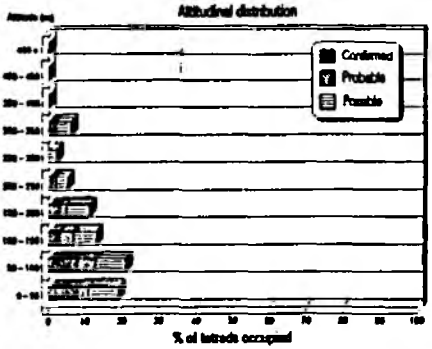

KINGFISHER
Possible = 107
Probable = 52
Confirmed = 74
Total = 233 13%
SS
ST
SX
SY
A F K O V
B G L R W
C H M S X
D I N T Y
E J P U Z


Waterways Birds Survey index
British waterways
100
50
30
74 75 76 77 78 79 80 81 82 83 84 85
Year


Altitudinal distribution
Confirmed
Probable
Possible
% of tetrads occupied

Grey Wagtail

Motacilla cinerea

Where Torridge tumbles
Duffodil and stone take flight.
Hail! the Grey Wagtail.

Haiku for spring — LRW.

THIS most elegant and dashing member of the wagtail family is common throughout the county. It is normally associated with fast-flowing streams and rivers where it is easily located bobbing up and down on water-splashed rocks or flying noisily along the course of the river, its dipping flight showing off its butter-yellow rump and under-tail coverts which contrast attractively with the blue-grey back and head.

The map shows that Grey Wagtails breed along all the main rivers in Devon, but two other features are also evident. First, Grey Wagtails may be found almost anywhere where there is flowing water, even on metre-wide leats and brooks or around reservoirs. One pair even nested close to a culvert running under the A38 near South Brent. Occasionally nests may be found well away from water; for example, a pair nested for some years in the ruin of a farm building at Dean Coombe near Burrator, a considerable distance from the nearest water of any kind. The map can be contrasted with that for the Dipper which has a much greater dependence on rivers and streams. The other interesting feature is that breeding occurs at almost any altitude, with many nests located around the coast or near river mouths as well as on the highest moorland (see altitude chart). The strong concentrations in the north and southwest of the county are probably indicative of the greater incidence of upland streams running off Exmoor and Dartmoor which is the preferred habitat of this species.

The Waterways Bird Survey indicates that in western hill country Grey Wagtail territories occur at the rate of one for every kilometre of river or stream, for example, in N Wales in 1974 territories occurred at the rate of 114 per 100km of waterway. A survey carried out on a stretch of the River Plym during the years 1983-85 came up with a similar figure of one pair per kilometre (R. J. Hubble). The RSPB Exmoor survey of 1978 found that approximately 40 pairs were proved to breed in a similar number of one-kilometre squares and the RSPB Dartmoor Survey of 1979 found 1.17 pairs per km² across all areas of suitable habitat. As an approximation it seems likely, therefore, that Devon holds between one and two pairs per occupied tetrad, or 1,000-2,000 pairs. This compares with the *BTO Breeding Atlas* estimate of the population for the whole of Britain and Ireland of 25,000-50,000 pairs.

Grey Wagtails breed throughout Europe as far south as Morocco and the Canaries, although they avoid the more northerly latitudes and are absent from most of Scandinavia. They are particularly susceptible to hard winters when streams become frozen, but the population usually recovers quickly. This is reflected by the WBS index which shows sharp reductions following the cold winters of 1978/79 and 1981/82.

A few pairs lay their first eggs relatively early, towards the end of March, but the majority of first clutches are laid during the latter half of April. Two clutches of normally five eggs are usual and a third is sometimes laid. The last young fledge in late July or early August (Tyler 1972).

There is no evidence of emigration by Devon-breeding Grey Wagtails, though it seems that there is some altitudinal movement off the higher parts of the moors in winter. Birds from northern parts of Britain, however, move south or southwest in winter giving rise to two recoveries in Devon of birds ringed in Angus, Scotland, as nestlings. The first, ringed in May 1976 was recovered near Plymouth on 4 March 1977 and the second, ringed in May 1978 was retrapped at Ottery St Mary on 27 January 1979. There are also recoveries which show that birds from the Continent (Belgium, Denmark and East Germany) move into southern Britain in winter. A small spring passage is noted on Lundy from late February to the end of March and there is a more significant passage in autumn during September and October (Dymond 1980). Occasionally, movements are noted on the mainland, such as a passage of 70 moving SW near Brixham on 1 October 1984.

One notable Devon ringing recovery concerns the oldest Grey Wagtail so far recorded by the BTO Ringing Scheme: a male first ringed at Higher Metcombe in September 1972 and retrapped at the same place in October 1977 and December 1978.

The Grey Wagtail feeds mainly on insects, including flies, small beetles and dragonfly nymphs and therefore the continued existence of unpolluted, free-flowing water where such insects can breed is of vital importance to the future of this attractive species.

R. J. HUBBLE

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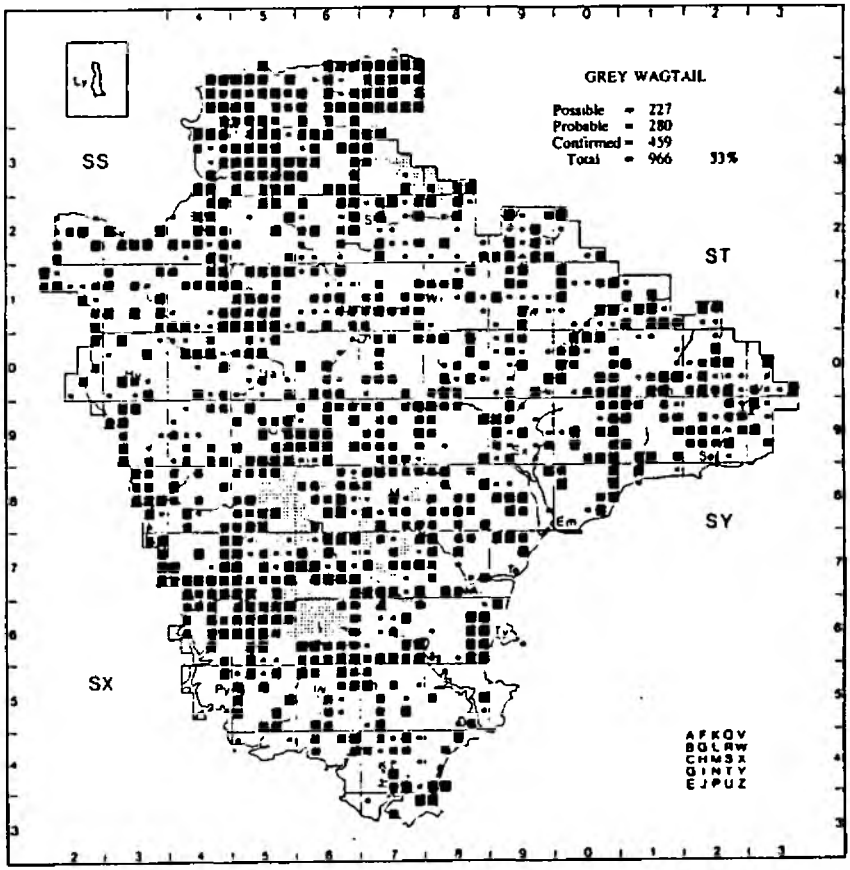
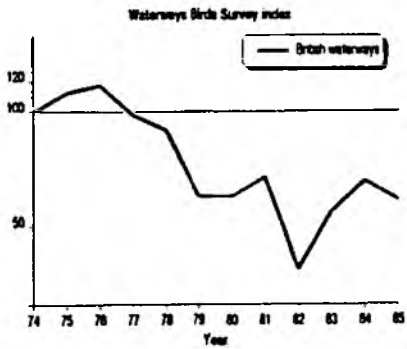
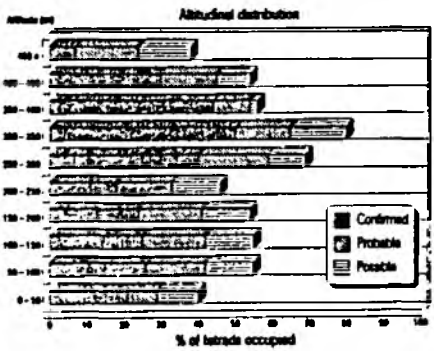

GREY WAGTAIL
Possible = 227
Probable = 280
Confirmed = 459
Total = 966 33%
SS
ST
SY
SX
A F K Q V
B G L R W
C H M S X
D I N T Y
E J P U Z


Waterways Birds Survey index
British waterways
120
100
50
74 75 76 77 78 79 80 81 82 83 84 85
Year


Altitudinal distribution
Confirmed
Probable
Possible
% of tetrads occupied

Sand Martin

Riparia riparia

ALONG with the Wheatear and Chiffchaff, the return of the Sand Martin is one of the earlier harbingers of spring. During the summer, breeding colonies are located along the county's many watercourses and in various sand-pits and quarries. Unhappily, in the last two decades, the population has crashed and it is now very hard to find more than 10 pairs in a colony, whereas in the mid-1960s there were numerous colonies of 50-150 pairs.

Since the 1960s, the breeding distribution has been well studied in Devon — during 1962-65 in an enquiry by the DBWPS (Ellicott 1975), during 1968-72 in the *BTO Breeding Atlas* and during 1977-85 in the Tetrad survey. During each of these periods the general distribution remained very similar and, whilst only the earlier survey was quantitative (total breeding population between 1500 and 2000 pairs), it was clear, during the subsequent surveys, that the species had declined considerably.

The map shows that the area to the east of the R Exe holds over 60% of the confirmed breeding records. In this region, many ideal Sand Martin nesting banks are provided by a combination of slow-running rivers in alluvial water meadows and the prevalence of sand-pits and quarries. The valleys of the Exe, Culm and Otter provide much suitable habitat and it is along these that most of the small scattered colonies occur. Sand Martins appear to show a preference for a new face for the excavation of their nesting holes, whether a freshly eroded river bank or a newly excavated sand-pit, and this factor accounts for the sometimes quite dramatic fluctuations in colony strength from year to year. The distribution in the remainder of the county is very similar to that previously recorded, with small scattered colonies on the Yeo near Crediton, the Teign, around the mouth of the Avon at Thurlestone, on the fringes of Dartmoor, on the higher reaches of the Tamar and on the Taw and Torridge. With the aggregation of records for several years, it is likely that the map reflects a more optimistic picture than is true for any one year. Most colonies have very few occupied burrows and the county population is estimated to have been in the range 300-600 pairs during 1977-85.

Sand Martins breed widely across almost the whole of the Palearctic and Nearctic regions, wintering in Africa south of the Sahara, S Asia and S America. Intensive ringing in Britain in the 1960s showed that, in autumn, migrants depart heading SSW down the Biscay coast, through Spain and into N Africa. Mostly as a result of the efforts of French ringers in Senegal, there have been 28 recoveries which show that many British Sand Martins occur there from February to April. The return in spring appears to occur on a much broader front across the Sahara, with several recoveries to or from Algeria, Tunisia, Libya, Malta, Italy and Switzerland (Mead and Harrison 1979).

During the mid-1960s, the Sand Martin population increased, reaching a peak in 1968, but in 1969 the population was reduced by 45%. The decrease continued until 1974. Numbers then began to increase, but there was a further drop in 1978 and there was another crash in 1984 reducing the population to less than 10% of what it had been in the mid-1960s. There is no doubt that the reason for this decline has been mortality resulting from drought in the Sahel wintering region in Africa. It is considered that the changes in the population described above are reflected in the ringing index. It is likely, however, that the index overemphasises the drop in 1969, because the Sand Martin was the subject of an intensive national ringing study which ended in 1968.

Quite apart from the problems Sand Martins have faced in Africa, there is evidence to suggest that a series of cool, late springs in Britain has contributed to the decline by delaying breeding and consequently affecting breeding success (Cowley 1979). Furthermore, in the spring of 1984, a persistent band of particularly cold and inhospitable weather faced migrants in the Mediterranean, producing a very prolonged migration resulting in a late start of breeding (Mead 1985).

Regrettably there is very little that can be done to halt the continuing decline of the Sand Martin population, although every effort should be made to ensure that all breeding colonies remain free from disturbance in the hope that the losses in Africa will be partly offset by increased breeding success.

P. W. ELLICOTT

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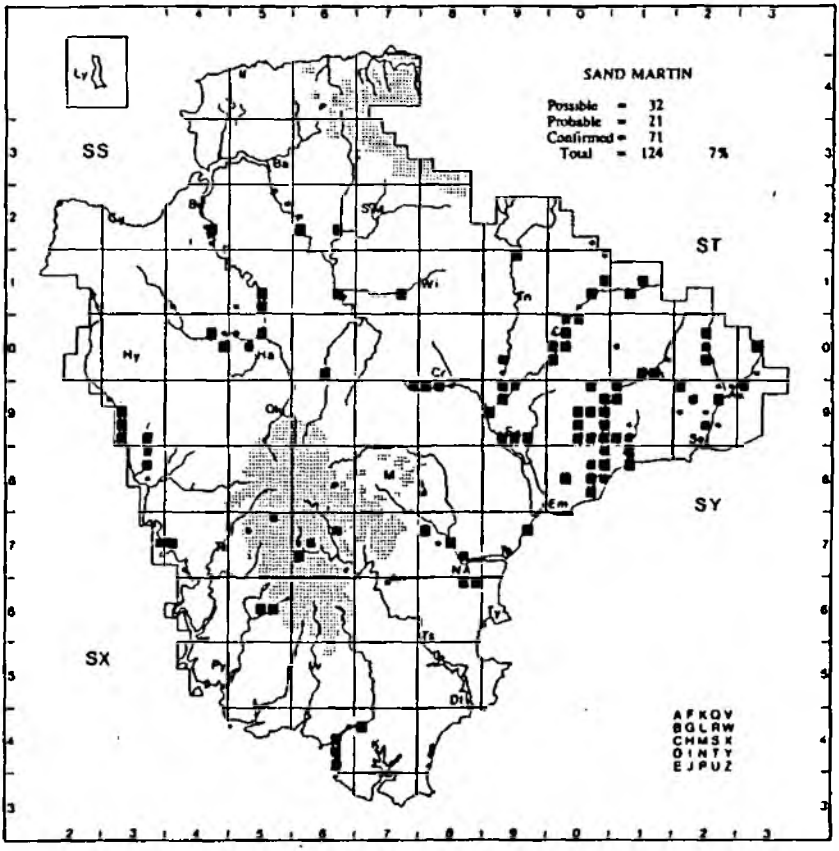
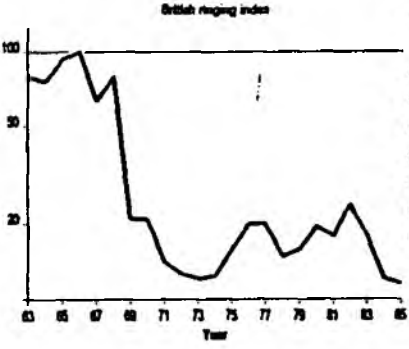
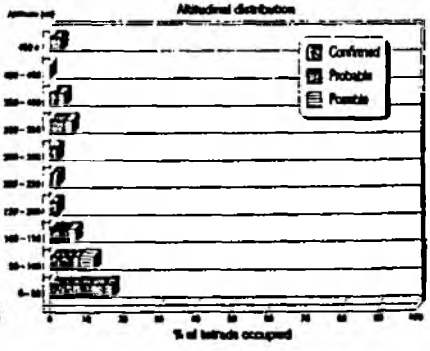
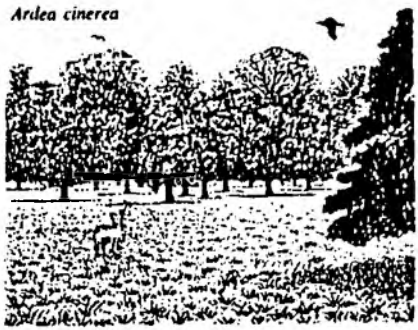

SAND MARTIN
Possible = 32
Probable = 21
Confirmed = 71
Total = 124 7%
SS
ST
SX
SY
A F K Q V
B G L R W
C H M S X
D I N T Y
E J P U Z


British ringing index
100
50
20
Year


Altitudinal distribution
Confirmed
Probable
Possible
% of latitude occupied

Grey Heron

Ardea cinerea



THE Grey Heron is one of the best known British birds, having been the subject of an annual census since 1928. It is also a bird which comes into conflict with man through its diet of fish, whether caught in a river, garden pond or trout farm.

In Devon, all heronries are in trees, both deciduous and coniferous; none nest in bushes or reeds or on cliffs as happens elsewhere.

When feeding, Herons are well distributed throughout Devon and can be seen on the coast, on estuaries, on all river systems, on inland waters, small streams and ditches, and they even forage high on Dartmoor. They often feed in areas far from the nearest heronry and sometimes fly to perch in trees, which can give rise to the mistaken supposition that they are nesting. This long-distance search for food is therefore likely to be the explanation for many of the 'possible' and 'probable' breeding records on the map. On the other hand, some small heronries may have been missed. Most Devon heronries are in the river valleys, with particular concentrations on the Dart and Torridge systems. Many are long lasting, especially the larger ones. Indeed, the one at Sharpham on the Dart was recorded in 1830 and, although deserted for a time in the 1960s, is still in existence today. In contrast, small heronries often come and go quickly, particularly if they are in areas where there is commercial forestry and the trees are regularly felled. During 1977-85, breeding was proved in 51 tetrads. Some of these were isolated occurrences, for example at Slapton (SX84 tetrad I) where one pair nested just in 1982. At other sites, established heronries have disappeared overnight when forestry plantations have been felled; for example Duchy Wood (SX67 tetrad E). The BTO organises the Annual Heronry Census and every few years a special effort is made to cover every heronry in Britain. Such a survey took place in 1985. In Devon, a total of 320 pairs was found in 33 heronries (see Appendix 3). During 1977-85, a total of 37 heronries was reported, but there were no more than 35 in any one year. The fact that the 1985 survey revealed very few additional heronries confirms that, in recent years, the annual census has been fairly comprehensive in Devon and has accurately reflected the changing fortunes of the county population.

The results of the Annual Heronry Census show that the population of England and Wales is normally around 4,000-5,000 pairs. However, severe winters, causing feeding sites to become unproductive, give rise to heavy mortality and reduce the population considerably. This happened during the cold winters of 1961/62 and 1962/63, following which it was estimated that numbers were down to 2,250 pairs. It took until 1970 for the population to recover to its previous level but numbers continued to increase until 1974, since when they have been stable at around 5,500 pairs (Reynolds 1979). In Devon, numbers continued to increase until 1980 with no reduction after the cold weather of 1978/79. The population was reduced slightly in 1981, possibly as a result of poor weather early in the breeding season, and again in 1982 following the severe winter, thereafter numbers increased (see graph). The 1985 survey showed that the population of England and Wales was 5,793 pairs plus 2,950 in Scotland (Marquiss and Reynolds 1986). The Devon total of 320 pairs is therefore of national significance, representing about 3.7% of the British population.

In Devon, all nests are built in tall trees. They are bulky constructions, made of sticks and twigs and lined with smaller twigs, leaves and grass. In Britain, a few eggs are sometimes laid in early February, but peak laying is not until the end of March or early April. There is usually one clutch of 3-5 eggs but second broods have been recorded. Hatching and fledging take 10-11 weeks, though the young will leave the nest 20-30 days before they fledge and clamber around on nearby branches. After they fledge they return regularly to the nest for another 10-20 days. Although a few immatures breed in their first year, most do not do so until they are two years old (*BWP*).

The Grey Heron ranges over most of the Old World except Australasia. In N America it is replaced by the Great Blue Heron *A. herodias* and in S America by the Cocoi Heron *A. cocoi*. It has been suggested that the three forms are conspecific, but they are usually regarded as forming a superspecies (Hancock and Kushlan 1984).

British Herons are fairly sedentary, even in severe winters, and most movements are limited to a radius of 150 km from the natal heronry. A few, however, cross to Ireland and a few from southern England cross to the Low Countries and France and, rarely, Spain (*BWP*). Some immigration into Britain takes place in winter as shown by the recovery of a Swedish-ringed nestling at Blackawton in March 1948. Very few Herons have been ringed in Devon and there is no evidence to show to what extent they disperse. Continental birds migrate to varying degrees and many cross the Sahara.

Ringing recoveries indicate that the commonest causes of death are from being shot and by hitting overhead wires. Since legal protection in 1954, the number of immatures surviving their first winter has increased, whereas the more extensive use of pesticides has brought about an increase in the mortality of older birds (Mead *et al* 1979). Recently, the possibility that Herons can be shot legally by fish farmers has given cause for concern. Another threat is the destruction of heronries through tree felling. Although it would seem that there is enough breeding habitat in Devon into which displaced birds may move, it should be remembered that the Heron is not a numerous bird and the full consequences of the loss of important traditional nesting sites are not properly understood. The destruction of heronries through tree felling and other development should therefore be resisted. The conservation of this species also requires that rivers, streams and estuaries are kept free from pollution.

J. F. JONES

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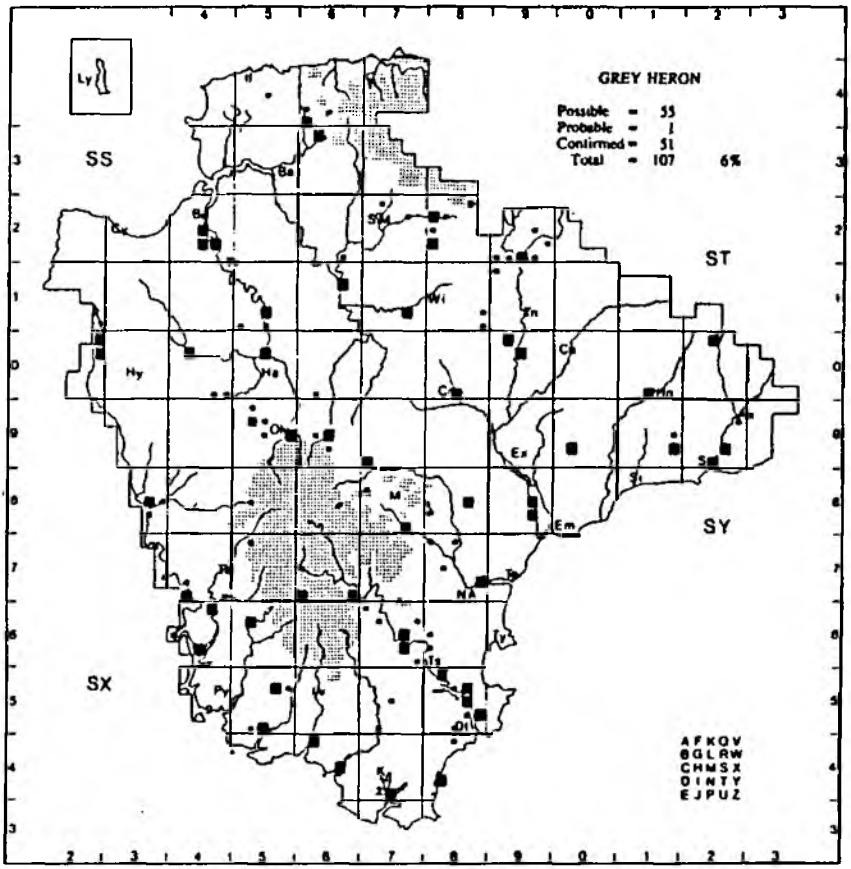
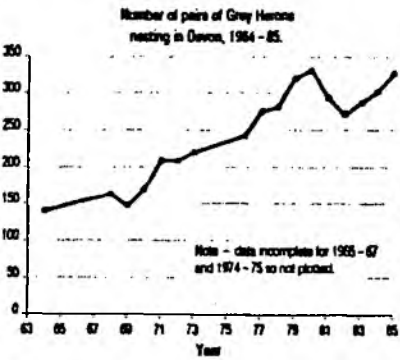

GREY HERON
Possible = 55
Probable = 1
Confirmed = 51
Total = 107 6%
SS
ST
SX
SY
Ly
Ba
Hy
Ha
Ex
Em
Ty
Ts
Dt
Pr
Ni
Tn
Cs
Sl
Mi
Wi
A F K O V
B G L R W
C H M S X
D I N T Y
E J P U Z


Number of pairs of Grey Herons nesting in Devon, 1964 - 85.
350
300
250
200
150
100
50
0
63
65
67
69
71
73
75
77
79
81
83
85
Year
Note - data incomplete for 1965 - 67 and 1974 - 75 so not plotted.

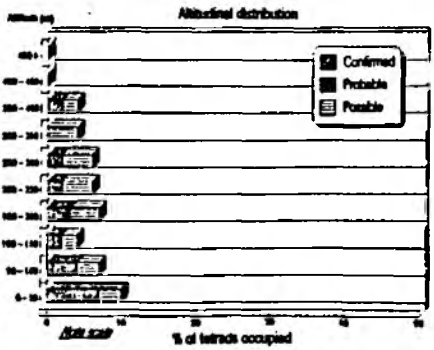

Altitudinal distribution
Confirmed
Probable
Possible
% of tetrads occupied

FIGURE D1c River birds of significance breeding on the rivers affected by Roadford. Distribution maps reproduced from Sitters (1988).

Avocet

Recurvirostra avosetta

The Avocet, whose elegant shape and distinctive pied plumage have become nationally familiar as the emblem of the RSPB, first started regular wintering in England in 1947, the year in which it also recolonised Britain as a regular breeder.

The winter distribution is largely on estuaries along the Channel and southern North Sea coasts of England; with concentrations in Devon/Cornwall and Suffolk. There are a few winter records elsewhere around the coast, including Ireland.

Wintering Avocets tend to frequent those estuaries in which the substrate is largely fine silt. The birds often feed communally in shallow water on a rising tide, sweeping the bill from side to side. Such behaviour is probably associated with feeding on opossum shrimps which congregate in large numbers to form a band at the edge of the rising water. Ragworms, too, are probably frequently taken, as they are on the Continent (Tjallingii 1971). In Suffolk, wintering Avocets roost gregariously on salt marshes or, with higher tides, they frequent islets of sparsely vegetated mud in shallow lagoons. On the Tamar the birds may remain swimming in a flock for much of the high tide period.

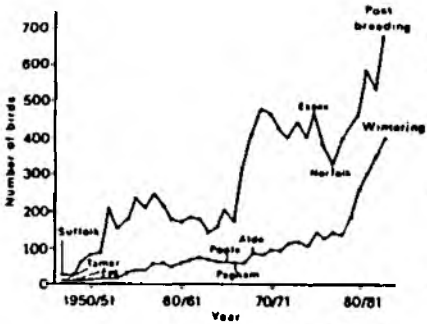
Until the mid 1970s most Suffolk birds had departed by the end of October, leaving only a few to overwinter. Subsequently an increasing number of what is apparently the local breeding population has overwintered. Ringing indicates that some British Avocets join autumn moulting concentrations in the Netherlands before moving to winter on coastal marshes in Spain and Portugal, if not N and W Africa (Cadbury and Olney 1978).

In Devon, Avocets do not arrive until late October, well after the main departure from Suffolk, and most usually leave by the end of February. One Avocet, colour-ringed in Suffolk, was seen on the Tamar in 4 successive winters 1971–75 and again in 1979/80 but it is probable that the majority of birds are from other NW European breeding populations. On 2 December 1981 at least 94 Avocets were seen off the Sussex coast, where a spring passage has also been observed.

The Figure below shows that except for a slight decline in the mid 1960s there was a fairly steady increase in the total numbers of Avocets wintering in Britain and Ireland until 1980/81. The sharp increase in 1981/82 is largely attributable to the increased Suffolk population. Since 1980/81 the British wintering population has represented over 50% of the total of adults and juveniles at the end of the previous breeding season. In the mid winter period of 1983/84 there were about 385 birds in Britain.

Over the period 1978–83 an average of about 34,400 Avocets has been counted in January on the Atlantic coasts of Europe, mainly in France and Portugal, though 600 or so have been wintering on the North Sea coast of the Netherlands and Germany (IWRB data). Britain is at the northwest extremity of the wintering range of the Avocet.

C. J. CADBURY



Post-breeding numbers (pairs and fledged young) in East Anglia, and maximum numbers of wintering Avocets in Britain and Ireland 1947–84. The start of regular breeding and wintering in particular areas is indicated.

Total number of squares in which recorded: 55 (1%)

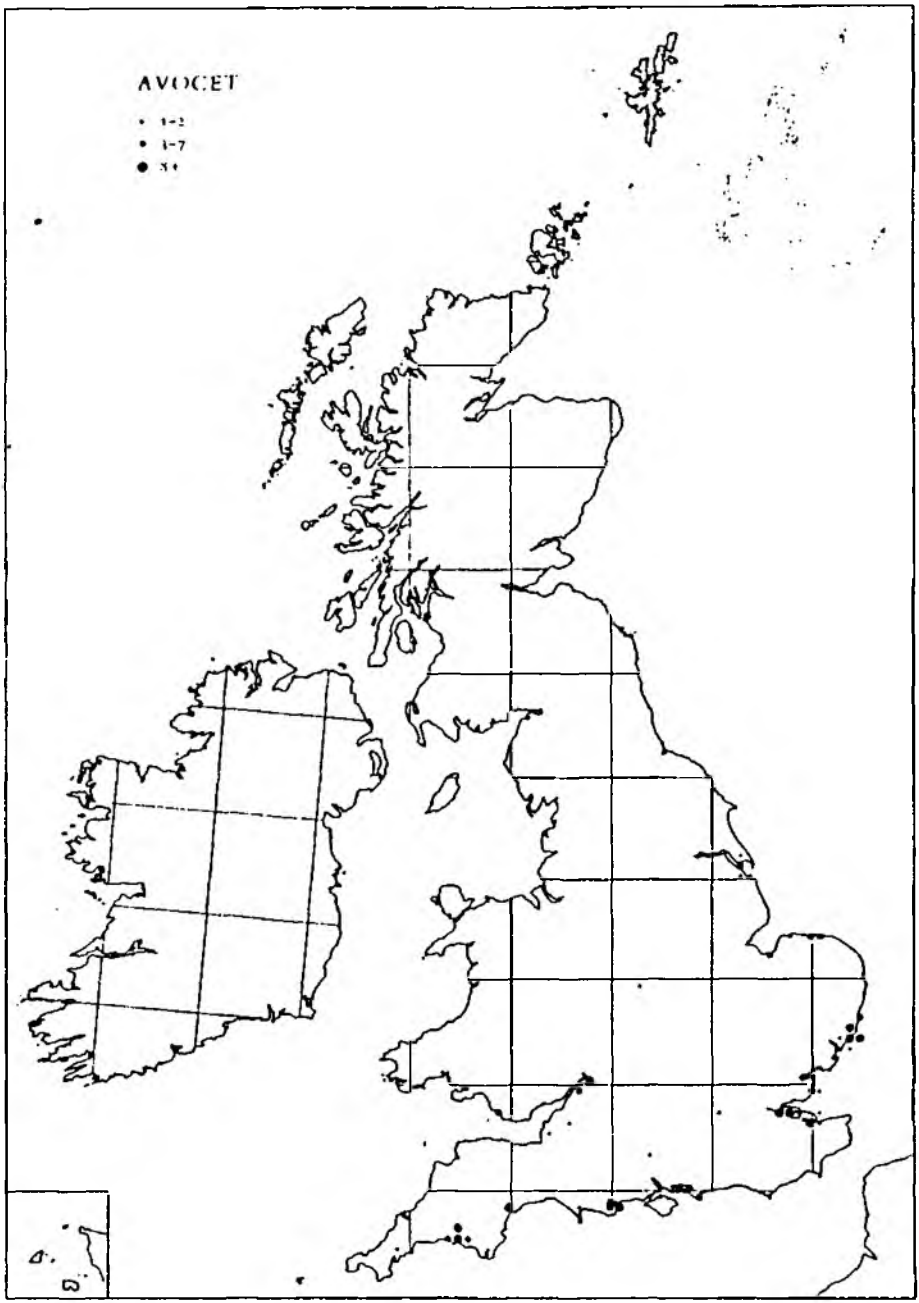
No. of birds seen in a day	Number (%) of squares Britain	Ireland	TOTAL (incl. C.I.)
1–2	27 (53%)	4 (100%)	31 (56%)
3–7	13 (26%)	0 (0%)	13 (24%)
8+	11 (22%)	0 (0%)	11 (20%)

References

CADBURY, C. J. and P. J. S. OLNEY. 1978. Avocet population dynamics in England. *Brit. Birds* 71: 102–121.

TJALLINGII, S. T. 1971. De Kluten van de Dollard. *Waddenbulletin* 6: 5–9.

Breeding Atlas p 198.


AVOCET

Turnstone

Arenaria interpres

The Turnstone is a common coastal wader frequenting estuaries, sandy beaches and, particularly, rocky shores. Its chittering call and striking wing pattern in flight make it one of the easiest of waders to recognise.

In winter, Turnstones are found along the entire coast line of Britain and Ireland, but are relatively scarce along the northwest coast of mainland Scotland and the Inner Hebrides.

As the name suggests, Turnstones are adept at turning over small stones to obtain hidden food items, though they also push aside fronds of wrack, and lift the trailing leaves of eel grass, probe sand and hammer barnacles when feeding. Turnstones have an extremely varied diet, but the main food items in Britain are shrimps, winkles and barnacles (Harris 1979). Small winkles are eaten whole and the shell is crushed in the gizzard, but with large winkles the foot, only, is torn from the shell.

Turnstones generally forage in small flocks with a more or less stable membership, and males usually dominate females when feeding. When the tide rises, larger numbers congregate to roost, often with other wader species, on exposed rocks, salt marshes and sand spits. Some continue to forage at high tide, either on banks of washed up kelp, or inland on grass fields.

The breeding range encompasses much of the high Arctic and also extends southward into Scandinavia. Autumn migration to Britain starts in July and includes Scandinavian and Canadian/Greenland birds. The latter population remains to moult and spends the winter whilst the former puts on fat for further migration to W Africa, where they moult and winter (Branson *et al* 1979).

The birds that stay for the winter show site tenacity from autumn to spring, and movements of over 10 km are rare. They also tend to return to the same stretch of shore each winter (Metcalfe and Furness 1985).

There are usually about 15% of first-year birds in the winter flocks but fewer after a poor breeding season. This happened in 1972, resulting in only 5% first-year birds in the winter flocks. The minimum annual survival of adults is 86% (Metcalfe and Furness 1985).

Turnstones put on a moderate amount of fat in winter in order to guard against food shortages, but it is lost by March. In April and May, fat for migration back to the breeding grounds is accumulated. The return to Greenland and Canada in early May, when they have only moderate amounts of fat, involves a stop-over in Iceland where birds can refuel. Birds that leave Britain in late May with a full load of fat could migrate to Greenland without stopping in Iceland (Clapham 1979). A few first-year birds migrate with the adults but most remain to summer on our coasts. The Scandinavian Turnstones which winter in Africa do not return through Britain on spring migration.

The winter population of Turnstones on British estuaries may be about 11,000, and Prater (1981) estimated that the overall winter population was in the order of 25,000, excluding Ireland which probably has well over 5,000 on the rocky shores. However, detailed surveys on the open shores of eastern Scotland (between Berwickshire and Orkney) has revealed a total of 15,000 (Summers *et al* 1975, Tay and Orkney Ringing Groups 1984), so the total population in Britain and Ireland is probably closer to 30,000.

The Turnstone has a cosmopolitan distribution during the non-breeding season, and Britain lies in the northern part of this range. They can be found on the rocky shores of New Zealand and South Africa, and coral islands and mangrove swamps of the tropics as well as the temperate shores of the Atlantic and Pacific Oceans.

R. W. SUMMERS

Total number of squares in which recorded: 933 (24%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–32	317 (47%)	147 (57%)	464 (50%)
33–100	198 (30%)	84 (33%)	284 (30%)
101 +	156 (23%)	27 (10%)	185 (20%)

References

BRANSON, N. J. B. A., E. D. PONTING and C. D. T. MINTON, 1979. Turnstone populations on the Wash. *Bird Study* 26: 47–54.

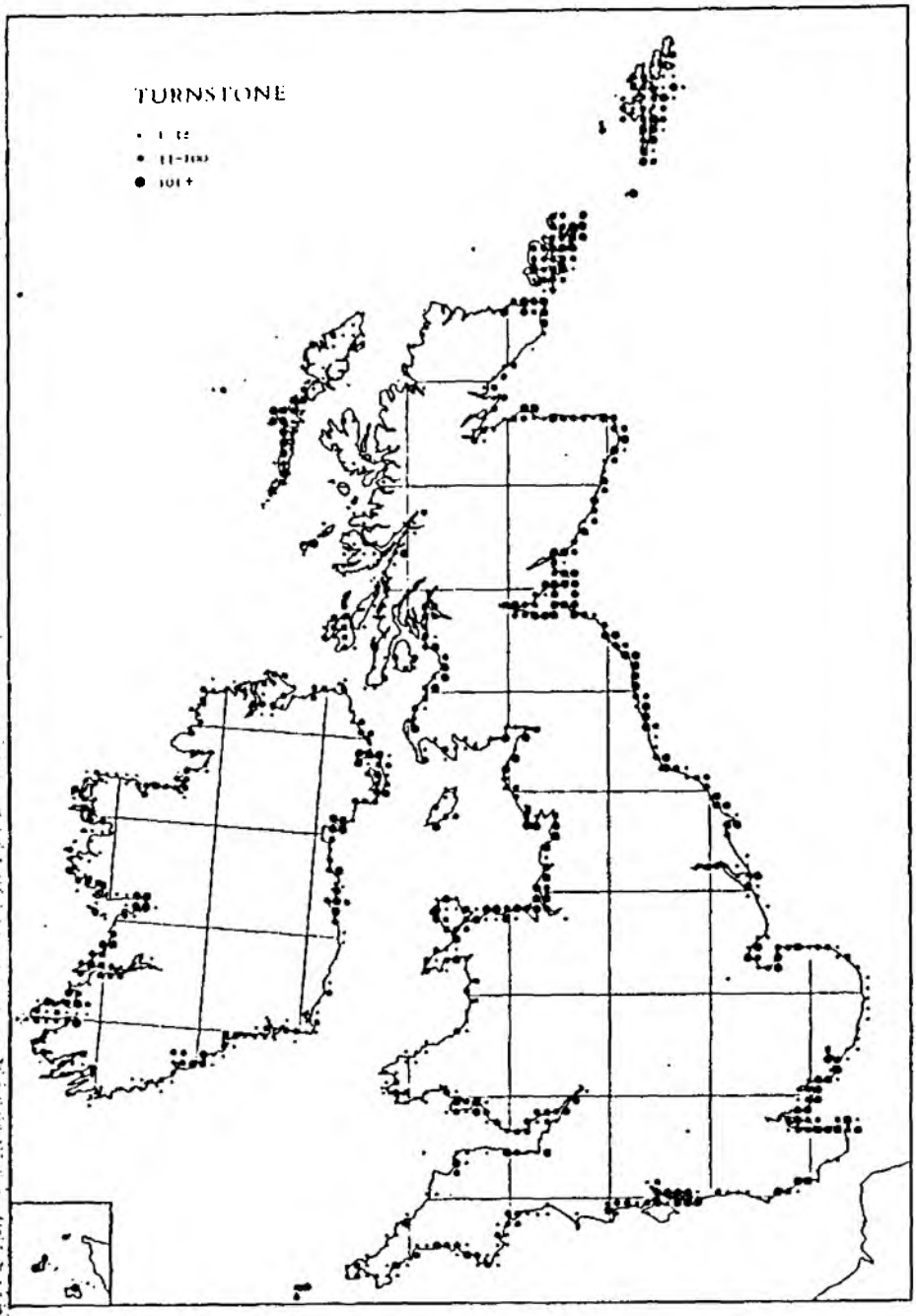
CLAPHAM, C. 1979. The Turnstone populations of Morecambe Bay. *Ringing and Migration* 2: 144–150.

HARRIS, P. R. 1979. The winter feeding of the Turnstone in North Wales. *Bird Study* 26: 259–266.

METCALFE, N. B. and R. W. FURNESS 1985. Survival, winter population stability and site fidelity in the Turnstone *Arenaria interpres*. *Bird Study* 32: 207–214.

SUMMERS, R. W., N. K. ATKINSON, and M. NICOLL. 1975. Wintering wader populations on the rocky shores of eastern Scotland. *Scot. Birds* 8: 299–308.

TAY AND ORKNEY RINGING GROUPS. 1984. *The Shore Birds of the Orkney Islands*. Tay Ringing Group, Perth.


TURNSTONE
1-10
11-100
101+

Common Sandpiper

Actitis hypoleucos

The Common Sandpiper's habit of bobbing prominently at the water's edge, or uttering its arresting call as it skims low over the surface on diagnostically bowed wings, make it a relatively conspicuous species. Despite this however, birds may remain contentedly within very restricted areas for long periods during the winter, and many which are not casually flushed must pass undetected.

As one would expect of a species at the extreme northern fringe of its world wintering range, it is very scarce with a patchy distribution. The records display a coastal bias and a concentration towards the southwest, with very few occurring elsewhere. Analysing the records from estuarine sites for the period 1969–1975, Prater (1981) found that about 65% of the total wintering population was in SW England. The present survey confirms this concentration of records and the results suggest that, taking inland records in addition to the coastal ones, the region holds about 50% of the entire population of Britain and Ireland. Although the species is almost certainly under-recorded in SW Ireland, where squares received minimal coverage, the paucity of records from the east coast is notable.

The distribution of winter records is almost an exact reversal of the breeding situation, with virtually no overlap in the ranges. That an entirely different type of habitat is utilised in winter is hardly surprising, for the fast flowing streams frequented in summer are now often raging torrents and upland lakes inhospitably barren and windswept. There is no evidence to show whether or not it is birds of the breeding population which remain to winter. These may well move south to be replaced by birds which nest at higher latitudes. A strong autumn passage is recorded from mid July to September, when large numbers occur on the east coast of England, with fewer in Ireland. Very few are seen after September.

In winter, Common Sandpipers resort to a fairly wide variety of habitats, varying from inland lakes, both natural and artificial at lower altitudes, to coastal estuaries and harbours. It is normally the inner reaches of estuaries which are favoured, especially areas having expanses of exposed stone or gravel, though birds are not infrequently found at estuary mouths, particularly where sea-walls and embankments are present. Heavily industrialised areas are occasionally inhabited when they are found adjacent to waterways, and sites such as settling ponds are frequented. Loyalty to favoured sites can be strong, some being occupied year after year and they may occasionally be defended against invaders. The effect of severe weather on the species is unknown, but birds at inland localities are more likely to be disadvantaged through freezing of lakes and waterways, and there may be a movement to the coast in hard winters. Common Sandpipers are normally found singly and seldom associate with other species, though during several winters birds at a site in Cork Harbour foraged with Starlings *Sturnus vulgaris* at a dump of animal feedstuff. Normally, though, the food is small invertebrates collected from the water's edge.

The normal winter range is south of the Sahara, but small numbers are recorded in the Mediterranean basin and in the maritime areas of western Europe, north as far as these islands. Wintering in Britain and Ireland has been known for many years, but appears to have increased in the past three decades. Prater (1981) estimated that the total number present in estuaries in winter did not exceed 50 birds, with as many again at other sites. The results of the present survey suggest that this is an accurate assessment, but with the possibility that the Irish population is underestimated.

Due to their scarcity during the winter months, it is likely that most Common Sandpipers will attract more than the casual glance; they certainly deserve more now that there have been several instances of overwintering in Britain by the very similar Spotted Sandpiper *A. macularia*.

K. PRESTON

Total number of squares in which recorded: 236 (6%)

No. of birds seen in a day	Number (%) of squares Britain	Ireland	TOTAL (incl. C.I.)
1	141 (74%)	22 (35%)	166 (70%)
2	37 (19%)	9 (22%)	46 (19%)
3+	15 (8%)	9 (22%)	24 (10%)

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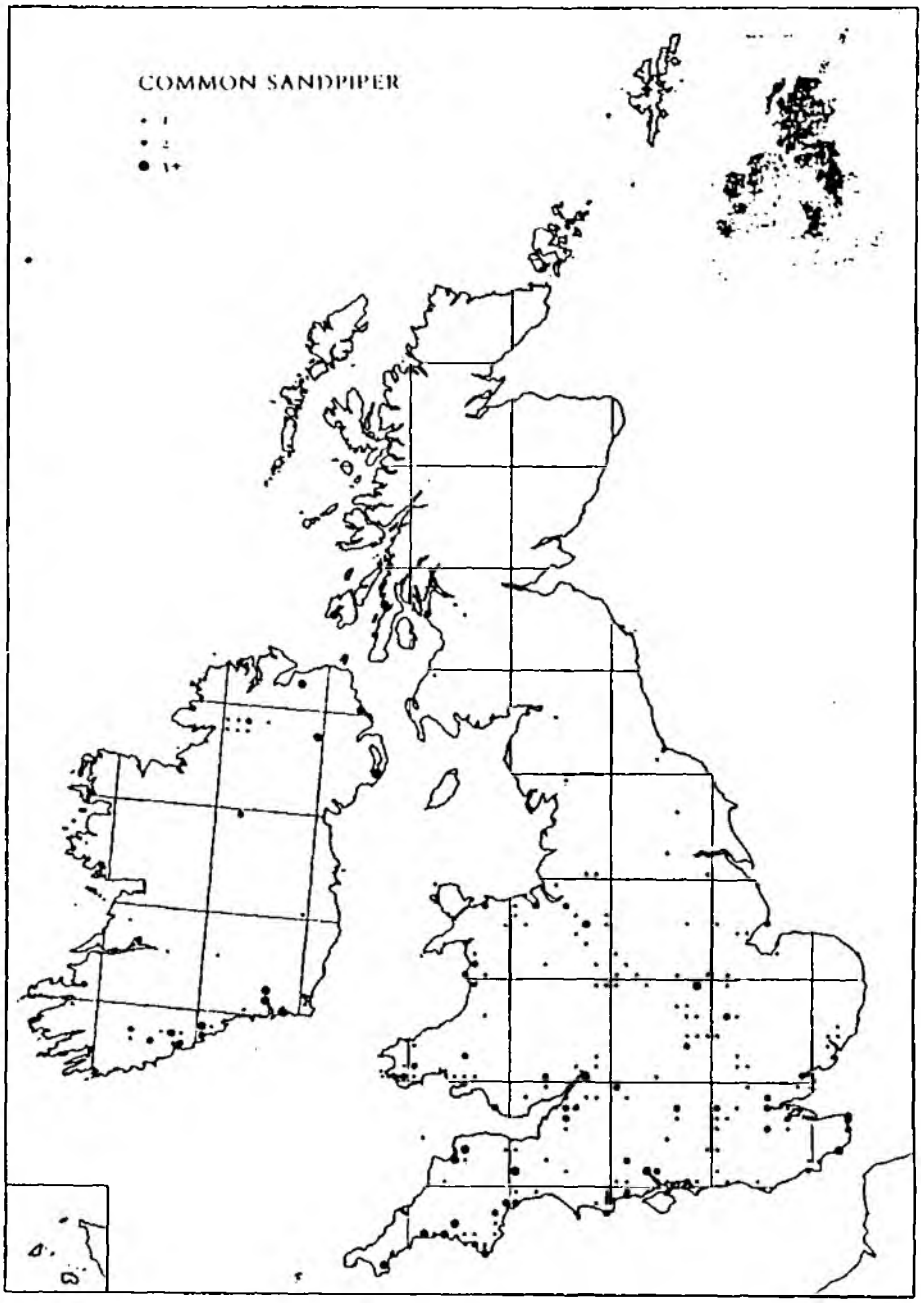

COMMON SANDPIPER

Green Sandpiper

Tringa ochropus

Green Sandpipers are most elusive birds in winter and for most fieldworkers their only contact would be a single wader, with white rump and black wings, flushed from a ditch or pool, flying off high with a liquid 'klu-eet-weet' call. Green Sandpipers are passage migrants and winter visitors to Britain and Ireland and generally occur in ones and twos at scattered inland localities, with very few records from estuaries and coastal sites. They are nowhere numerous and even on passage are seldom found in large numbers. The distribution map shows that there were most records in SE England. Those in the rest of England, Wales and southern Ireland were mostly of single birds, and there were very few records from Scotland.

Green Sandpipers breed in the sub-boreal zone from Fennoscandia eastwards and are one of the earliest waders to return on autumn passage. They are regularly recorded in late June, although the peak does not occur until August. During passage they can occur in concentrations of up to 20 or so birds at inland wetland areas, such as gravel pits and sewage works. However Britain and Ireland are on the northern limits of the species' wintering range and only a few birds remain after October. There are also a few wintering areas elsewhere in NW Europe, but the majority of the population apparently spends the winter in the Mediterranean basin and in Africa south of the Sahara.

In winter, Green Sandpipers can be found on the margins of streams, ditches, farm ponds, gravel pits and sewage works. They often occur near chalk streams and at watercress beds where the shallow water is particularly suitable for them. There are also occasional records of birds using wet farm gateways and small floods in cultivated fields. Their food is largely aquatic invertebrates (*BWP*) although there are observations of them occasionally taking small fish. In specially suitable feeding sites numbers can build up. For instance up to 15 have been observed in mid winter on a small disused watercress bed in southern England. In that situation individual birds were intensely territorial, but such behaviour has not been reported elsewhere (Smith *et al* 1984). Birds apparently roost away from the feeding areas but no information is available on the sites used.

There is considerable evidence that individual birds may return to the same wintering areas for a number of years. However, there can also be much movement between sites during the course of the winter, particularly during periods of severe weather when some sites become untenable and birds may be forced to change, move south or leave these islands altogether. In much of N England and Scotland the weather is probably too severe to allow Green Sandpipers to remain on shallow fresh waters through the winter. There are as yet no ringing recoveries to indicate the origins of our wintering birds, although a pullus ringed in Finland was recovered in Morocco in December.

With such a secretive and mobile species it is difficult to arrive at an estimate of the wintering population. An analysis of county bird reports for the 5 winters preceding the *Winter Atlas* period (Smith in prep) indicates a maximum of around 600 birds in Britain and Ireland. This figure must however be treated with some caution. Movements between sites during the course of the winter would lead to an overestimate, whilst an unknown number of birds may not have been located or reported to the county bird recorders. A realistic figure for the wintering population is therefore probably in the range 500–1,000 birds. This represents a very small proportion of the western Palearctic breeding population of some 450,000 pairs (T. Piersma).

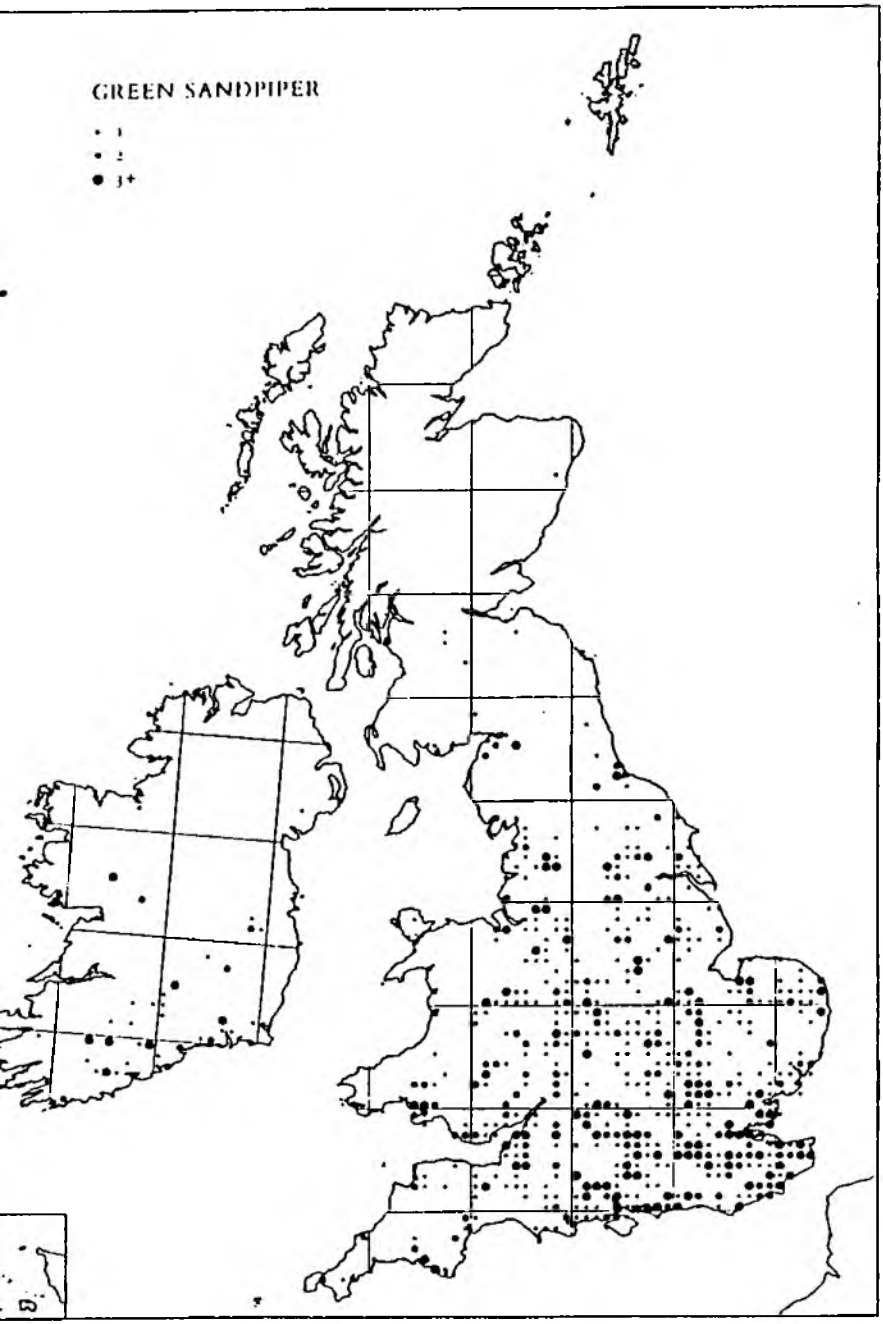
K. W. SMITH

Total number of squares in which recorded: 593 (15%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1	338 (62%)	31 (67%)	371 (63%)
2	104 (19%)	8 (17%)	112 (19%)
3+	103 (19%)	7 (15%)	110 (19%)

References

SMITH, K. W., J. M. REED and D. E. TREVIS. 1984. Studies of Green Sandpipers wintering in southern England. *Wader Study Group Bull.* 42: 15.


GREEN SANDPIPER
1
2
3+

Greenshank

Tringa nebularia

The shrill 'tew-tew-tew' call of the Greenshank is the most obvious indication of its presence on estuaries or small creeks in winter. The birds themselves in their grey and white plumage are inconspicuous against the mud, but they take flight readily, flashing white rump and dark wings, and calling repeatedly.

The winter distribution in Britain and Ireland is predominantly westerly, with perhaps three-quarters in Ireland. One of the most striking features of the map is the extent of the distribution. Very few Greenshanks winter in eastern Britain, but in SW England, Wales and western Scotland Greenshanks are found in small numbers on many estuaries. In Ireland they are found almost anywhere there is a stretch of mud, except on the east coast south of Dublin and on the northeast coast. The principal winter Greenshank localities in Britain and Ireland in 1969–75 were mapped by Prater (1981) and concentrations of over 25 were recorded for 6 estuaries, 5 of which were in Ireland.

The Greenshank's summer distribution is quite different. The species nests across most of northern Scotland and one pair bred in western Ireland in 1972 and 1974. The breeding population has been estimated at 805–905 pairs (Nethersole-Thompson and Nethersole-Thompson 1979). There have been only two recoveries of Scottish ringed birds: one was recorded in Co. Cork in October and one in France in September. The Cork bird may have been wintering, but the French bird was clearly moving south. However, the timing of spring migration provides a strong indication that our wintering birds are drawn from the Scottish breeders. Scottish Greenshanks are back on their territories in early April, about a month earlier than Scandinavian breeders, and in approximately the same period that birds leave the Irish and W British estuaries. In SE Britain relatively few winter, but passage is noticeable in April and May, presumably involving Scandinavian birds. It was thought that the wintering population in Britain and Ireland was less than the Scottish breeding population, after taking account of recruitment, and that the remainder of the Scottish birds winter farther south, in France or on the Mediterranean or NW African coasts. However, it now appears that a much larger proportion of Scottish breeders may spend the winter in these islands than was previously suspected.

Greenshanks feed extremely actively. They probe in the mud and in vegetation but also pursue prey in shallow water by dashing forward with head and bill outstretched. The diet includes more fish than any other European wader (Burton 1979). Even on the shore, Greenshanks feed on shrimps, small fish, *Nereis* worms and crabs, rather than on the small *Hydrobia* and *Corophium* which Redshanks *T. totanus* prefer. These prey items are widely dispersed in a variety of habitats and help to account for the wide distribution of the species in Ireland.

Prater (1981) estimated a total winter population of about 600 for both islands. From the number of squares in which birds were recorded during 1981/82 to 1983/84 it can be seen that this is a substantial underestimate and one might guess at a total winter population of over 1,000, but probably less than 1,500.

The Greenshank is an abundant breeding bird in Scandinavia and the USSR, but almost all these birds are believed to winter south of the Sahara (*BWP*). Our birds are important because they appear to represent the bulk of the Scottish breeding population and because this population is the most westerly in Europe. Annual indices for the Birds of Estuaries Enquiry indicate that the species is maintaining its numbers but the sample is small and excludes most of the Irish winterers.

C. D. HUTCHINSON

Total number of squares in which recorded: 480 (12%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–2	171 (69%)	107 (46%)	278 (58%)
3–5	49 (20%)	69 (30%)	118 (25%)
6 +	27 (11%)	56 (24%)	84 (18%)

References

BURTON, P. J. K. 1979. The Greenshank's food. Pp 174–177 in NETHERSOLE-THOMPSON, D. and M. NETHERSOLE-THOMPSON. *Greenshanks*. Poyser, Berkhamsted.

NETHERSOLE-THOMPSON, D. and M. NETHERSOLE-THOMPSON. 1979. *Greenshanks*. Poyser, Berkhamsted.

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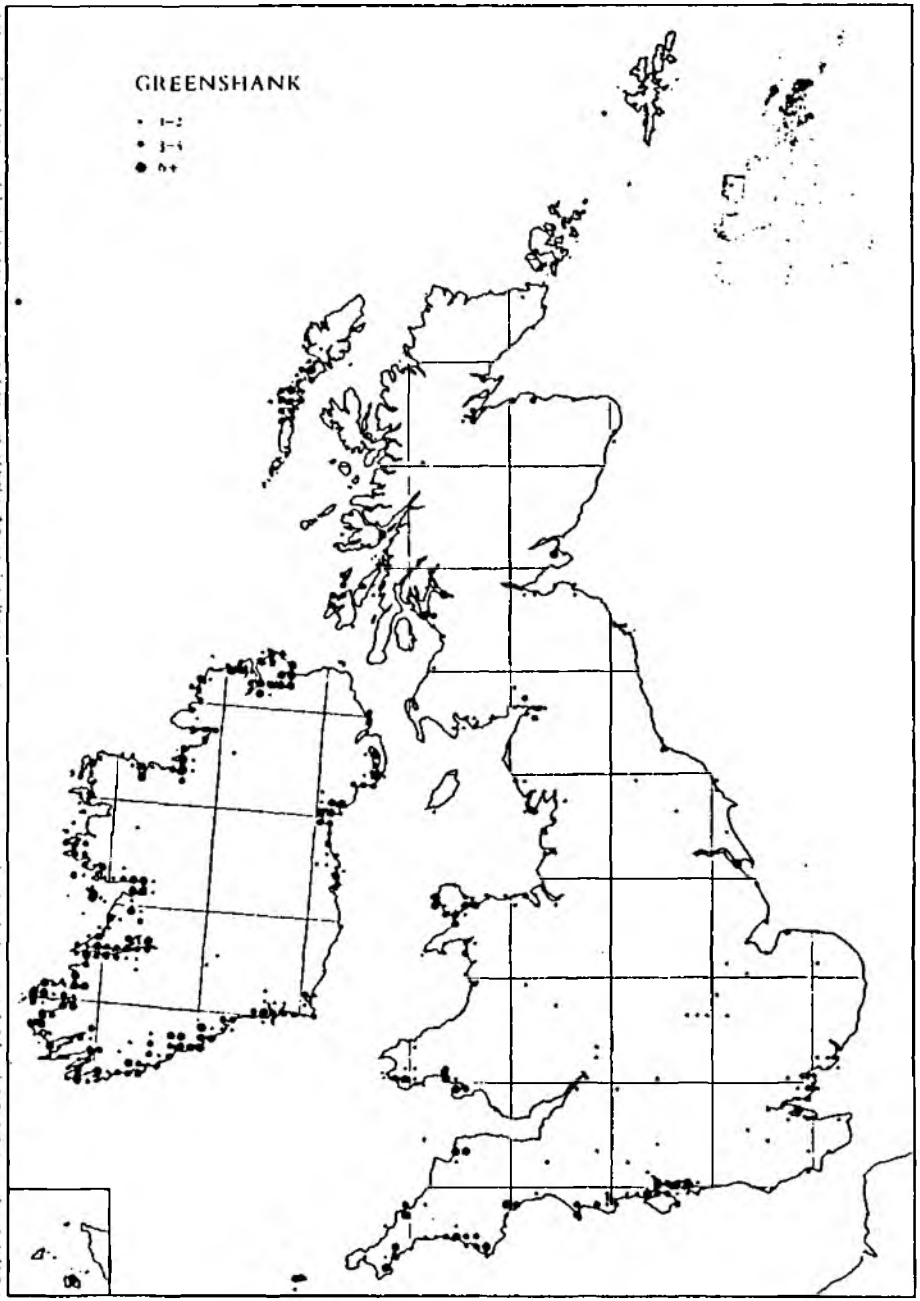
GREENSHANK

Redshank

Tringa totanus

Throughout the year the Redshank's frequent calling attracts attention to its presence. A medium sized wader, it is immediately recognised in flight by the broad, white trailing edge to its wings, its white back and rump and usually bright red legs.

In comparison with the breeding season, the Redshank's winter distribution is more coastal, and it occurs along all the coasts of Britain and Ireland where there is suitable feeding habitat. Some Redshanks winter inland, this habit being commoner the further south one goes, but Redshanks remain inland in winter only so long as prolonged frosts do not affect the ground. When they can no longer feed they move to coastal areas.

During the winter, Redshanks occupy areas from which they are absent during the breeding season, such as the S coasts of Ireland, W Wales, Devon and Cornwall where they are common winter visitors.

Their winter food consists mainly of marine invertebrates collected on the mudflats, *Hydrobia*, *Corophium* and nereid worms being the chief food items, though away from the shore fresh water invertebrates and insects are taken. Their habit of feeding on the upper areas of the shore, which freeze more easily, means that Redshanks are more vulnerable than many other waders to spells of cold weather, and are amongst the commonest fatalities in such conditions.

Redshanks usually feed singly or in small groups. On smaller estuaries, particularly in the south of England, some individuals take up winter feeding territories which are defended against other Redshanks; on larger estuaries and in N Britain this is rare.

Ringing recoveries and observations on colour-marked Redshanks, show that the British and Irish breeding population is less migratory than any other, and many winter on the coastal areas on which they breed. In addition to hard weather movements there is probably considerable movement between estuaries. Colour marking has shown movements away from small estuaries in winter, probably in search of better food supplies, but usually other birds move in. Thus, the population of Redshanks on many smaller wintering areas appears stable but is probably transitory. However, some birds visit the same wintering areas year after year, as shown by individual, wing-tagged Ribble breeding birds, which are known to winter regularly in Jersey, Devon and W Wales. In general juvenile birds tend to make longer migratory journeys than adults, and there is evidence to suggest that movement of the British breeding population is a slow drift south until January, with a more direct return journey north.

Hale (1984) suggested that hybridisation between previously separated populations has resulted in larger individuals which are better able to winter further north, and they constitute the British and Icelandic populations. Many Icelandic birds move into Britain and Ireland in winter and it is likely that the majority of our wintering birds are of Icelandic origin. There is also evidence of movement of Continental birds into Britain and Ireland, particularly during hard weather on the Continent. These are birds of the western European hybrid zone which have bred in Denmark, Holland and Belgium.

The wintering population of Ireland probably consists of Icelandic birds, of residents and many Scottish breeders, and some birds from the north of England.

The wintering population of Redshanks in Britain and Ireland has been estimated at approximately 95,000 (Prater 1981). The difficulties of counting wintering Redshanks probably leads to underestimates so our wintering population probably well exceeds 100,000 birds. Figures from the 15 years of the Birds of Estuaries Enquiry have shown a steady decline in the January population levels in Britain (BOEE reports). Declines have been particularly marked on some estuaries such as the Clyde.

As wintering areas Britain and Ireland are by far the most important in Europe, harbouring some 75% of the total. This is probably of the order of 15–20% of the world population of the species which almost certainly exceeds 500,000 birds and may well top the million mark.

W. G. HALE

Total number of squares in which recorded: 1,607 (42%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–14	611 (51%)	192 (49%)	805 (50%)
15–120	356 (29%)	123 (31%)	480 (30%)
121 +	243 (20%)	78 (20%)	322 (20%)

References

HALE, W. G. 1971. A revision of the taxonomy of the Redshank, *Tringa totanus*. *Zool. J. Linn. Soc.* 50: 199–268.

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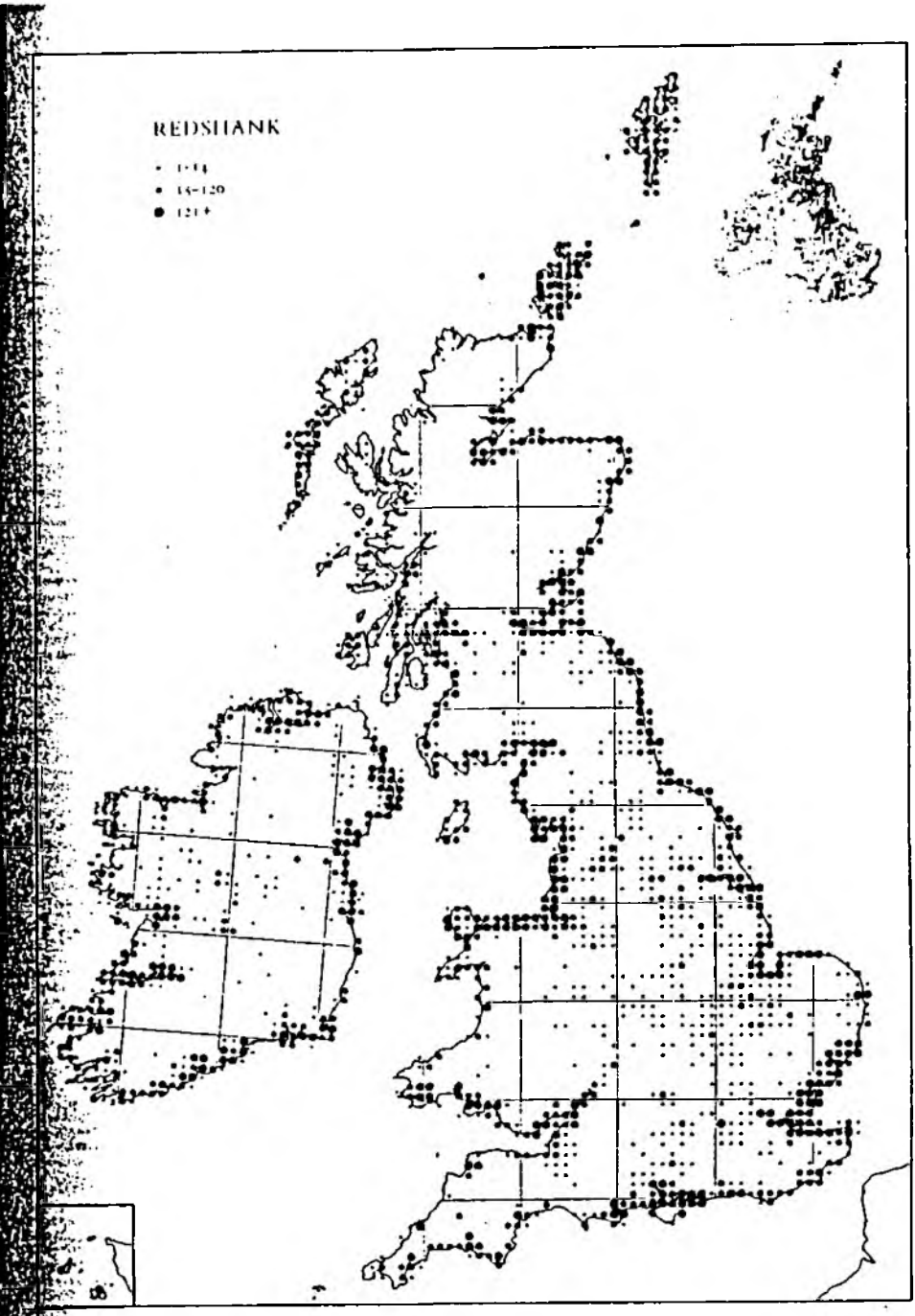
HALE, W. G. 1984. The changing face of European wintering areas. In EVANS, P. R., J. D. GOSS-CUSTARD and W. G. HALE, (eds). *Coastal Waders and Wildfowl in Winter*. University Press, Cambridge.

Breeding Atlas p 188


REDSHANK
1-14
14-120
121+

Black-tailed Godwit

Limosa limosa

Tall, elegant and gregarious, Black-tailed Godwits have a much more limited distribution in Britain and Ireland than the more widespread but decidedly drabber Bar-tailed Godwits *L. lapponica*.

The Black-tailed Godwits which winter in Britain and Ireland are of the Icelandic breeding race *L. l. islandica*. Some birds may nest in northern Scotland, and there is a noticeable passage from the end of June onwards as birds move south to winter in Britain, Ireland, France and probably Iberia. Most of Europe's breeding birds are of the nominate race *L. l. limosa* which winter mainly in West Africa north of the equator; a small number breed in England, mainly in East Anglia, and there may be a small passage, but few if any winter.

The main concentrations in winter, as in autumn, are on the estuaries of the south coasts of Ireland and England, inland in the Shannon valley, on the Stour and Hamford Water in eastern England and on the Ribble and Dee in NW England. The preferred estuaries are muddy, and where Black-tailed Godwits occur at the same sites as Bar-tailed Godwits they are usually found feeding on the inner estuary where the sediments are finer, while the Bar-tailed Godwits prefer sandier banks on the outer estuary. Black-tailed Godwits form relatively tight flocks while feeding, normally separate from other waders, though sometimes with Redshanks *Tringa totanus*. Although there have not been many studies of winter diet, Black-tailed Godwits appear to feed largely on worms at this season. Lugworms and ragworms are favourites on the Ribble (Hale 1980) and earthworms inland in France (*BWP*), though a current Irish study indicates that *Hydrobia* and small bivalves are important at Clonakilty estuary. When high tide covers the coastal feeding zone they fly to roosts, normally on damp pasture but often on reclaimed land and only rarely on stony shores. Frequently they fly several kilometres inland to suitable pasture. In western Ireland, flocks of several hundred birds winter on flooded pastures at sites in the River Shannon valley and on the edge of a few lakes; these show up well on the map. Here they occur close to large numbers of Icelandic Golden Plovers *Pluvialis apricaria*, though mixed flocks are unusual.

Black-tailed Godwits occur in peak numbers in the period from mid August to mid September. In Britain there is a fall in numbers in October, but this is far less marked in Ireland where numbers at most sites are not much lower in December than in autumn.

There is an increase in S and SW England after low numbers in November, but the reason is unknown (Prater 1981). From January onwards, Black-tailed Godwits decrease on the Irish south coast and assemble on the Shannon estuary (where over 16,000 have been counted in April) and on the Little Brosna in the Shannon valley (up to 4,600 in February). Except for the cold winter of 1962/63, when Black-tailed Godwits were scarce in S and SW England, there was a steady and sustained increase in numbers in Britain from the early 1930s, when less than 100 wintered, to the mid 1970s (Prater 1975), and a considerable increase was also noted in Ireland (Ruttledge 1966). This increase in wintering numbers was attributed to higher breeding numbers in Iceland and followed climatic amelioration. From the mid 1960s, a cooling of the spring climate was noted and a decline in wintering numbers was predicted (Prater 1975). This followed, and after the early 1970s the decline was rapid, the population reaching its nadir in 1977/78 in Britain when only 20% of the numbers wintering in 1972/73 were counted (Marchant 1981). Since then, there has been a steady recovery in Britain and numbers in Ireland appear to be holding up well.

The winter population in Ireland was estimated at about 8,000–10,000 birds in the years 1971–75 (Hutchinson 1979); in Britain there are presently perhaps another 4,000–5,000 (Birds of Estuaries Enquiry reports). There are no more recent estimates of numbers in Ireland.

C. D. HUTCHINSON

Total number of squares in which recorded: 246 (6%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–4	90 (60%)	31 (33%)	122 (50%)
5–120	38 (25%)	37 (39%)	75 (30%)
121+	23 (15%)	26 (28%)	49 (20%)

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PRATER, A. J. 1975. The wintering population of the Black-tailed Godwit. *Bird Study* 22: 169–176.

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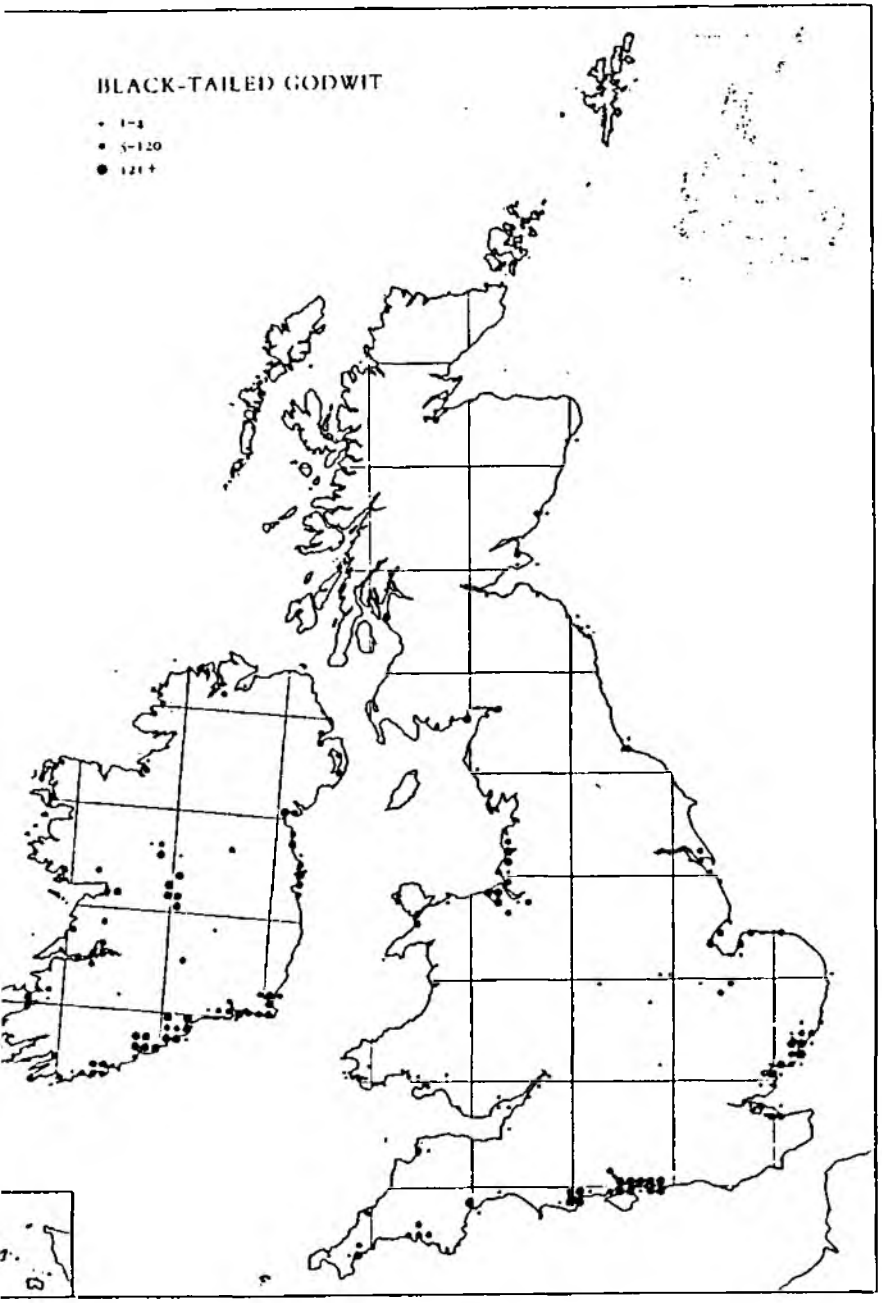
Breeding Atlas p 182


BLACK-TAILED GODWIT
1-4
5-120
121+

Dunlin

Calidris alpina

The Dunlin is the most abundant of our shore waders in winter, occurring almost anywhere on the coast where mud is present. The tightly packed, concerted aerobatics of large flocks moving to high-water roosts are one of the major attractions of large estuaries.

In winter, Dunlins are predominantly coastal, with large concentrations at estuaries and other large tidal flats. They commonly occur also on most other parts of the coast, except cliffs and very exposed situations, particularly in the northwest. Smaller numbers occur at inland sites, especially at migration times, and mainly from Yorkshire southwards in Britain and in Ireland. At such sites, they require exposed mud or shallow water, for example at sewage farms or on the banks of reservoirs.

In winter, Dunlins feed mainly on small invertebrates living in mud. These are often detected tactually by the bill, and small prey may even be swallowed while the bill is still in the mud. The birds generally feed in flocks, staying close to the tide edge, where the prey animals tend to be nearer the surface than are those on drying mud. The birds may form large roosting flocks at high water but, particularly in mid winter, feeding may continue in nearby fields and at night. The probability of very severe weather, when food is most needed and most difficult to find, is greatest in the east of Britain. Accordingly, birds wintering in the northeast carry the largest mid winter fat reserves to aid survival over such periods, whereas those in the southwest accumulate little fat (Pienkowski *et al* 1979)

The winter distribution differs totally from the breeding one, which features moorland, machair and some salt marshes, mainly in the north (*Breeding Atlas*). Different birds are involved in the two seasons: British and Irish breeding birds winter further south, probably in W Africa, whilst the birds wintering in Britain and Ireland arrive from northern Scandinavia and USSR. Birds from Iceland and Greenland pass through Britain in spring and autumn (Hardy and Minton 1980, *BWP*).

In autumn and early winter, the Wash and the Wadden Sea, extending from Denmark along the German and Netherlands coasts, are particularly important moulting sites, possibly because their vast areas give greater safety from land-based predators while the birds' flying abilities are impaired. In October–November, after moulting, many birds move westwards to areas of milder winter climate. In the Wadden Sea, in addition to colder weather, there is more chance than further west of tides being held over the feeding grounds by high winds (Pienkowski and Evans 1984). Some areas, (*eg* east coast of England, Irish Sea estuaries of Britain, SW Netherlands) both lose and gain Dunlin populations at this time; whilst others receive their main influx for the mid winter period (*eg* E Scotland, Ireland, S and SW England and Wales, France and Iberia) (Pienkowski and Pienkowski 1983). In February to April many birds return eastwards again, before the migration to the breeding grounds. Within each seasonally used area, individual birds tend to be faithful to particular sites, both within and between years (Symonds *et al* 1984). (Symonds *et al* 1984).

Winter counts indicate the population size of the nominate race (from N Scandinavia and USSR) to be about 1.5 million, while that of the other E Atlantic populations (Greenland, Iceland, Britain, Ireland and Baltic basin) to be about 1 million (*BWP*). About half a million of the former spend the winter in Britain and Ireland. Population numbers have fluctuated over the period of census in the last 15 years, particularly further south in Europe. This may reflect variable breeding success in different years in Arctic areas.

Britain and Ireland are extremely important areas for Dunlins, holding about half of the W European mid winter population and probably many other individuals of E Atlantic populations during migrations.

M. W. PIENKOWSKI

Total number of squares in which recorded: 1,065 (28%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–90	425 (52%)	108 (44%)	535 (50%)
91–900	223 (27%)	97 (39%)	319 (30%)
901 +	169 (21%)	41 (17%)	211 (20%)

References

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PIENKOWSKI, M. W. and A. E. PIENKOWSKI. 1983. WSG project on the movement of wader populations in western Europe: eighth progress report. *Wader Study Group Bull.* 38: 13–22.

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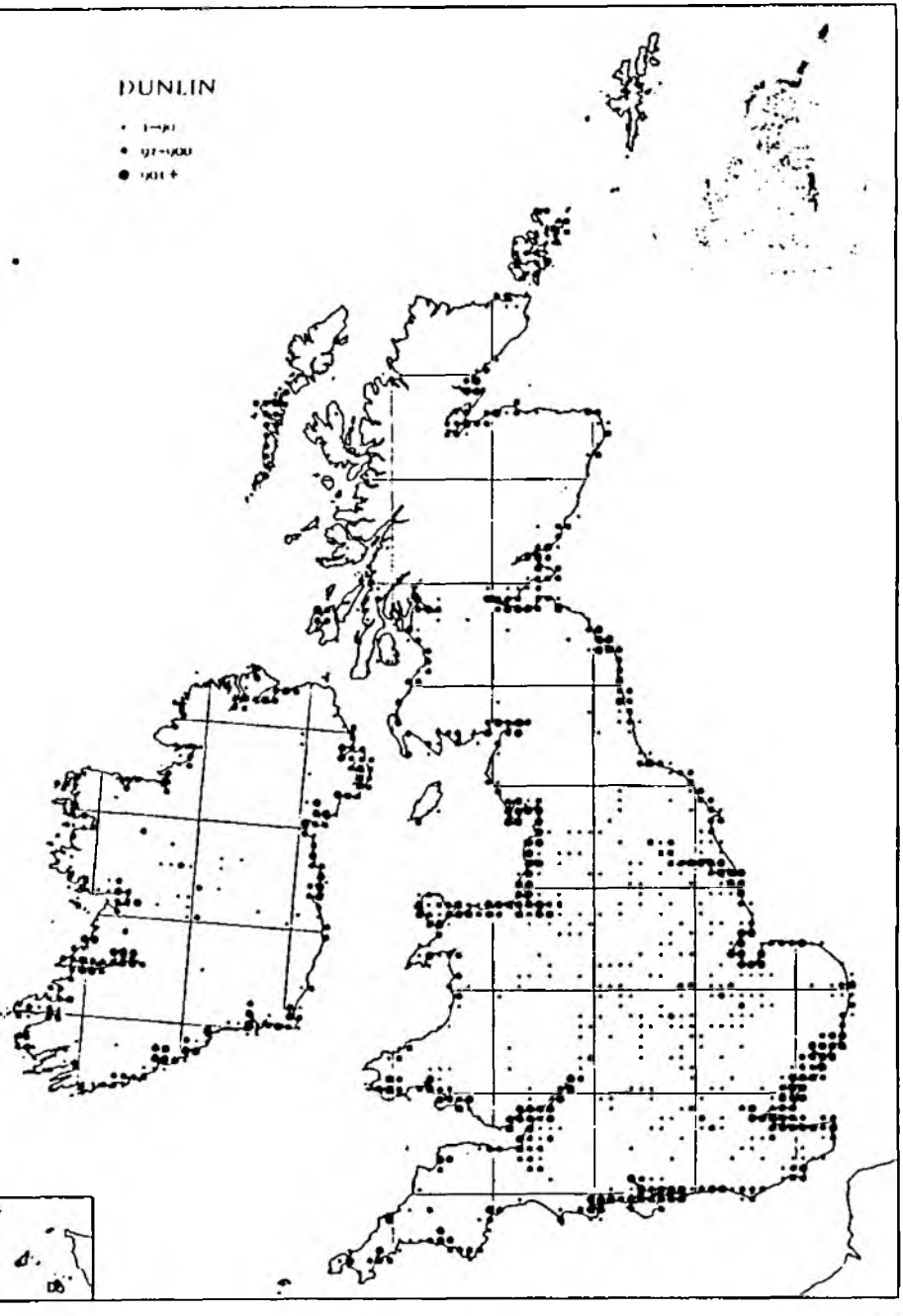
DUNLIN
1–90
91–900
901+

Grey Plover

Pluvialis squatarola

Although Grey Plovers are often seen roosting at high water within dense flocks of Knots *Calidris canutus* and Dunlins *C. alpina*, they avoid such flocks while feeding. Instead, Grey Plovers characteristically space out across the higher mudflats, away from the concentrations of other waders at the tide edge.

The winter distribution is almost entirely coastal, the few records inland probably being of juveniles on migration. Grey Plovers are concentrated on the larger and muddier estuaries, particularly in SE England from the Wash to the Solent and in NW England. They are widespread but less abundant elsewhere in Britain and Ireland, but absent from large areas of N and W Scotland, Orkney and Shetland.

Grey Plovers eat a variety of burrowing intertidal invertebrates, their diet changing between sites in parallel with the prey species available (Pienkowski 1982). Their feeding method relies upon not disturbing prey temporarily present at the surface of the mud, so Grey Plovers never feed in tight flocks. On some, but not all, intertidal areas they defend feeding territories. A fixed area of mud may be defended by the same individual each low water period, by day and night, throughout several successive winters. However, within an estuary, Grey Plovers do not defend feeding sites on all mudflats and territoriality is more likely under certain conditions of prey availability, bird density and habitat type (Townshend *et al* 1984). Night feeding may provide at least as much of their food requirements as daytime feeding.

Grey Plovers visiting Britain and Ireland come to us from the W Siberian breeding grounds. Their migrations are complex and occur throughout the non-breeding period. In August the Wash is the most important area in Britain and Ireland for Grey Plovers, with up to 2,000 moulting and 2,000 passage birds (Branson and Minton 1976). Juveniles arrive in September and October; and in November, after moulting, some adults and juveniles migrate south to SW Europe and W Africa; others remain all winter, and more birds arrive from mainland Europe. The same pattern is seen at Teesmouth, where further influxes occur in December of birds that left the European coast due to low temperatures there, followed by an arrival in late winter of Grey Plovers moving north after spending the mid winter period further south in Europe. A gradual emigration, probably to the Wadden Sea, occurs during February and March, and spring passage during April and May. This pattern of movements is probably typical for east and south coast estuaries. In W Britain and Ireland there is a smaller autumn passage; also some westerly movement from the Wash (eg to the Severn) may occur in November.

The pattern of intertidal territorial behaviour and timing of seasonal movements of each individual are determined during the first autumn of life, following competition especially with adults (Townshend 1985). Larger juveniles are more likely to acquire territories and more likely to stay at Teesmouth all winter.

The number of Grey Plovers recorded by the Birds of Estuaries Enquiry increased steadily during the 1970s, perhaps due to a reduction in shooting pressure and a series of good breeding seasons. Certainly, year to year variation in the number arriving in Britain and Ireland each autumn is due mainly to differences in the number of juveniles. Because of their complex pattern of seasonal movements it is difficult to estimate the total number of Grey Plovers visiting Britain and Ireland during the whole non-breeding period.

Recent counts from the Birds of Estuaries Enquiry and Hutchinson's (1979) estimate for Ireland support a total of nearly 20,000 birds in January. This constitutes more than one third of the European winter population (about 50,000, *BWP*). Britain and Ireland are at the northern edge of the range of the Grey Plover in mid winter. Large numbers of Grey Plovers also occur on the Wadden Sea in autumn and spring and in W France, Iberia and W Africa in mid winter, with mainly males in the north of the range and females in the south.

D. J. TOWNSHEND

Total number of squares in which recorded: 621 (16%)

Number (%) of squares

No. of birds seen in a day	Britain	Ireland	TOTAL (incl. C.I.)
1–6	231 (49%)	78 (52%)	311 (50%)
7–65	132 (29%)	51 (34%)	186 (30%)
66+	101 (22%)	21 (14%)	124 (20%)

References

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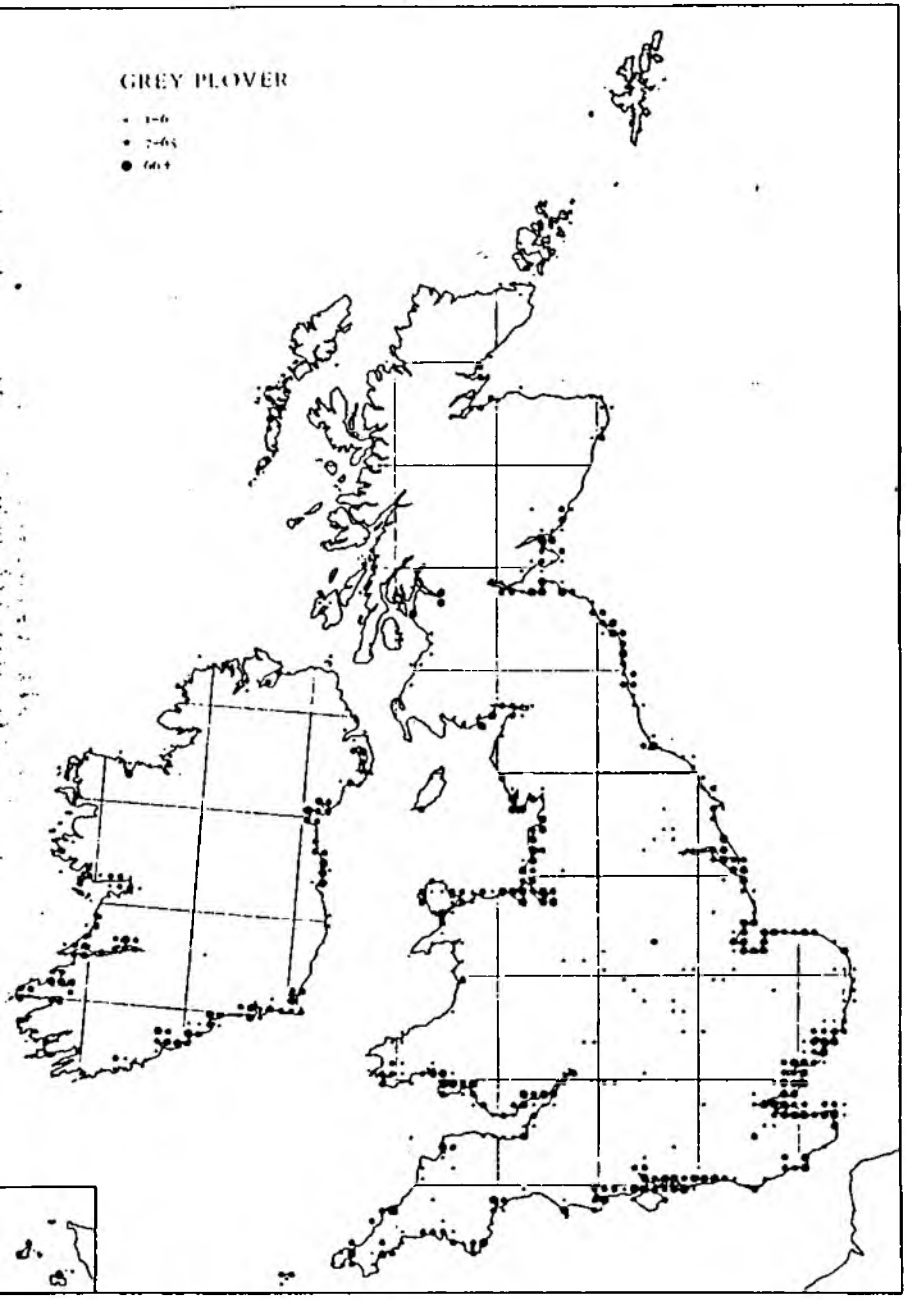
PIENKOWSKI, M. W. 1982. Diet and energy intake of Grey and Ringed Plovers, *Pluvialis squatarola* and *Charadrius hiaticula*, in the non-breeding season. *J. Zool. Lond.* 197: 511–549.

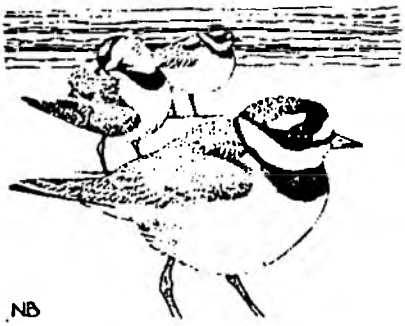
TOWNSHEND, D. J. 1985. Decisions for a lifetime: establishment of spatial defence and movement patterns by juvenile Grey Plovers (*Pluvialis squatarola*). *J. Anim. Ecol.* 54: 267–274.

TOWNSHEND, D. J., P. J. DUGAN and M. W. PIENKOWSKI. 1984. The unsociable plover—use of intertidal areas by Grey Plovers. Pp 140–159 in EVANS, P. R., J. D. GOSS-CUSTARD and W. G. HALE (eds), *Coastal Waders and Wildfowl in Winter*. University Press, Cambridge.


GREY PLOVER

Ringed Plover

Charadrius hiaticula



Found around almost all our coasts in winter, Ringed Plovers can be remarkably inconspicuous until they call or dart to catch a prey animal. This is because their disruptive head and breast markings can cause them to merge with the background, until they move.

The winter distribution is largely coastal, with small numbers at some inland wetland sites. These inland occurrences are mainly in lowland eastern England and do not generally coincide with the inland sites recorded in the *Breeding Atlas*, which were mainly upland areas and river systems in northern Britain and Ireland, and some East Anglian heaths. The rocky coasts, cliffs and other narrow, exposed shores, mainly in NW Scotland and SW Britain, are avoided in winter. Most other coastal areas are used, though not all by breeding birds in summer, probably because of human disturbance. The main winter concentrations are on areas of broad sandy beaches and muddy sand in estuaries, where the birds feed on a wide variety of small invertebrates, especially worms and crustaceans (Pienkowski 1982, *BWP*). Plovers hunt visually, standing still, scanning an area for signs of movement which indicate the presence of prey at or near the sand surface.

Some Ringed Plovers remain near their breeding areas in winter (Pienkowski 1984, N. E. Buxton), giving rise to the concentrations in the Thames estuary, NE England/SE Scotland, Orkney and the Outer Hebrides. Many others move westwards, as feeding conditions become more severe in the colder east, where low temperatures increase food demand but make prey inactive and therefore difficult to detect (Pienkowski 1982). Thus there are high numbers on Irish Sea estuaries and at suitable sites around Ireland. Because some British birds return to their breeding areas as early as February, this concentration in the west in winter may be even more marked than recorded on the map.

In addition to British breeding birds, some Continental birds, mainly from the Wadden Sea and Baltic coasts, winter in Britain and Ireland. In the south, colour-ringed birds from East Germany have been seen (A. Siefke). Some British breeding birds move south to the Continent. Birds from the larger arctic breeding populations occur only on spring and autumn passage.

The *Breeding Atlas* estimated the number of pairs in Britain and Ireland as 8,000, but the 1983 Wader Study Group/Nature Conservancy Council Survey of the Uists doubled the previous estimate for the area to 2,100 (Green 1983), making the total about 9,000 pairs. This is perhaps equivalent to a winter population of about 30,000 birds, after allowing for young produced and surviving. Prater (1981) estimated the mid winter population of Ringed Plovers in Britain and Ireland to be 10,000–15,000. However, the map suggests that the real total may be more than 20,000. This difference from Prater (1981) is not surprising as the Birds of Estuaries Enquiry (and the Wetlands Enquiry in Ireland) did not attempt to cover all non-estuarine coasts, some of which are very important to this species. In fact as a result of the BTO/WSG Winter Shorebird Count, the wintering population is now known to be 25,000–30,000 birds. In addition, Hutchinson (1979) estimated 5,000–10,000 birds in Ireland, making a total of about 35,000. Allowing for the emigration of some birds and immigration of others, the breeding and wintering estimates are now of the same order of magnitude.

Many more Ringed Plovers winter in SW Europe and Africa, where this species forms a much higher proportion of the shorebird community (Pienkowski 1981). Britain and Ireland are on the northern edge of the species wintering range, but the coasts are obviously of great importance to the locally breeding birds and short distance migrants.

M. W. PIENKOWSKI

Total number of squares in which recorded: 1,031 (27%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–18	414 (54%)	102 (40%)	517 (50%)
19–60	221 (29%)	84 (33%)	307 (30%)
61+	137 (18%)	69 (27%)	207 (20%)

References

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PIENKOWSKI, M. W. 1981. Differences in habitat requirements and distribution patterns of plovers and sandpipers as investigated by studies of feeding behaviour. Proc. IWRB Feeding Ecology Symp., Gwatt, Switzerland, September 1977. *Verh. Ornithol. Ges. Bayern* 23: 105–124.

PIENKOWSKI, M. W. 1982. Diet and energy intake of Grey and Ringed Plovers, *Pluvialis squatarola* and *Charadrius hiaticula*, in the non-breeding season. *J. Zool. Lond.* 197: 511–547.

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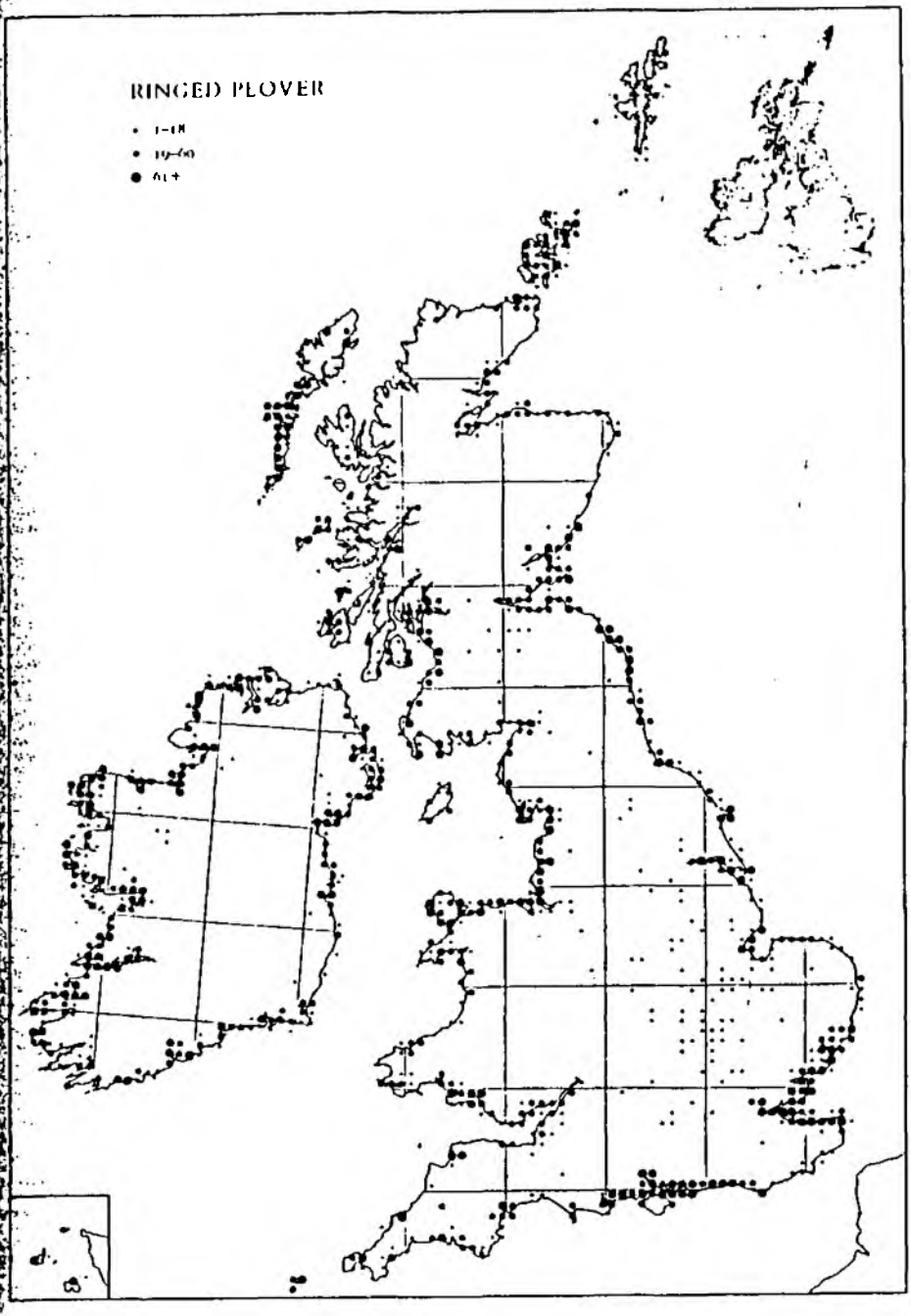
RINGED PLOVER
1-18
19-60
61+

Oystercatcher

Haematopus ostralegus

The Oystercatcher is a familiar and unmistakable coastal species which has caused much controversy over its supposed competition with man.

Most of our breeding birds winter on the coasts of Britain and Ireland, where they are joined by immigrants. Adults leave the estuaries in February and March and start returning in late July. The origins of these birds differ between coasts. Birds wintering on the west coast of Britain and in Ireland breed in Scotland, the Faeroes and Iceland whilst those wintering on the east coast of Britain are almost exclusively of Norwegian origin (Dare 1970).

The biology of Oystercatchers is closely dependent upon that of shellfish. Cockles and mussels are lucrative, thick-shelled prey that other waders are incapable of opening. With their powerful beaks and strong musculatures Oystercatchers are well adapted to open these bivalves, and the abundance of these prey species (plus the other bivalves *Mytilus edulis* and *Scrobicularia plana*) largely determines the distribution of the largest winter gatherings. Six estuaries hold over 50% of Britain's Oystercatcher population, but as they also take polychaete worms, crabs and limpets Oystercatchers are found around practically the entire coast.

In parallel with the increase in inland nesting recorded in the *Breeding Atlas*, there has also been an increase in feeding in fields up to 7 km inland especially around the Irish Sea and the Solway. Seeking for earthworms appears to be a recent habit which Dare (1966) suggested originated in the 1962/63 winter after much of the estuarine prey had been killed by the harsh weather.

As Oystercatchers are usually faithful to their wintering grounds, populations appear fairly constant from year to year. This situation can alter markedly if there are dramatic changes in the prey population. Between the winters of 1960/61 and 1963/64 the vast cockle stocks of Morecambe Bay practically disappeared and the number of birds plummeted from about 120,000 to 11,000 (Dare 1966). The fate of the missing birds is unknown although Dare suggested they may have moved to the Wadden Sea. A similar, though reverse, phenomenon occurred on the Ribble Estuary (Lancashire) in which a 2,000-fold increase in the number of cockles resulted in a four-fold increase in the number of Oystercatchers (Sutherland 1982). There was evidence that juveniles and immatures were disproportionately abundant during the year of population increase; in the subsequent years the declining population consisted predominantly of adults. Thus it seems that juveniles and immatures move to estuaries with unexploited food whilst adults return to previous haunts.

The Oystercatchers' skill at opening cockles and mussels has made them unpopular with fishermen with whom they may compete for food. During the winter of 1963/64 there was a massive spatfall of cockles on the Burry Inlet which led to excellent yields in subsequent years. By the time the cockle population had returned to its usual level, Oystercatcher numbers had increased from 8,000 to 15,000. The fishermen demanded a cull of Oystercatchers to return the population to earlier levels, and a total of 10,000 was shot in the autumns of 1973 and 1974. Ironically, after this cull had been carried out, the cockle population plummeted for unknown reasons. Horwood and Goss-Custard (1977) reanalysed the data and suggested the impact of Oystercatchers had been exaggerated. The public outrage, the shifting of opinion towards conservation and the subsequent reanalysis of the Burry Inlet data make it unlikely that such a cull will be repeated.

The Birds of Estuaries Enquiry estimates the British and Irish wintering population as 300,000 birds, which probably accounts for more than 45% of Europe's Oystercatchers.

W. J. SUTHERLAND

Total number of squares in which recorded: 1,535 (40%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–44	621 (53%)	146 (41%)	768 (50%)
45–225	321 (27%)	138 (39%)	460 (30%)
226+	234 (20%)	70 (20%)	307 (20%)

References

DARE, P. J. 1966. The breeding and wintering populations of the Oystercatcher (*Haematopus ostralegus* Linnaeus) in the British Isles. *Fishery Invest. Lond. Ser.* ii 25 (5): 1–69.

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HORWOOD, J. W. and J. D. GOSS-CUSTARD. 1977. Predation by the oystercatcher *Haematopus ostralegus* in relation to the cockle *Cerastoderma edule* (L.) fishery in the Burry Inlet, South Wales. *J. Appl. Ecol.* 14: 139–158.

SUTHERLAND, W. J. 1982. Food supply and dispersal in the determination of wintering population levels of oystercatchers *Haematopus ostralegus*. *Est. Coast. and Shelf Science* 14: 223–229.

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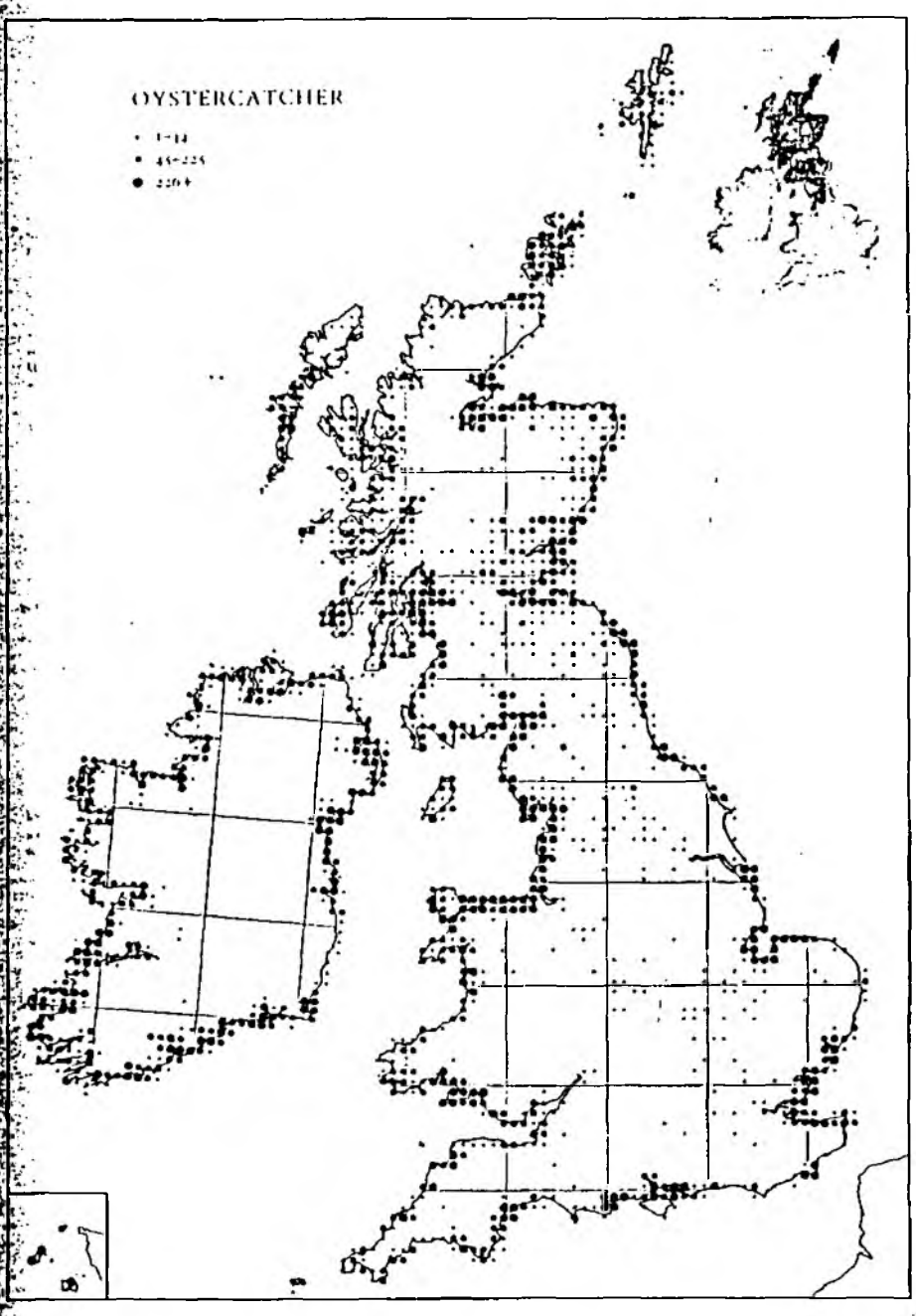
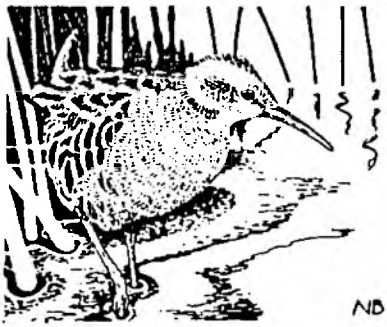

OYSTERCATCHER

Water Rail

Rallus aquaticus



The Water Rail is one of the most elusive birds, winter and summer alike. It is the prime skulker in dense wetland vegetation, its body as well adapted in its lateral compression to slipping between the reed stems as are its long-toed feet to supporting it on soft mud or floating leaves. Its plumage, a mixture of browns, greys and buffs, camouflages it well, and every movement it makes seems to be considered beforehand, executed slowly and carried out with stealth. In summer, breeding Water Rails draw attention to themselves by horrific pig-like squealing cries, but such advertisement of their presence is rare in winter. Only when conditions are really hard, when frozen mud and water force the Water Rails to seek food outside the shelter of their protective vegetation, or when the observer is particularly stalwart and prepared for a long quiet wait, are they likely to be seen well.

Against this background, it is interesting to see that the winter distribution of Water Rails is at least as wide as that of summer birds portrayed in the *Breeding Atlas*. Clearly the distribution of suitable swamps, and their chances of remaining unfrozen through the winter, play a major role in determining this distribution, and if the bird was more conspicuous there is little doubt that it would be reported even more widely.

In Scotland, the winter pattern resembles that of the breeding season, but with more positive squares in winter in Orkney and Shetland. In England and Wales the pattern is roughly the same between seasons, though occupied squares are denser overall in winter and there are appreciably more records from Devon, Cornwall and along the Welsh coast. Only in Ireland does there seem to be little change in distribution, coupled with fewer squares with records in winter than in summer, but perhaps this is a reflection of recording difficulties where ornithologists are fewer and potentially suitable habitats more numerous.

Under normal conditions, Water Rails have a very varied diet, including a wide range of wetland invertebrates, ranging in size from insects and their larvae to shrimps and molluscs; to which can be added many vertebrates they may encounter, such as frogs and newts, and an unknown proportion of vegetable matter. This includes energy-rich tuberous roots and rhizomes, seeds and berries (including grain), and (less profitably) grasses.

When weather conditions become severe, Water Rails are forced by hunger to tackle carrion and also larger live prey, often including birds, of which 9 species have been recorded. These attacks are characterised by an initial stealthy stalking approach, ending in a rush to seize prey, which is then battered to death on the ground. The Water Rails themselves may be at risk too, as there are records of several Grey Herons *Ardea cinerea* catching, drowning and eating Water Rails flushed from hiding on the Dee Marshes in Cheshire (Flegg 1981). Normally, Water Rails are solitary or only loosely gregarious during the winter months, but there are places, for example the Dee Marshes, where concentrations, sometimes of hundreds of birds, occur.

Ringing recoveries provide little evidence of movement of British and Irish breeding birds. There are recoveries of birds moving into Britain and Ireland from the Continent for the winter. Most arrivals were in October and November, and came on westerly or southwesterly bearings. Returning in spring (March and April), the heading of most recovered birds was, interestingly, SE rather than E or NE as might be expected. Recoveries come from most countries of northern Europe, and from as far afield as Sweden, Poland and Czechoslovakia. Despite its terrestrial habits, ineffectual looking wings and apparently feeble flight, the Water Rail is clearly a competent long-haul migrant.

Attaching numbers to such a secretive and enigmatic species is a difficult task. The *Breeding Atlas* suggested a summer population in Britain and Ireland of 2,000–4,000 pairs: it seems most probable that these remain during the winter, and that their numbers are considerably augmented by incoming migrants. There is little factual evidence on population changes, though land drainage may have some adverse impact.

J. J. M. FLEGG

Total number of squares in which recorded: 981 (25%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1	447 (55%)	97 (57%)	545 (56%)
2	183 (23%)	33 (19%)	216 (22%)
3+	178 (22%)	40 (24%)	220 (22%)

References

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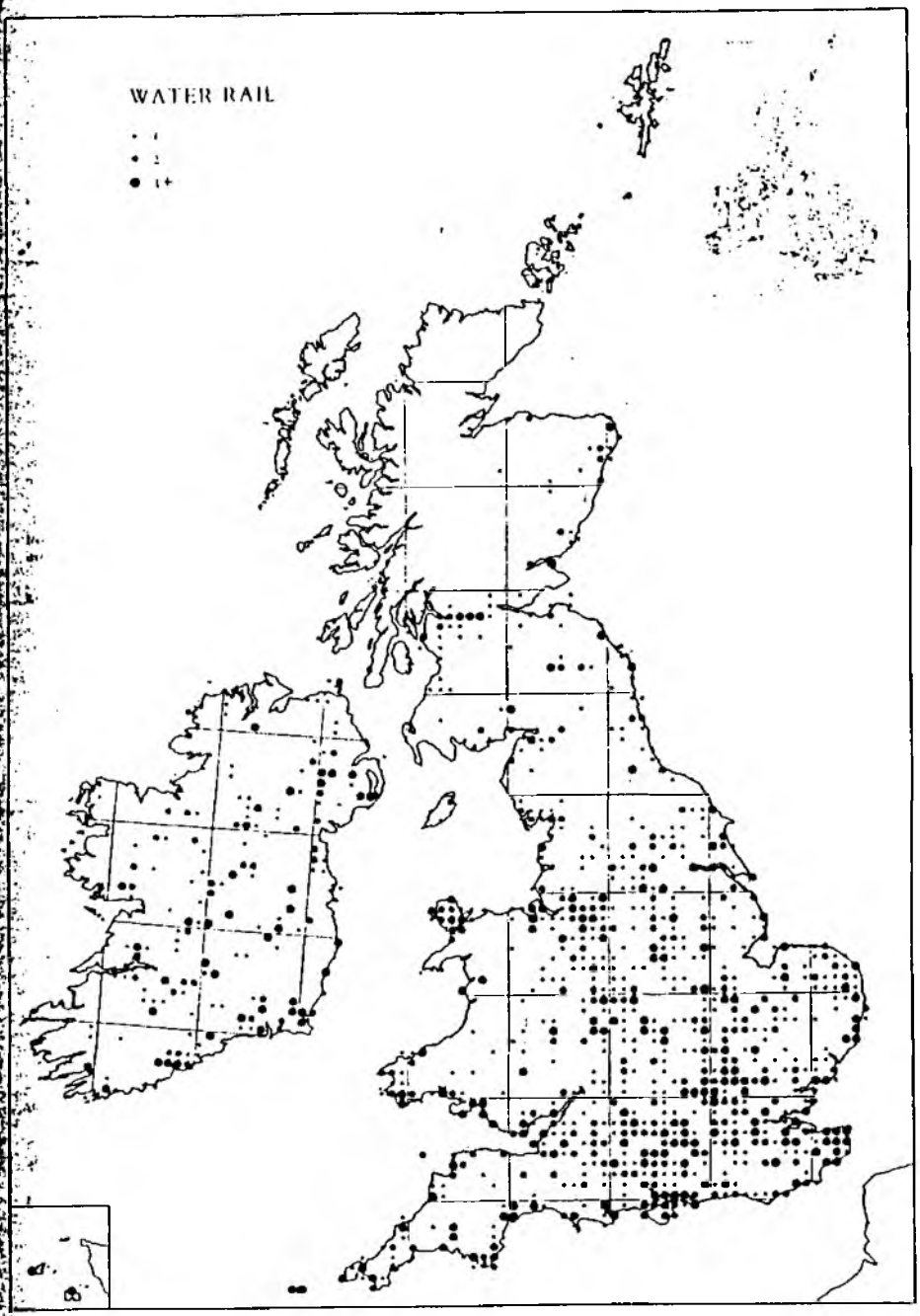
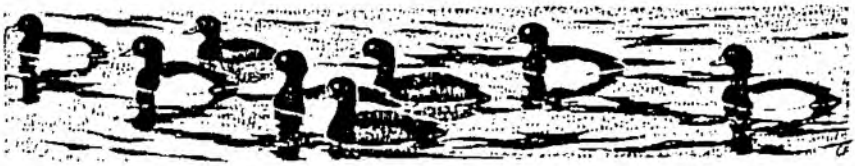
Breeding Atlas p 152


WATER RAIL
1
2
1+



Tufted Duck

Aythya fuligula

The commonest diving duck in Britain and Ireland, the Tufted Duck is a widespread breeding species, while numbers in winter are greatly augmented by immigrants from northern Europe.

There are few fertile fresh waters which do not hold Tufted Ducks in winter, this being especially true of drinking water reservoirs and gravel pits in lowland areas. Acid waters, and lakes and reservoirs in upland areas, are on the whole avoided and only very small numbers, less than 5% of the total, are found on brackish or salt water habitats (Owen *et al* 1986). The map clearly shows the lowland distribution of the species, with concentrations in the Thames, Ouse and Trent valleys, on the reservoirs around London, in west central, and NW England, and on the lochs and reservoirs of central Scotland. There are important waters for Tufted Ducks in central and W Ireland, and, particularly, on Lough Neagh in Northern Ireland.

Flocks of Tufted Ducks are generally small, rarely more than 1,000. By becoming tolerant of man, Tufted Ducks have successfully moved into town and city park lakes where they supplement their natural diet with food from the public.

The breeding and winter distributions in Britain and Ireland are very similar, although the larger waters, or those without islands or thick fringing vegetation, are not used for nesting.

Tufted Ducks live mainly on animal food, which they obtain by diving with occasional upending. The preferred depth is down to about 2.5 m, but there are many records of them feeding down to at least 5 m. Dives normally last 15–20 seconds, and rarely more than 35–40. Up to 100 dives per hour are common, with 10 second pauses between dives (*BWP*).

Whilst underwater, the bill is used to pluck larger molluscs, such as the zebra mussel and the spire-shell, from the bottom or off the leaves of submerged plants. Chironomid and other larvae are taken in large quantities, and are sieved from the bottom mud while the bird maintains its body at an angle of about 45°. Plant seeds are eaten, particularly in autumn.

As males dive to greater depths and so stay down longer than females, there is some separation of the sexes in feeding flocks. Feeding is commonest during the day than during the night.

Ringing has shown that the breeding birds of Scotland move to Ireland for the winter, but those breeding in Ireland and in the rest of Britain are more or less sedentary, at least in normal winters. Immigrants from Iceland, northern Scandinavia and Russia east to about 80°E, arrive in Britain in late September onwards and stay to early spring. In the autumn, some Tufted Ducks may move through Britain into France, and there is further onward movement in spells of hard weather. Moulting concentrations have been recorded at a few places, but the origins of the birds are unknown.

Tufted Ducks have increased enormously in Britain in the last hundred years and are still increasing. From the first breeding record in Yorkshire in 1849, the nesting population is now put at over 7,000 pairs (Owen *et al* 1986). Similarly in Ireland, where the first breeding record was in 1877 and there are now thought to be at least 2,000 pairs (Hutchinson 1979). The wintering population has similarly increased. The mid winter peak has roughly trebled since the early 1960s, and now stands at just over 60,000 (Owen *et al* 1986). Although this could be accounted for in large part by the growth of the breeding population, because many of our breeders move out of Britain for the winter, it seems more likely that there has been a genuine growth in numbers of immigrants coming to replace them. The picture in Ireland is confused by the mid winter presence on Lough Neagh of over 30,000 birds in the mid 1960s. The few complete counts since then were 29,000 in January 1978, falling to 19,000 in November 1979 and only 8,000 in the following November. It is not known whether such large numbers still occur there. Elsewhere in Ireland, a peak winter population of up to 25,000 has been estimated (Hutchinson 1979).

The NW European population of Tufted Ducks is put at over 500,000; there are a further 350,000 in the Mediterranean–Black Sea region; and at least half a million in Asia (Scott 1980).

M. A. OGILVIE

Total number of squares in which recorded: 2,042 (53%)

No of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–25	794 (49%)	216 (51%)	1,011 (50%)
26–94	493 (31%)	128 (30%)	621 (30%)
95+	327 (20%)	82 (19%)	410 (20%)

References

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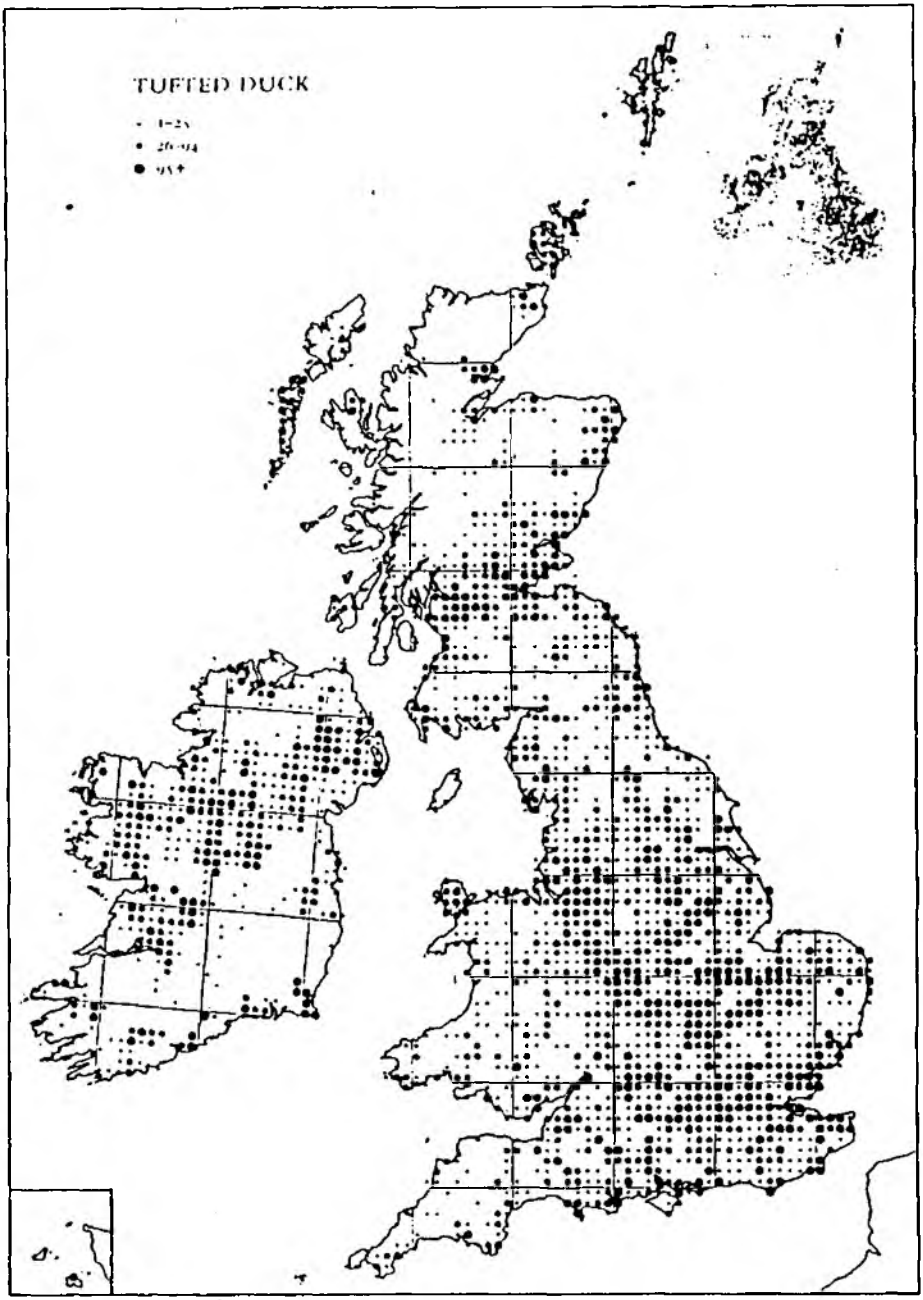
TUFTED DUCK

Shoveler

Anas clypeata

Whilst a female Shoveler may briefly escape detection amongst female Mallards *A. platyrhynchos*, the male Shoveler is clearly distinctive. The snowy breast and chestnut flanks are diagnostic, but above all one notices the long spatulate bill. The lamellae or corrugations on the inside of the bill are more pronounced than in any other northern hemisphere duck, so that it is particularly well adapted for filter feeding.

Like most other ducks, the Shoveler is virtually absent from the East Anglian chalk and from hilly and mountainous areas. The species is particularly scarce and local in Scotland and northernmost England, where there is a paucity of low-lying standing water. The map understates the extent to which Shovelers prefer fresh water. Except in Essex, Kent and Dublin there are few estuaries which hold many more than 35. A number of apparently coastal concentrations are on enclosed waters a short distance inland.

The only studies of Shovelers' food have taken place on some coastal sites and the Ouse Washes—not entirely typical habitats. In salt water, *Hydrobia* snails are favoured, and in brackish water seeds and insects. On the Ouse Washes (Cambridgeshire/Norfolk) the Shoveler is the most carnivorous dabbling duck, preferring snails, crustaceans and insects, as well as seeds (Thomas 1978). Food is usually obtained while swimming rather than by upending. They probably feed both by day and night, at least in undisturbed areas.

In Britain and Ireland, as in NW Europe as a whole, gatherings of more than a few hundred Shovelers rarely occur. An exception is Lough Owel (Westmeath), where up to 2,000 have occurred in autumn, but fewer stay for the winter. If disturbed, these birds move to the nearby Lough Iron (Hutchinson 1979). Otherwise, only about a dozen places in Britain and Ireland regularly hold over 250 Shovelers between November and February, and none more than 400.

The movements of British and Irish Shovelers are by no means clear. The breeding population, estimated at about 1,000 pairs in the *Breeding Atlas*, apparently moves to France and Spain in the autumn, to be replaced by immigrants from as far east as western Siberia, many of which in turn move on southwards later in the winter (Ogilvie 1962, Perdeck and Clason 1980). Britain formerly held its highest numbers in February or March (Atkinson-Willes 1956), but nowadays there is a clear November peak. It is possible that the succession of mild winters from the mid 1960s to mid 1970s precluded the need for return migrants from Spain and France to stop off in Britain, and that this habit has persisted (Owen *et al* 1986). In Ireland, however, several places still carry their largest numbers in February or March, although these birds may simply have wintered elsewhere in Ireland.

At the time of the November peak there are about 9,000 Shovelers in Britain and 8,000 in Ireland. In Britain the numbers decline steadily during the winter, only 5,000–7,000 nowadays being present in February and March, compared with perhaps 8,000–10,000 in the 1960s, when the spring passage was much larger. In Ireland, there may be as few as 4,000 by January, although (as mentioned above) there is evidence of an increase in spring.

Numbers in Britain and Ireland are less significant internationally than those of most wildfowl. About 20,000 Shovelers were thought to winter in NW Europe in the early 1970s, and some 25,000 pairs to breed in the region and to winter further south. NW Europe therefore probably supported about 100,000 birds, allowing for non-breeders (Scott 1980). Recent analyses by the IWRB show a continuing increase throughout Europe.

D. G. SALMON

Total number of squares in which recorded: 909 (24%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–7	367 (50%)	75 (43%)	442 (49%)
8–34	232 (32%)	49 (28%)	281 (31%)
35+	135 (18%)	57 (29%)	186 (20%)

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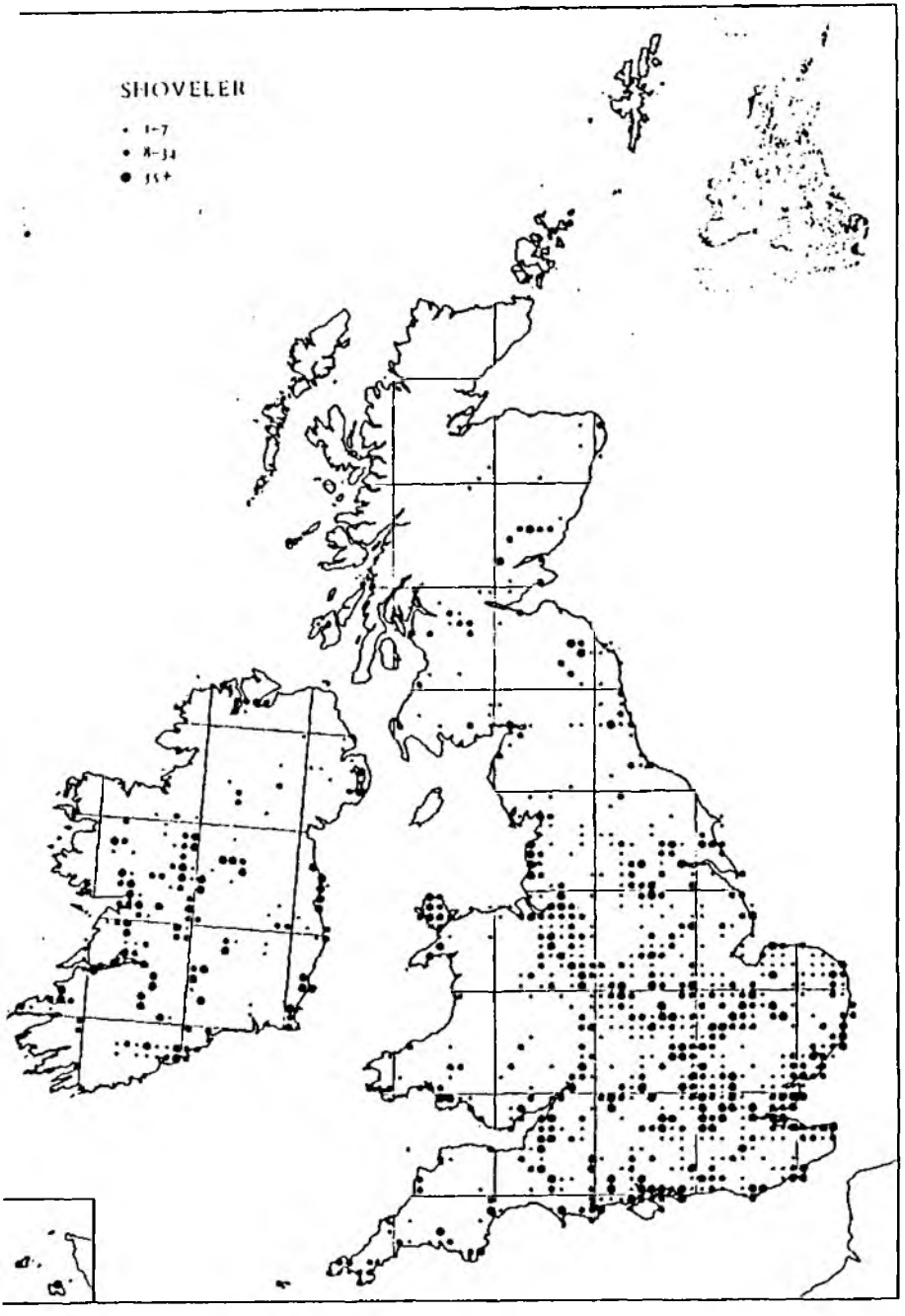
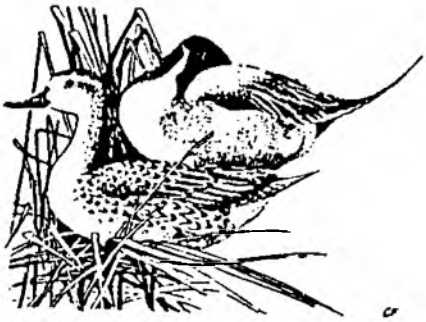

SHOVELER
1–7
8–34
35+

Pintail

Anas acuta



The drake Pintail is one of the most striking and elegant of our dabbling ducks, with its pointed tail and chocolate and white head pattern.

The map clearly shows the Pintails' preference for estuaries, especially the larger ones. The only inland squares with over 30 birds are around the Ouse and Nene Washes, apart from a few containing isolated floodlands or large enclosed waters not far from the coast. The courses of rivers lined with gravel workings (such as the Trent) are traced by some of the smaller symbols. Away from the most low lying areas Pintails are virtually absent.

In estuaries small snails of the genus *Hydrobia* are apparently by far the most favoured food, although seeds are also commonly taken (Olney 1965), while on the Ouse Washes seeds, notably of common spikerush, account for over four fifths of the diet. In recent years the arable land around the Washes has also provided food for many of the local Pintails. Cereal stubbles are preferred in the autumn, waste potato and sugar beet thereafter (Thomas 1978, 1981). Field feeding is now common in many other areas.

It is not known where the very small breeding population of Britain and Ireland winters, but from September onwards birds from western Siberia and, to a lesser extent, Scandinavia and Iceland reach our shores. The peak occurs in December in Britain, November or December in eastern Ireland and October or November in western Ireland (Owen *et al* 1986, Hutchinson 1979). Pintails are highly mobile and quickly take advantage of temporary floodwater, yet are extremely concentrated within their NW European range. In Britain, 70–80% of the numbers recorded between November and January by the Wildfowl Trust's National Wildfowl Counts are usually on just 6 sites. The Mersey and Dee estuaries are by far the most important areas.

On the Mersey, the average annual maxima in the Wildfowl Counts (including an occasional October peak) rose from 1,200 in the 1960s to 10,600 in the 1970s and early 1980s, with a maximum of 13,800 in January 1983. On the Dee, a less spectacular increase began in the mid 1970s, the annual peaks rising from 1,000–2,000 to 5,000–6,000, with the exceptional 11,300 in November 1983. The Dee also holds large numbers for much longer than formerly. These increases, though conforming broadly to the national trend (see below), are particularly marked, due apparently to favourable habitat changes on the south shore of the Mersey and to the creation of reserves in both estuaries.

Movements in response to hard weather are not as clear cut as might be expected, but there are indications that a shift from northern into southern Europe occurred in some recent cold winters (Owen *et al* 1986, International Waterfowl Research Bureau).

The NW European wintering population increased from about 50,000 in the early 1970s (Atkinson-Willes 1976) to 75,000 at the end of the decade (Scott 1980). In Britain there was a parallel increase after a period of relative stability in the 1960s, and the present wintering population exceeds 25,000 (Owen *et al* 1986). The total numbers in Ireland were thought to peak (in November) at about 7,000 in the 1970s (Hutchinson 1979).

D. G. SALMON

Total number of squares in which recorded: 674 (17%)

No. of birds seen in a day	Number (%) of squares		
	Britain	Ireland	TOTAL (incl. C.I.)
1–3	286 (50%)	37 (36%)	324 (48%)
4–29	178 (31%)	38 (36%)	217 (32%)
30+	104 (18%)	29 (28%)	133 (20%)

References

ATKINSON-WILLES, G. L. 1976. The numerical distribution of ducks, swans and coots as a guide to assessing the importance of wetlands in midwinter. *Proc. Int. Conf. Conserv. Wetlands and Waterfowl, Heiligenhafen, 1974*: 199–254. IWRB, Slimbridge.

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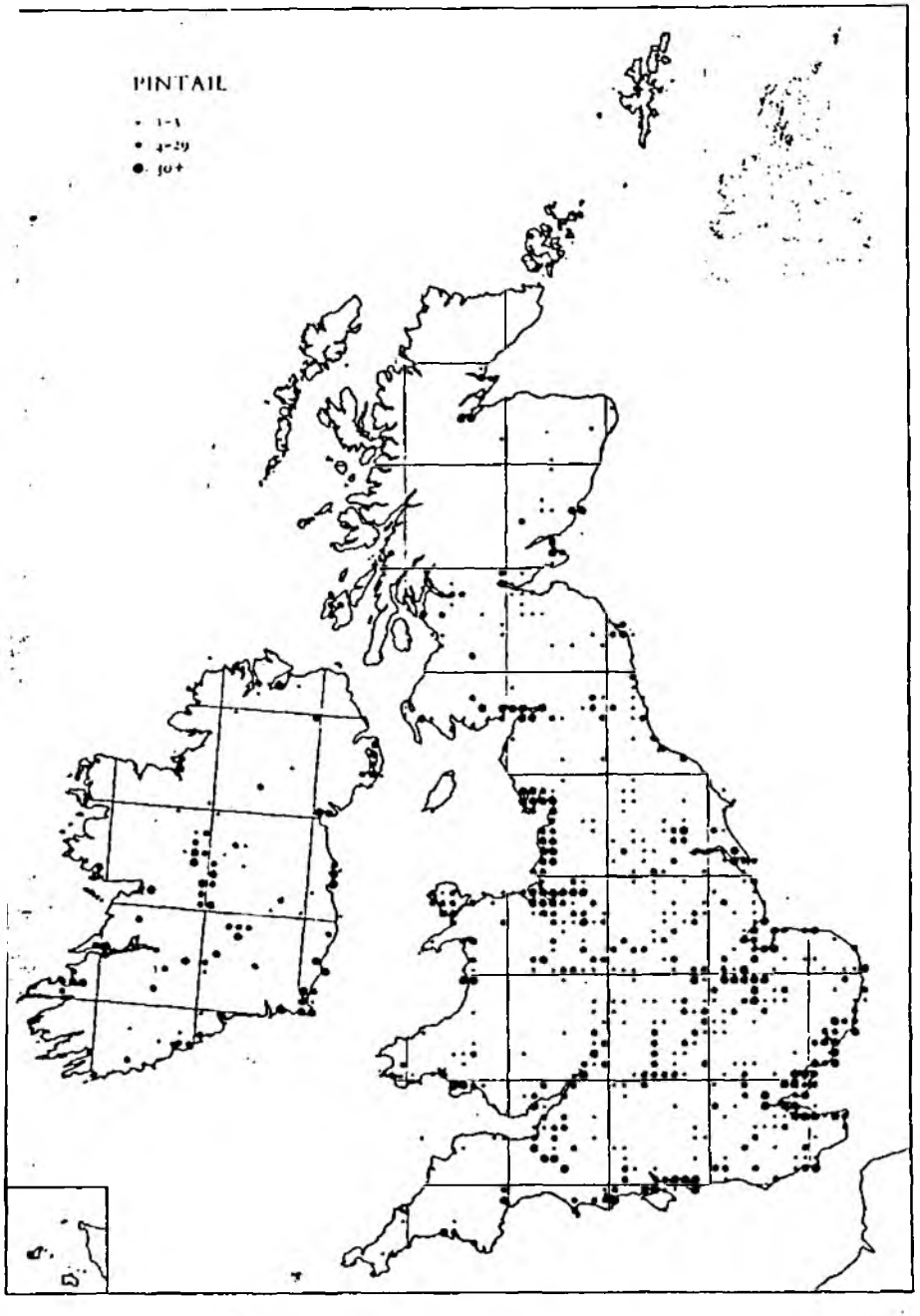
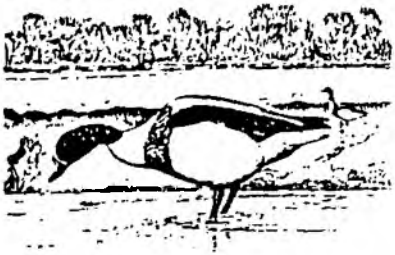

PINTAIL
1-3
4-29
30+

Shelduck

Tadorna tadorna



The Shelduck is one of the most conspicuous wildfowl occurring on British estuaries in winter. Its large size and contrasting black, white and chestnut plumage make it stand out from other ducks and waders with which it often associates, particularly when it is illuminated by mellow winter sunshine.

The winter distribution is chiefly coastal, with most birds occurring on the muddier estuaries of southern and eastern England, southern Ireland, around the shores of the Irish Sea, and in SW Scotland. Mid winter numbers in Scotland depend partly on the severity of the weather there, some adults returning later from their moulting grounds in colder winters. Shelducks can occur at very high densities on some estuaries, the map does not show the size and character of the concentrations. For example, in some winters up to 4,000 have occurred on the Tees estuary, on only 140 ha of mudflat.

Many of the birds breeding in northern and western Scotland are absent from these areas in winter. Although small numbers of Shelducks in Britain and Ireland nest around pools some tens of kilometres from the coast, in central and southern England they are not as regularly found inland in summer as they are in winter; the map shows a scattering of wintering birds on many reservoirs and gravel pits in England.

On estuaries, Shelducks feed chiefly on areas of more liquid mud, which they sieve through their lamellated bills, extracting a variety of small snails, worms and crustaceans. The most obvious remains found in their guts and faeces are the crushed shells of the snail *Hydrobia ulvae*, but in some estuaries this prey is too scarce to form more than a small proportion of their daily food intake. In such localities Shelducks rely on abundant small polychaete and oligochaete worms. At the coast, birds alter their feeding method according to the stage of the tidal cycle, from scything through the mud at low water to upending in shallow water as the tide covers and uncovers the mudflats. Inland, it is likely that freshwater snails and earthworms are important, but perhaps aquatic plants and algae are also taken.

After breeding, most adult Shelducks from Britain and Ireland move to the German section of the Wadden Sea, where they moult alongside breeding birds from the rest of western Europe. Several thousands remain to moult on the Forth, Humber, Wash and more especially in Bridgwater Bay, but this habit appears to be of relatively recent origin. Moulted birds begin to return to southeastern England in October, and large gatherings also assemble on the Dee estuary and Morecambe Bay. By mid winter, birds have spread northwards and westwards from East Anglia, but others have arrived to replace them. These include not only British and Irish breeding stock but also some immigrants from continental European populations. Thus each estuary tends to be used by a succession of individuals, rather like a winter holiday resort. Birds arrive on their eventual breeding grounds over a period of several months.

After fledging in July, young Shelducks do not follow their parents to the Wadden Sea, but disperse later from their birthplaces. Ducklings hatched on the coast of East Lothian, Scotland, have been seen in the autumn and winter at several sites along the northeast coast of England, and one as far afield as the Camargue, S France, but many move into the upper reaches of the Firth of Forth. Birds from the same brood have been found in several different wintering sites.

In recent winters, 60,000–65,000 Shelducks have been counted in mid winter in Britain, a considerable increase over the 50,000 level recorded regularly up to the early 1970s. This probably results in part from an increase in the breeding population in Britain, but may also reflect more birds moving westwards from the Wadden Sea in response to the more frequent severe winters of recent years. The Irish wintering population is between 6,500 and 8,000 birds. As the whole western European population is of the order of only 120,000–130,000 birds, the importance of the British wintering sites is obvious.

P. R. EVANS

Total number of squares in which recorded: 1,135 (29%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–7	306 (53%)	71 (38%)	579 (51%)
8–80	257 (27%)	72 (38%)	329 (29%)
81 +	183 (19%)	44 (24%)	227 (20%)

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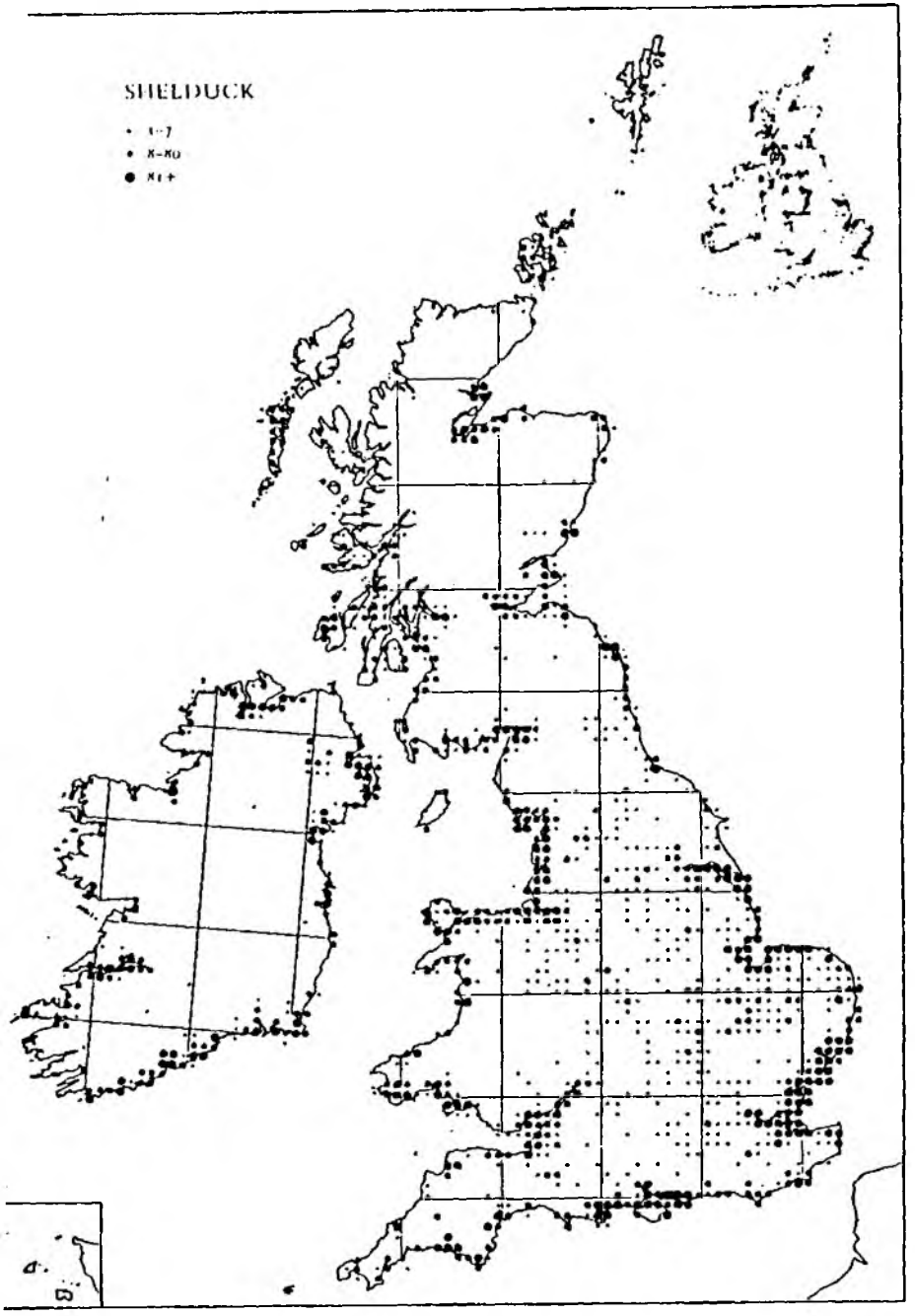
SHELDUCK
1–7
8–80
81+

Wigeon

Anas penelope

A medium sized, gregarious duck, the Wigeon is a familiar sight around our coasts and its musical whistling a pleasant evocative sound, commonly heard over mudflats or at night as the flock leaves the estuary to feed on nearby marshes or flooded pastures.

The numerical distribution is more coastal than the map suggests. In Britain, in the early 1970s 81% of Wigeons still roosted on the coast and 54% on estuarine habitats, although a move to inland habitats had taken place in this century (Owen and Williams 1976). In Ireland they have always been more of an inland species. Though the major concentrations are on estuaries, they also gather in large numbers in the flooded pastures of the Shannon valley in mid winter. There are 9 sites in Britain holding internationally important concentrations of more than 5,000, but 2 are outstanding: Lindisfarne, Northumberland, with an average peak of nearly 30,000 in October/November has always been important, and the Ouse Washes in East Anglia became so after protection and management of part of the area by voluntary bodies. Both sites have held more than 40,000 Wigeons in some seasons.

The traditional diet of Wigeons was eel grass, algae and grasses gathered on mudflats and saltings, but with the move inland their taste has become more catholic. At the Ouse Washes a wide variety of foods and habitats is used, including stubble grain and winter wheat gathered from the sprouting fields in late winter. The flocks, sometimes numbered in thousands, are often tightly bunched when grazing on land but more spread out on water. Wigeons often feed by picking floating leaves off the water surface or by dabbling in the shallows. In disturbed areas most of the feeding takes place at night, but elsewhere they feed during the day as well. Most birds feed within 8 km of the roost although in a few places they fly up to 15 km (Owen and Thomas 1979).

The movements of Wigeons are complex and not well understood. Birds wintering in Britain and Ireland come from Scandinavia and Siberia, and some from Iceland. Most birds recovered in Iceland in summer come from Scotland and Ireland, but Wigeon ringed in Iceland are sometimes found in later years in continental Europe, so there is some mixing of the stocks. There is some southward and westward movement within Britain and Ireland as the winter progresses and probably a movement into Ireland from Scotland. The peak count is nearly always recorded in January, after a mid winter influx of Continental migrants, which also concentrate on the east coast when there is hard weather in the Netherlands and Germany (Owen *et al* 1986).

Because Wigeons are generally found in large concentrations, they are well covered by Wildfowl Counts. The average maximum in Britain is estimated at about 200,000, with up to 250,000 in some years. There is a less recent estimate of over 100,000 for Ireland (Hutchinson 1979), and the total in NW Europe has been put at about half a million birds (Owen *et al* 1986). The numbers in Britain have shown no trend overall since 1960, but there have been changes in distribution, largely linked to the creation of reserves. Thus there has been a significant increase in numbers on protected sites and a decrease on unprotected areas. This has resulted also in a continuation of the move from coastal to inland habitats.

Britain and Ireland are crucially important wintering areas for NW European Wigeons, jointly holding more than half the total at peak times. Another half a million or so birds, not entirely isolated from the NW European group, winter around the Mediterranean and the Black Sea (Atkinson-Willes 1976).

M. OWEN

Total number of squares in which recorded: 1,885 (49%)

No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–43	750 (53%)	194 (42%)	944 (50%)
44–299	405 (29%)	158 (34%)	564 (30%)
300 +	268 (19%)	108 (24%)	377 (20%)

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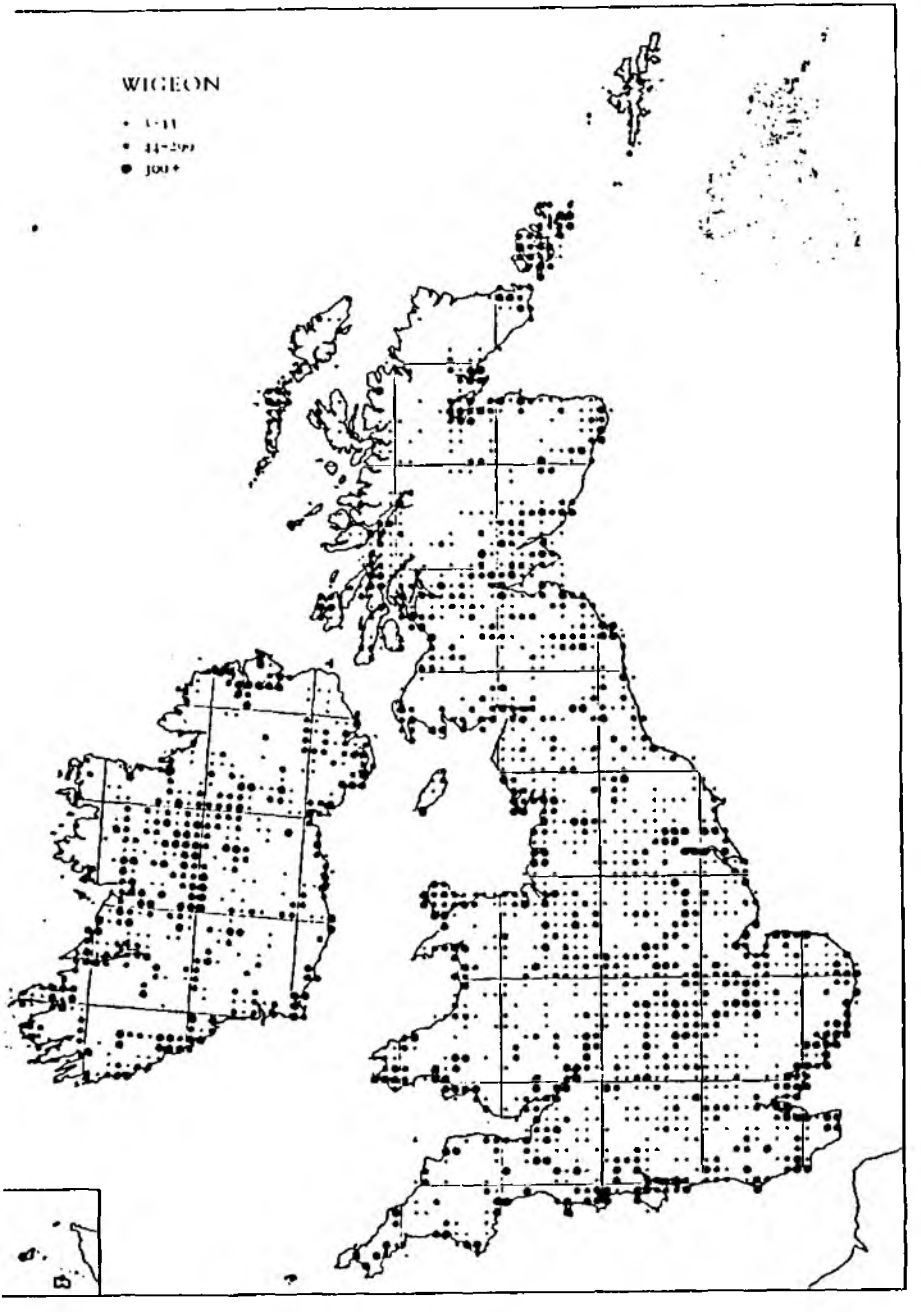
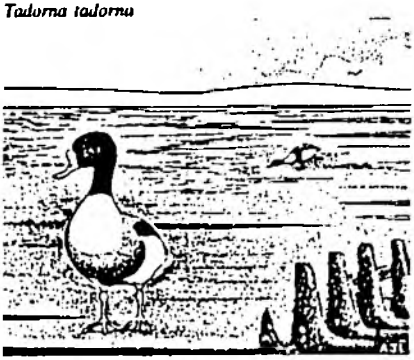

WIGEON
1-11
11-200
300+

Shelduck

Tadorna tadorna



THE Shelduck is one of our most attractive and brightly coloured wildfowl and, during this century, it has increased considerably, such that it is now a familiar sight on all of Devon's estuaries.

Shelducks feed mainly on small invertebrates, particularly *Hydrobia*, which are to be found on productive mud and sand flats. Their reliance on this habitat for food explains their breeding distribution which is very much based on estuaries. Where birds have penetrated further inland, as they have to the west of the Exe estuary and on the rivers Torridge, Taw, Otter and Axe, they will still fly down to the estuaries to feed. On the estuaries, all pairs defend a feeding territory. No territory is defended around the nest except for the immediate vicinity. Some nests may be very close together, even in the same burrow. *(BWP)*.

The nest is usually built in a hole, often a rabbit burrow, but sometimes a hole in a tree or a crevice in a sea wall. Although the majority of nests in Devon are found in such situations, there are some cliff-nesting pairs, such as on the south coast near Prawle Point, and some of the inland sites are under dense thickets of vegetation rather than in holes. Finding nest sites is not particularly easy and, for this reason, the majority of confirmed breeding records relate to sightings of small young. The difficulty with this is that the young are led directly to the feeding areas by the adults very soon after they hatch. Thus, unless an adult is seen to enter or leave a nest site or the family party is seen *en route* to the estuary, the actual location of the nest cannot always be established.

Once the young birds reach the feeding area on the estuary, the parents start to lose interest in them and, by July, many adults are beginning to leave for their moulting area. At this time, the young birds join together into large crèches which are tended by just a few of the adults which may moult locally. When the young fledge they disperse. In Britain as a whole, it is known that many young move west to southwest to the Irish Sea and SW England, while others move south to the Bay of Biscay. There is no information on the dispersal of Devon-bred juveniles.

It is believed that most of the adult Shelduck from Devon move across to the Dutch and north German coast where they congregate to moult in the late summer along with about 100,000 other birds which comprise most of the NW European population. This is indicated by the recovery of a bird at Dartmouth in March 1963 which had been ringed in the Heligoland Bight in July 1958. The moulting flock of 3,000-4,000 in Bridgwater Bay, Somerset, is thought to be of Irish origin *(BWP)*.

By September, there are very few Shelduck left in Devon but, from that time onwards, they return at a steady but rather leisurely pace, many not appearing until the early spring.

In view of the difficulties in locating nests and the fact that broods amalgamate soon after they appear on the estuary, it is not easy to establish the number of breeding pairs. A further problem is that, in addition to the breeding pairs, there are a considerable number of non-breeding birds, for the females do not breed until they are two years old and the males not until they are four or five *(BWP)*. In 1976, a survey covering all Devon estuaries except the Tamar located 610 adult birds together with 316 young in early June (Price 1977). The Wildfowl Counts for early spring indicate that a further increase took place after that time, with counts of over 1,000 birds, but since 1980 numbers appear to have stabilised at around 800. It is thought that this may represent 200-300 breeding pairs. At the beginning of the century, Shelduck only bred in Devon in very limited numbers, so it is evident that there has been a considerable increase since then.

In NW Europe, the Shelduck is principally a coastal species, rarely straying more than 1-2km out to sea and little farther inland. A separate population is found inland, extending across the S Palearctic eastwards from the Black Sea. These birds are mostly associated with salt lakes and marshes in steppe and semi-desert *(BWP)*.

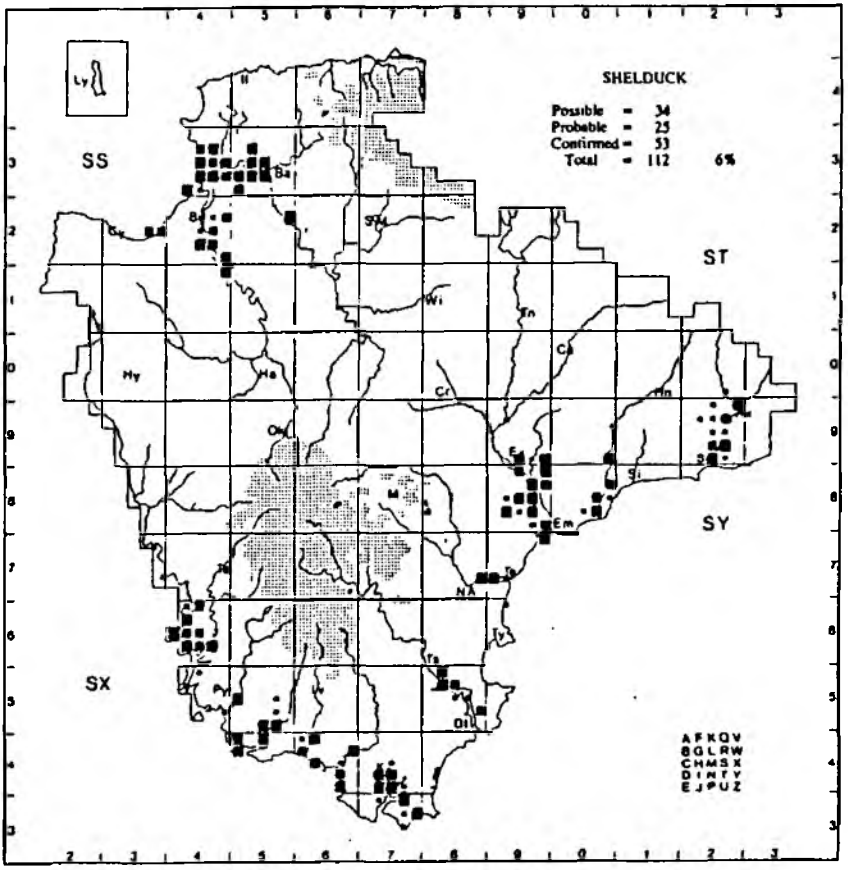
In Britain, egg laying starts at the beginning of May. The normal clutch is 8-10 eggs which are laid at daily intervals. Incubation is by the female alone and lasts 29-31 days, starting when the last egg has been laid. The eggs hatch synchronously and both adults then lead the young to the feeding area on the local estuary. Only a single brood is reared, but second clutches may be laid if the first is lost early in incubation. Studies in Britain have shown that the average number of young reared to fledging per pair is only 1.5 *(BWP)*.

It is likely that the main factor which will restrict the Shelduck population in future is its requirement for sufficient areas of intertidal mud on which to feed. The population having stabilised recently, it would appear that it is now limited in this way. Thus, any future loss of estuarine habitat is likely to have an adverse affect on the Shelduck population.

D. J. PRICE

Reference

PRICE, D. 1977. Canada Goose, Mute Swan and Shelduck in Devon 1976. *Devon Birds* 30: 21-27.


SHELDUCK
Possible = 34
Probable = 25
Confirmed = 53
Total = 112 6%
SS
ST
SY
SX
Ly
Ba
Wi
Tn
Cl
Hy
Ha
Cr
Ox
M
Em
Sl
NA
Ty
Ts
Dil
A F K Q V
B G L R W
C H M S X
D I N T Y
E J P U Z

Mandarin

Aix galericulata

THE male Mandarin is one of nature's masterpieces as far as colour and intricacy of patterning are concerned. The female is quite different and is as subdued as her mate is showy. After breeding, the males moult into eclipse plumage so that in late summer both sexes are very similar in appearance. In the wooded waterways which they frequent, they can be extremely inconspicuous, especially when they perch high in trees, sitting quietly for long periods.

A small population of these exotic ducks is now established on the River Plym in the vicinity of Plymbridge Woods, where they were first noted in the winter of 1980/81. Breeding was first proved in 1984 when two broods of ducklings were seen near Plym Bridge. In 1985, a brood of four was found on 8 June and another of six on 17 August, both on the Plym. In addition, the *Devon Bird Reports* for 1982-85 record sightings of one or more adults at a number of widely scattered sites in the county — at Torquay, on the Torridge estuary at Bideford, on the River Otter, at Slapton, at Shobrooke Park near Crediton (where there was a pair in March and April 1985), at Marwood Hill near Barnstaple and at Chapleton on the River Taw. Some of these records were outside the breeding season, but they indicate that there are now a fair number of free-flying Mandarins in Devon. Furthermore, it is very likely that they breed by other secluded stretches of river besides the Plym, for they can be very elusive and take to cover at the least sign of disturbance.

The first recorded breeding in Britain was at London Zoo in 1834. Since then, Mandarins have been kept in many waterfowl collections and escapes have bred, so that there is now a substantial population in SE England. The Plym Bridge birds originated from the Saltram collection of Mr S. N. S. Pearce, who obtained two pinioned pairs in 1974, which became free-flying after their next moult. This was deliberate on the part of Mr Pearce because it afforded the ducks some protection from persistent vandalism and attempted theft. The total population was over 20 birds in the autumn of 1985. The birds on the Plym are fairly sedentary, although they often return to the ornamental pond at Saltram where food is always available. The origin of the other Mandarins that have been recorded in Devon is not known, though it is likely that they include immigrants from outside the county. That such immigration takes place is shown by a bird which was ringed as a chick on Guernsey in the Channel Islands in July 1980, and recovered at Ottery St Mary in December the same year.

Davies (1985) draws attention to the precarious state of this species in its native homelands in E Asia. The clearing of woods in Manchuria and China, due to human population pressures, has so reduced its natural habitat that there are now believed to be fewer pairs in the whole of China than there are in Britain. The feral population in Britain has recently been estimated at about 1,000 pairs, second only to Japan which is the species' main stronghold and has a population of some 4,500-5,000 pairs.

Mandarins normally nest in holes in trees, usually quite high up, but they will occasionally nest on the ground in thick vegetation. Although the nest site is often close to a river, stream or pond, it is sometimes several hundred metres from the nearest water. In Britain, the first eggs are laid in mid-April, but the main laying period is at the end of April and beginning of May. The usual clutch is 9-12 eggs. Incubation, by the female alone, lasts 28-30 days. The young, which are precocial and self-feeding, are cared for by the female who may lead them up to 2km from the nest to their first feeding area. They fledge at 40-45 days, becoming independent at about the same time. Only a single brood is reared *(BWP)*.

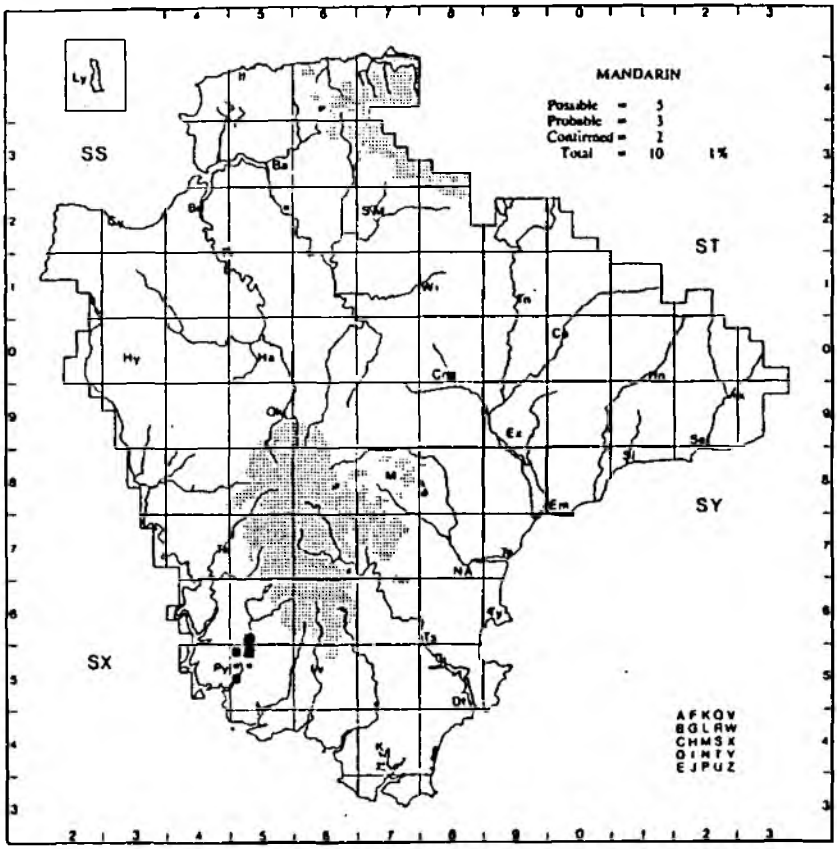
The Mandarin was only officially added to the British List in 1971, by which time it had been breeding in the wild in Surrey for at least 40 years. The population which has built up over that time is now of international importance, so that anything which can be done to promote the spread of this attractive and harmless duck will help to ensure the survival of the species. There is certainly much suitable habitat which it could colonise in various parts of Devon. As a hole-nester it has been known to use nestboxes put out for such birds as Tawny Owl, Kestrel, Stock Dove and Jackdaw, so the provision of suitable boxes in likely breeding areas, such as where rivers wind through woods and are overhung with trees, could be of benefit, especially if there is a shortage of natural holes.

H. T. TURNER

Reference

DAVIES, A. K. 1985. A place for Mandarins. *Birds* 10: 12-14.

FIGURE D3a Breeding Mandarin in Devon (from Sitters;


MANDARIN
Possible = 5
Probable = 3
Confirmed = 2
Total = 10 1%
SS
ST
SY
SX
AFKQV
BGLRW
CHMSX
DINTY
EJPUZ

1988).

River Tamar catchment

1.	R.Tamar,	Nether Bridge	SX 344 866
2.		Timbrelham A384 br	367 804
3.		Endsleigh Cottage, left bank	389 784
4.		Horsebridge	400 748
5.		Latchley	415 735
6.		Gunnislake A390, upstream to gauging station	433 722
7.	R.Thrushel,	u/s Wrixhill	463 893
8.		u/s Hayne, Aracott	422 871
9.	R. Wolf,	Kellacott	407 876
10.	R.Lyd,	Track to Widgery Cross	532 857
11.		Copse, left bank	482 838
12.		Marystow, road bridge	435 833
13.		Lifton Bridge	389 848
14.		Lifton Park	385 842
15.		Downstream of Lew inflow	440 833

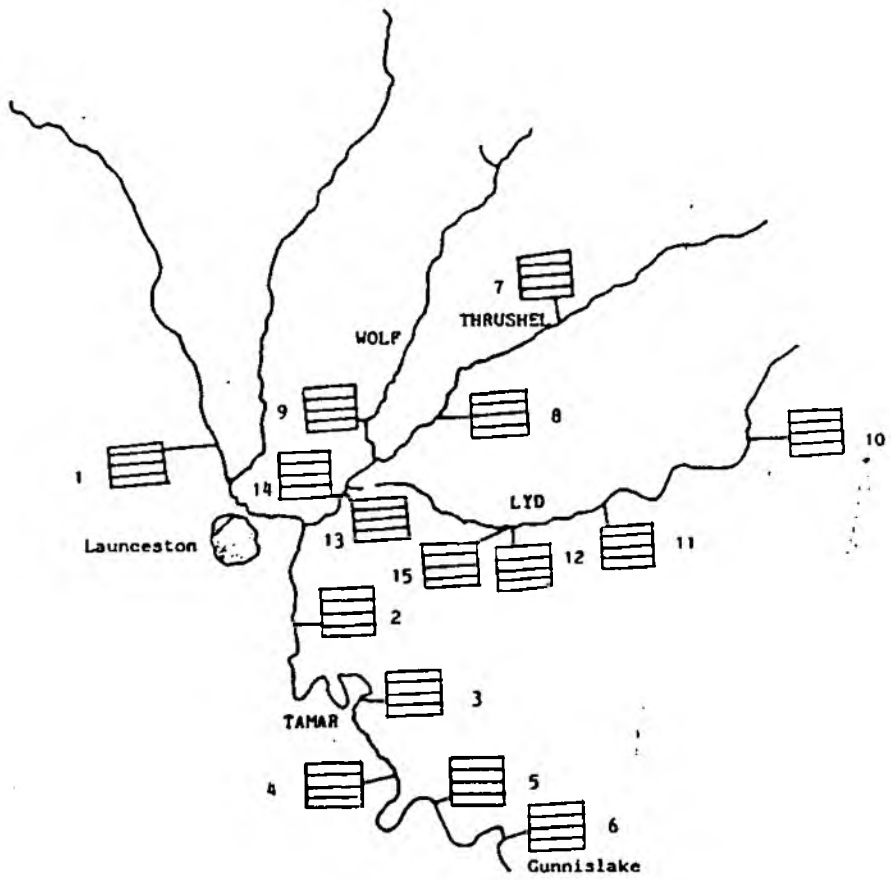
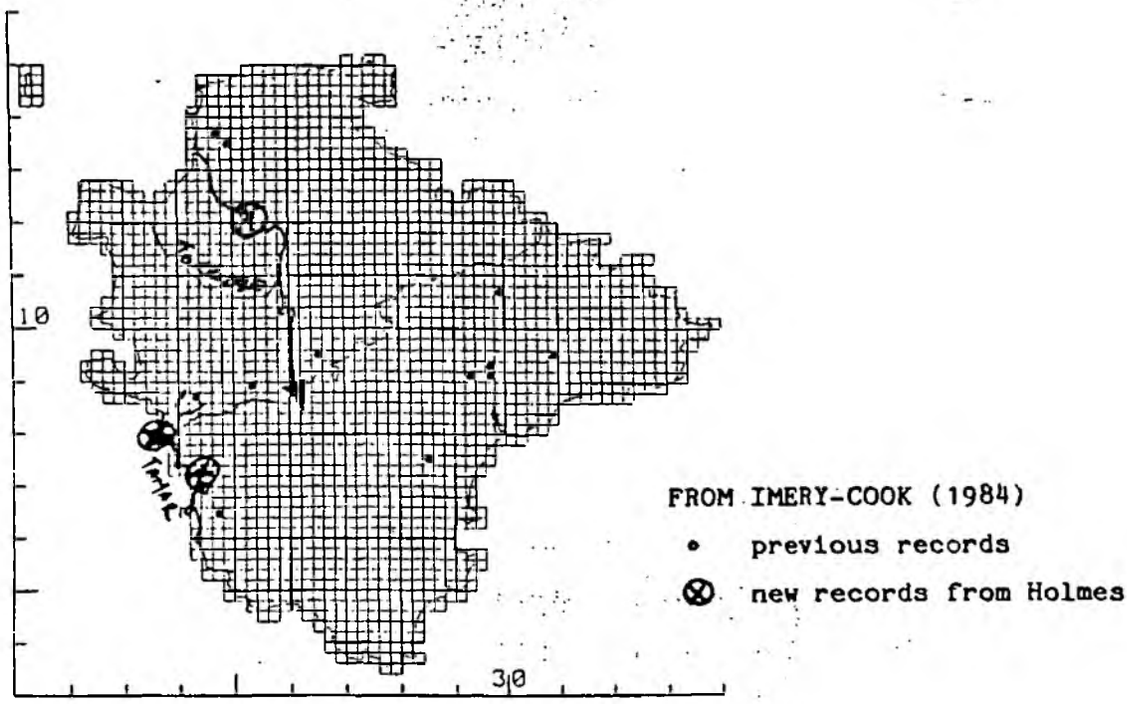


FIGURE D1d Location of sites surveyed on the Tamar catchment for macrophytes by Holmes (1987)

Potamogeton berchtoldii Fieb. Small Pondweed
In ponds and ditches. Scattered over the county and apparently rare, though perhaps overlooked. (12)



Potamogeton x nitens Weber
(*P. perfoliatus* x *gramineus*)
This hybrid has been recorded on one occasion near Beaford.

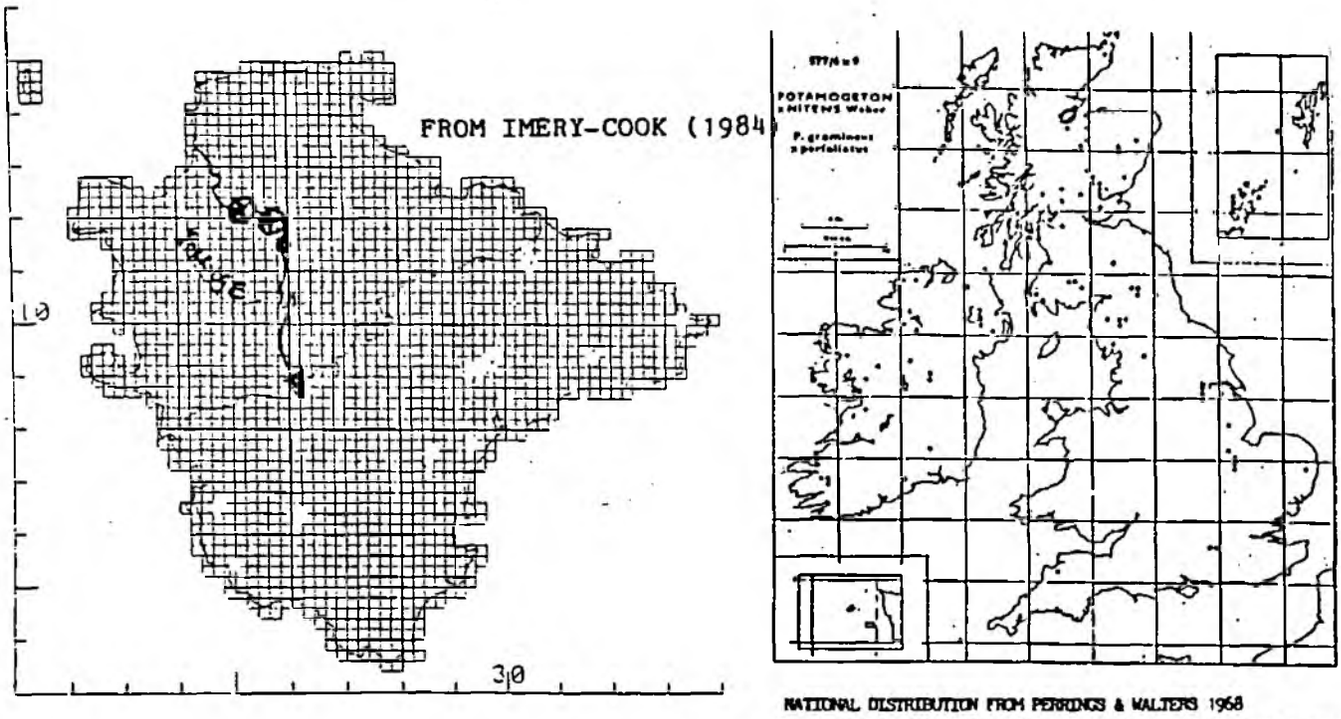


FIGURE D1e Distribution of two rare aquatic plants (P x nitens and P berchtoldii) in Devon. This shows the importance of the Torridge for both species and the Tamar for one.

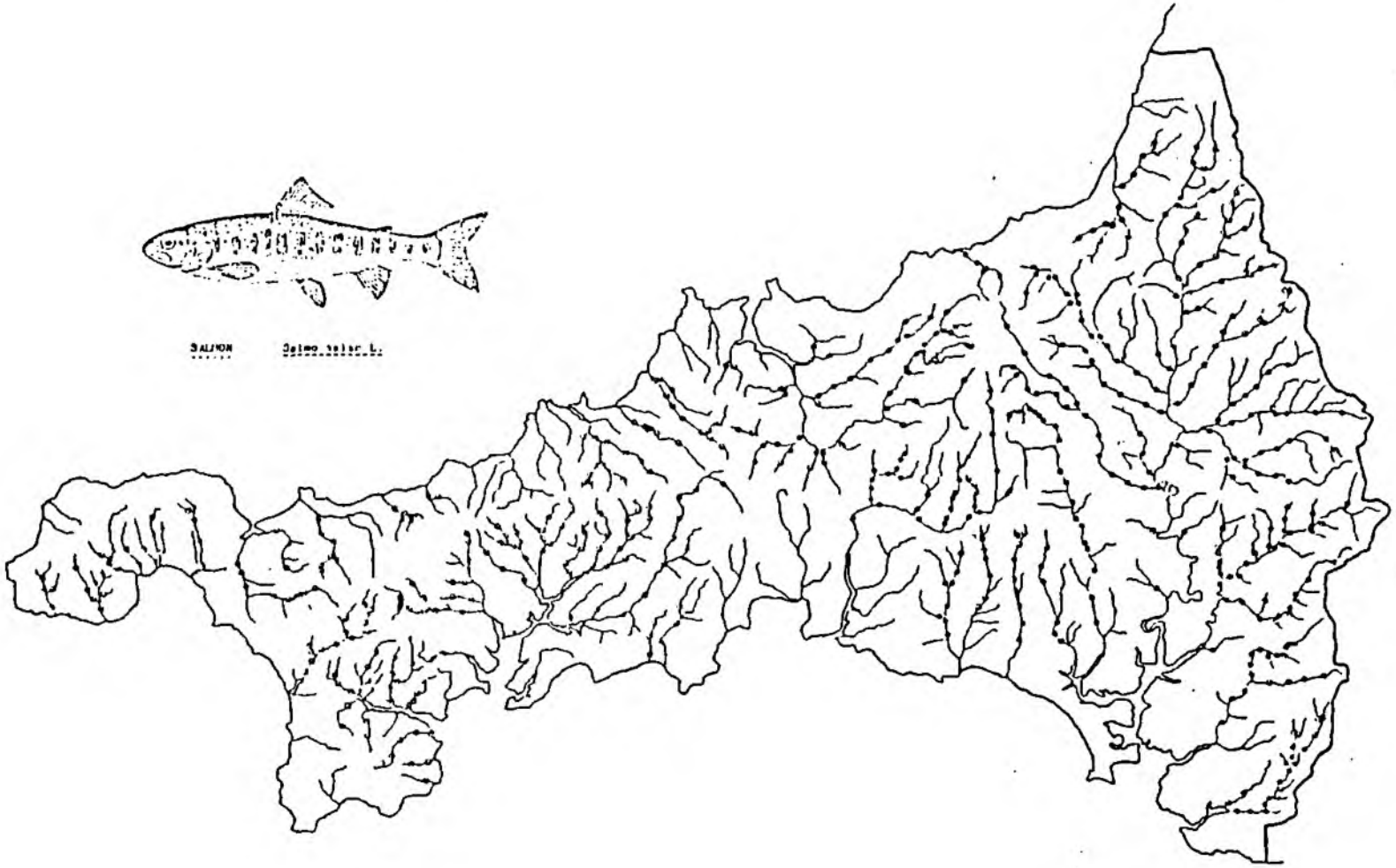
FIGURE D1f Distribution of 10 fish in the rivers of Cornwall and East Devon (1982-1987).

—●— PRESENT

—○— ABSENT

FIGURE 1.

SALMON *Salmo salar L.*



Atlantic salmon *Salmo salar L*

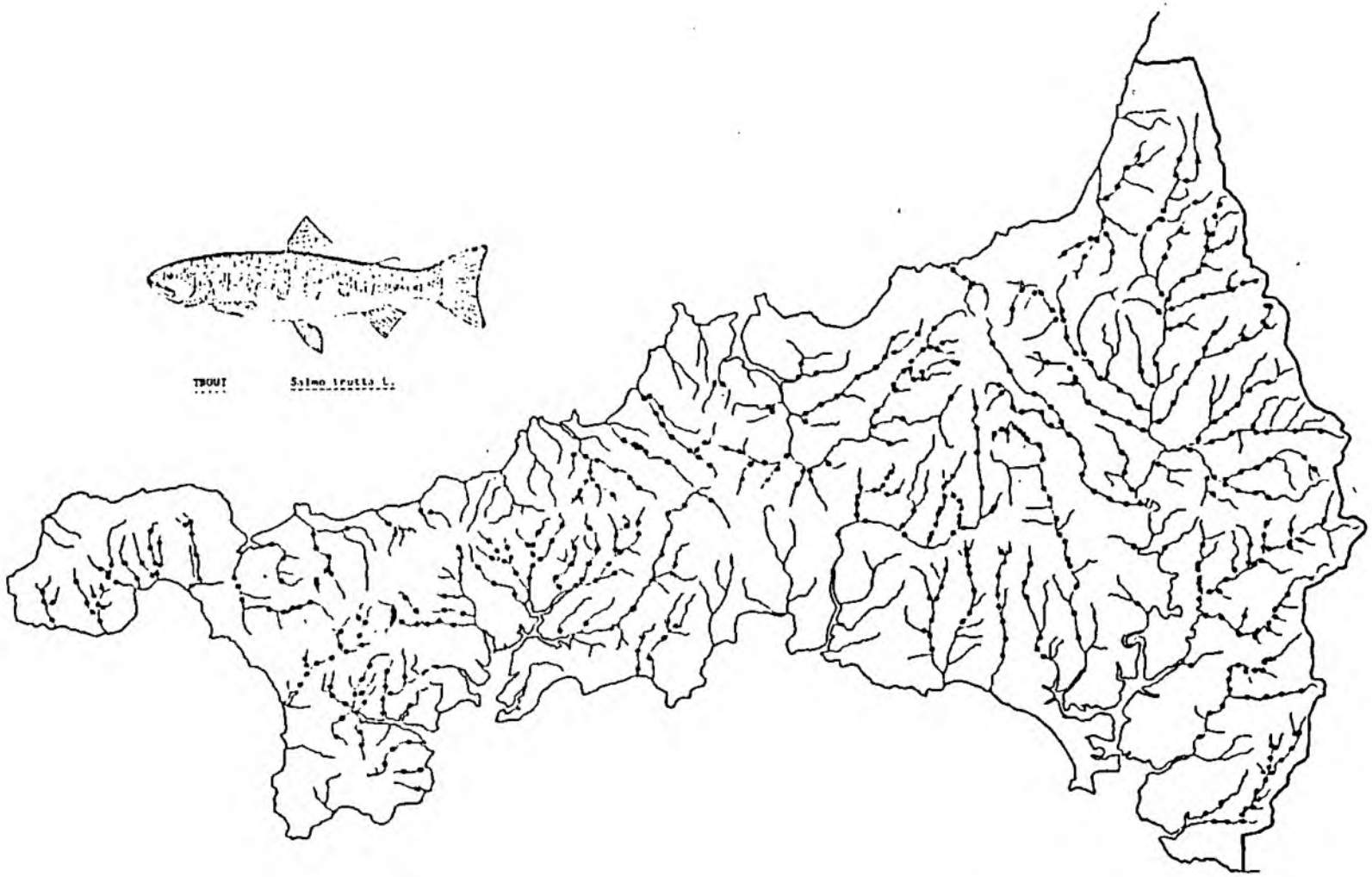
Notes :

- The salmon is seen by many as a symbol illustrating the decline in the quality of the aquatic environment. The species requires cool water of high water quality.

- Salmon spawn in freshwater between October-January. In some late run rivers, salmon have been observed spawning in February. The eggs (4.0mm dia.) are laid in the gravels in running waters. The eggs are fertilized by the cock fish. The large male is often accompanied by sexually active, precocious male parr (average length 11-13cm.), which also partake in spawning. The eggs hatch and the alevin stage is sustained by a yolk sac. In April/May, the free-swimming fry emerge from the redds and establish feeding territories. The fry grow into parr before migrating to sea as smolts. The majority of salmon smolts are 2 years old, with only a small proportion of 1 and 3 year old smolts in each annual migration. The size range of salmon smolts is 12-17cm. Significant growth occurs at sea where there is an abundant food source. The precise feeding grounds used by the South-west stocks are unknown, but salmon do travel long distances to the seas around the Faroes and off the west coast of Greenland. Fish returning to spawn after an absence of 1-sea winter, ie. grilse, range in size from 4-18lbs. Other salmon return as maiden fish after 2 and 3 winters at sea. The majority of salmon die after spawning, but some survive the downstream migration as kelts, to spawn a second or even third time. Multiple spawned fish are not common in rivers of the South-west.

FIGURE 2.

TROUT Salmo trutta L.



Brown trout/Sea trout Salmo trutta L

Notes :

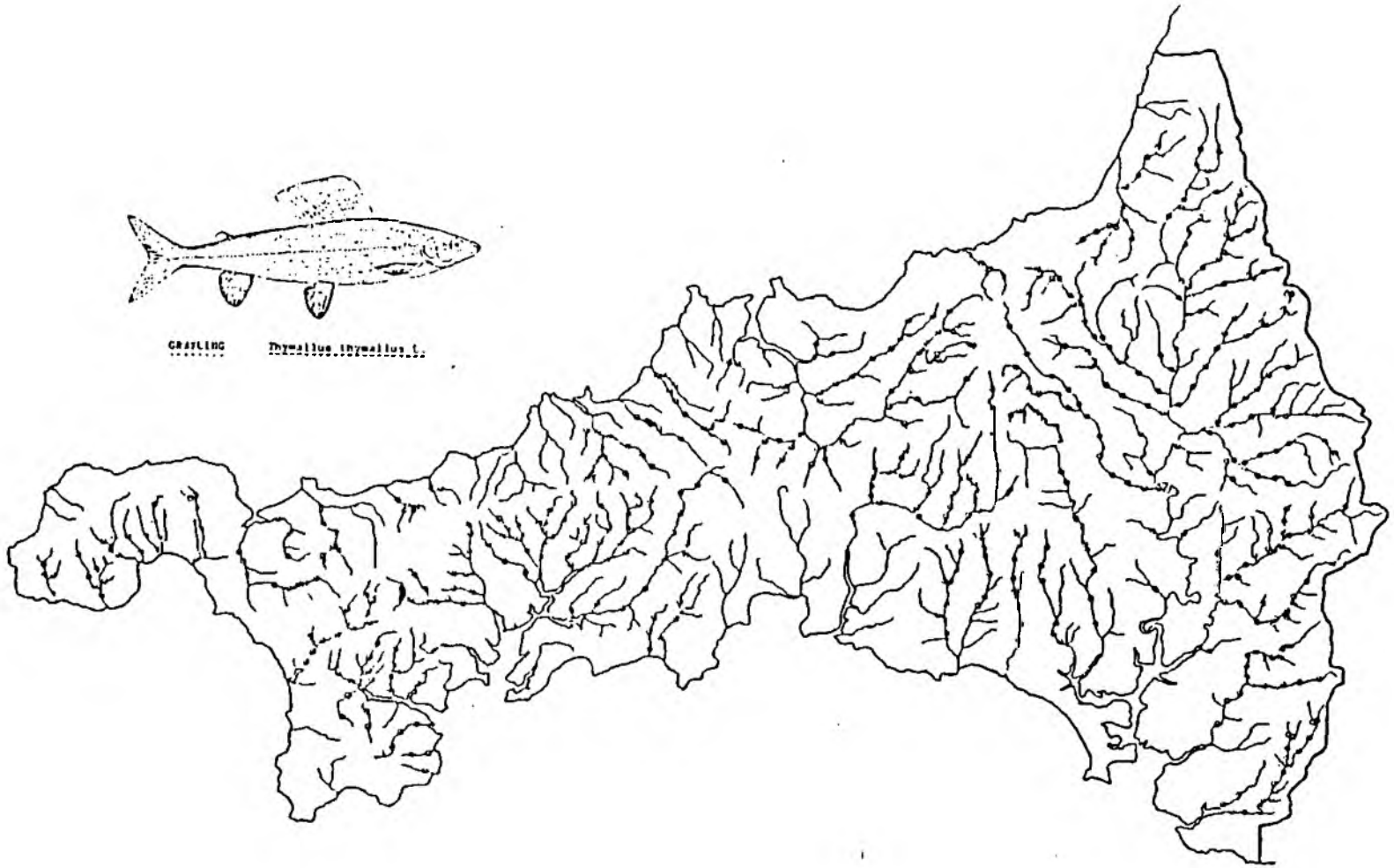
- The species exhibits two extremes of life history stategy, which result in a migratory and non-migratory form. The sea trout constitutes the anadromous component and the brown trout the resicent component. However, the two forms are indistinguishable at the fry and parr stage. Only at the smolt stage can the migratory component be recognized.

- Trout require cool water of relatively high water quality and consequently suffer from pollution, deterioration in water quality/habitat and misuse of the water resource.

- Trout spawn in the winter months from October-December. The eggs (4.0mm dia.) are laid in redds in running waters. The fry emerge from the gravel after approx. 400-450 degree-days, (average size 1.8cm.). The young feed on small crustaceans and insect larvae. The adults can mature as early as 2-3 years. The resident trout population remain in freshwater, feeding, growing and spawning throughout their lives. In rivers of the South-west, resident trout will live to 8-9 years old. The migratory component has a freshwater phase of 2-3 years before it migrates to sea for the first time as a smolt. The duration at sea varies from 10 weeks to 24 months before the fish returns to spawn as a maiden, ie. at the school peal, 1+ or 2+ maiden stage. Post-spawning survival is high among adult sea trout and as a result multiple spawned fish are common. Sea feeding is local and within inshore waters. The food source is primarily fish and large crustaceans.

FIGURE 3.

GRAYLING Thymallus thymallus L.



Grayling Thymallus thymallus L

Notes :

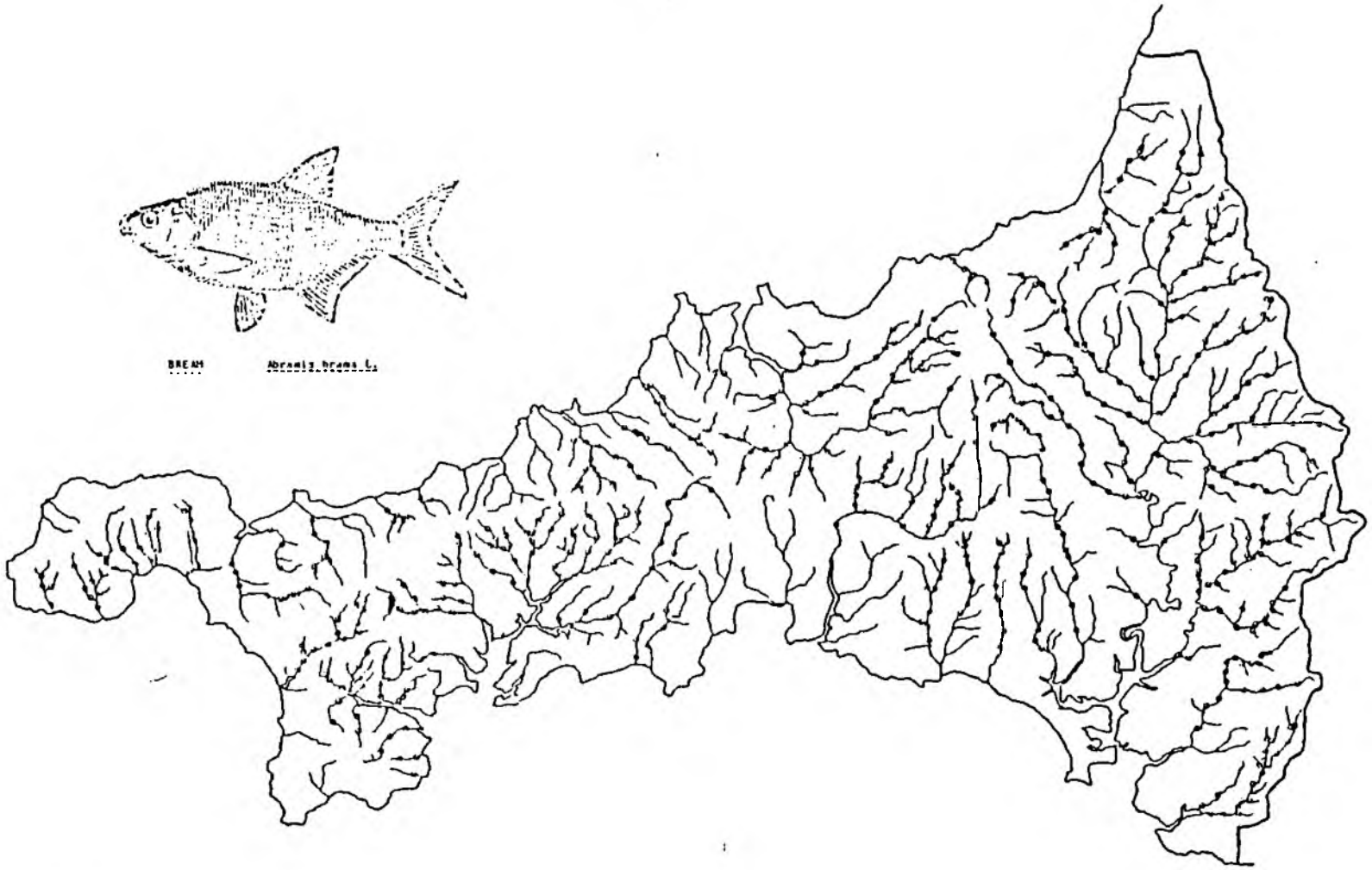
- The grayling has an elongated, but stout body with a small head and small teeth in both jaws. The dorsal fin is high, with numerous rays. An adipose fin is present and the caudal fin is forked.

- The grayling is essentially a riverine species and is found in clean, cool, well-oxygenated waters. It feeds mainly on benthic fauna, but will also feed on insects at the surface.

- Grayling spawn on gravel shallows between March-May. The yellow eggs (3.6mm dia.) are laid in shallow redds in running waters. The fry hatch after 20-30 days. Growth is rapid and the fry can reach 7-12 cm. in their first year. The young mature at 3-4 years, ie. approx. length 20-35 cm.

FIGURE 4.

BREAM Abramis brama L.



Bream Abramis brama L

Notes :

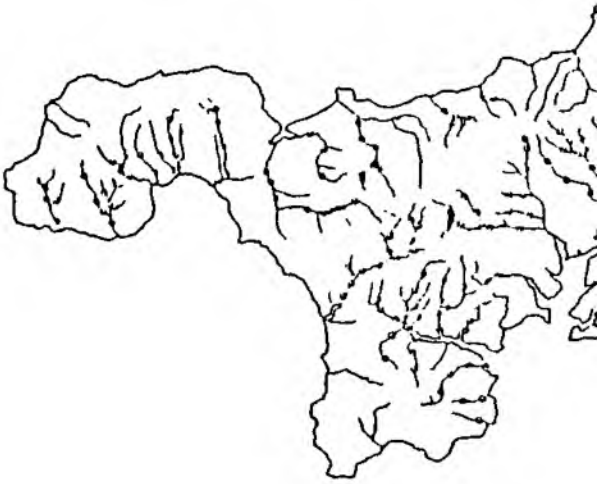
- The bream is a deep bodied fish and is compressed laterally. The head is comparatively small, with mouth ventral. The scales are small with 51-60 scales in the lateral line. The anal fin origin is beneath the rear of the dorsal fin, its base is long with 24-30 branched rays, and its outline is strongly concave. The back of the fish is dark brown or greyish in colour, while the sides of the adult and juvenile fish are golden and silver respectively.

- Bream inhabit slow-flowing rivers, lakes, ponds and canals. A shoaling species which usually feeds, in schools on the river bed, on a diet of insect larvae, worms and molluscs.

- The adults spawn in May-July among dense vegetation, often in shallow water and at night. The yellow eggs (1.5mm dia.) adhere to the weeds and the fry hatch in 3-12 days. The young mature after 3-5 years, ie. approx. length 20-40 cm.

FIGURE 5.

MINNOW Phoxinus phoxinus L.



Minnow Phoxinus phoxinus L.

Notes :

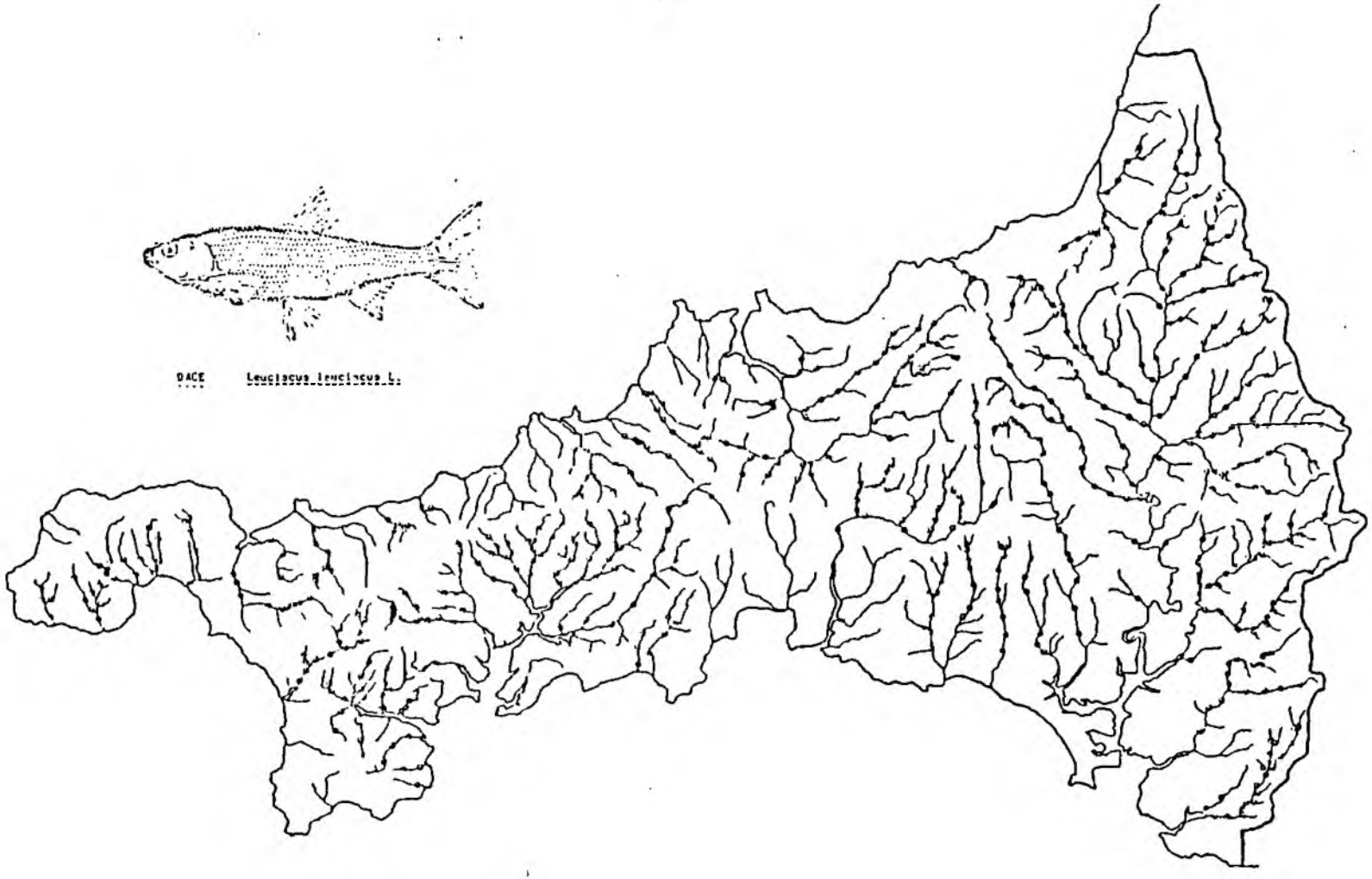
- The minnow is a small slender-bodied fish with short-based rounded dorsal and anal fins. The scales are minute and the lateral line is short and interrupted to form an incomplete line. The back and upper sides are coloured olive brown and ventrally whitish. There are numerous brown and black blotches along the sides, which sometimes merge to form stripes. Young fish are lighter. Males become brightly coloured during the spawning period.

- Typically a fish of clean and moderately fast-flowing waters, it is also found in stony lakes. It schools at or near to the surface in summer and retires to the deeper water in the winter.

- Minnows spawn, between April and early July, on gravel shoals just downstream of a riffle. The yellow eggs (1.5mm dia.) are attached to the stones and hatch in 5-10 days. The young mature after 2-3 years, (adult length 6-10 cm.)

FIGURE 6.

DACE Leuciscus leuciscus L.



Dace Leuciscus leuciscus L.

Notes :

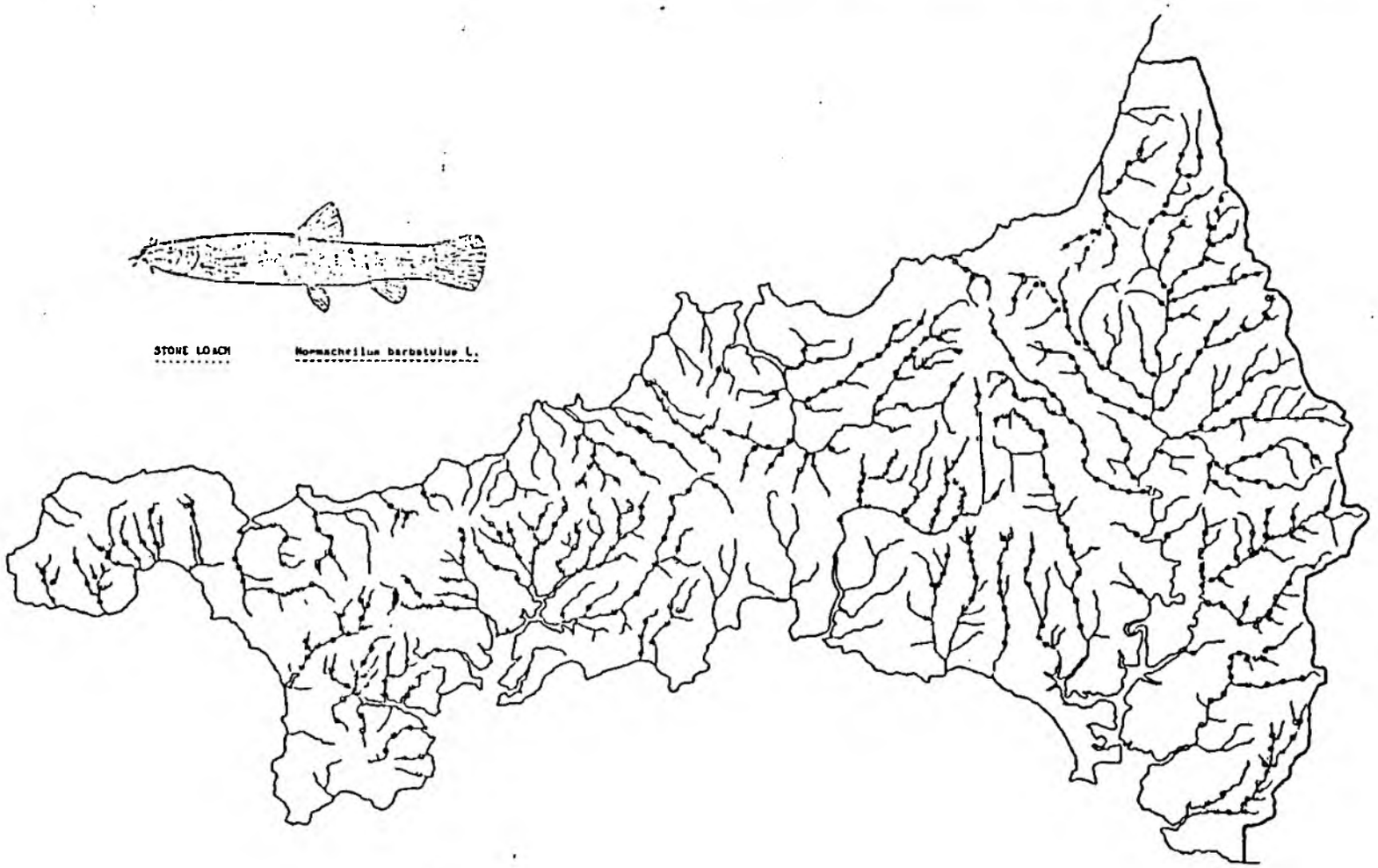
- The dace is a rather slim-bodied fish with a narrow head and small mouth. The scales are large and silvery, 46-51 scales along the lateral line. The outer edge of both the dorsal and anal fins is concave. Coloration: greenish olive dorsally, silvery sides and silver-white ventrally. The fins are greyish, but the pectorals, pelvics and anal fin can be yellow-pale orange.

- The dace is typically found in the middle reaches of rivers and in streams, but also in lakes and lowland rivers at lower densities. The species requires moderate current and clean water. It is usually present in large shoals and it feeds mainly on invertebrates, particularly the larvae and adults of aquatic insects.

- Dace spawn between March-May, often at night and usually on gravel shallows downstream of a riffle. The pale orange eggs (1.5mm dia.) take about 325 degree-days to develop. The young mature in their second year; adult length 15-25 cm.

FIGURE 7.

STONE LOACH Nemacheilus barbatulus L.



Stone loach Nemacheilus barbatulus L

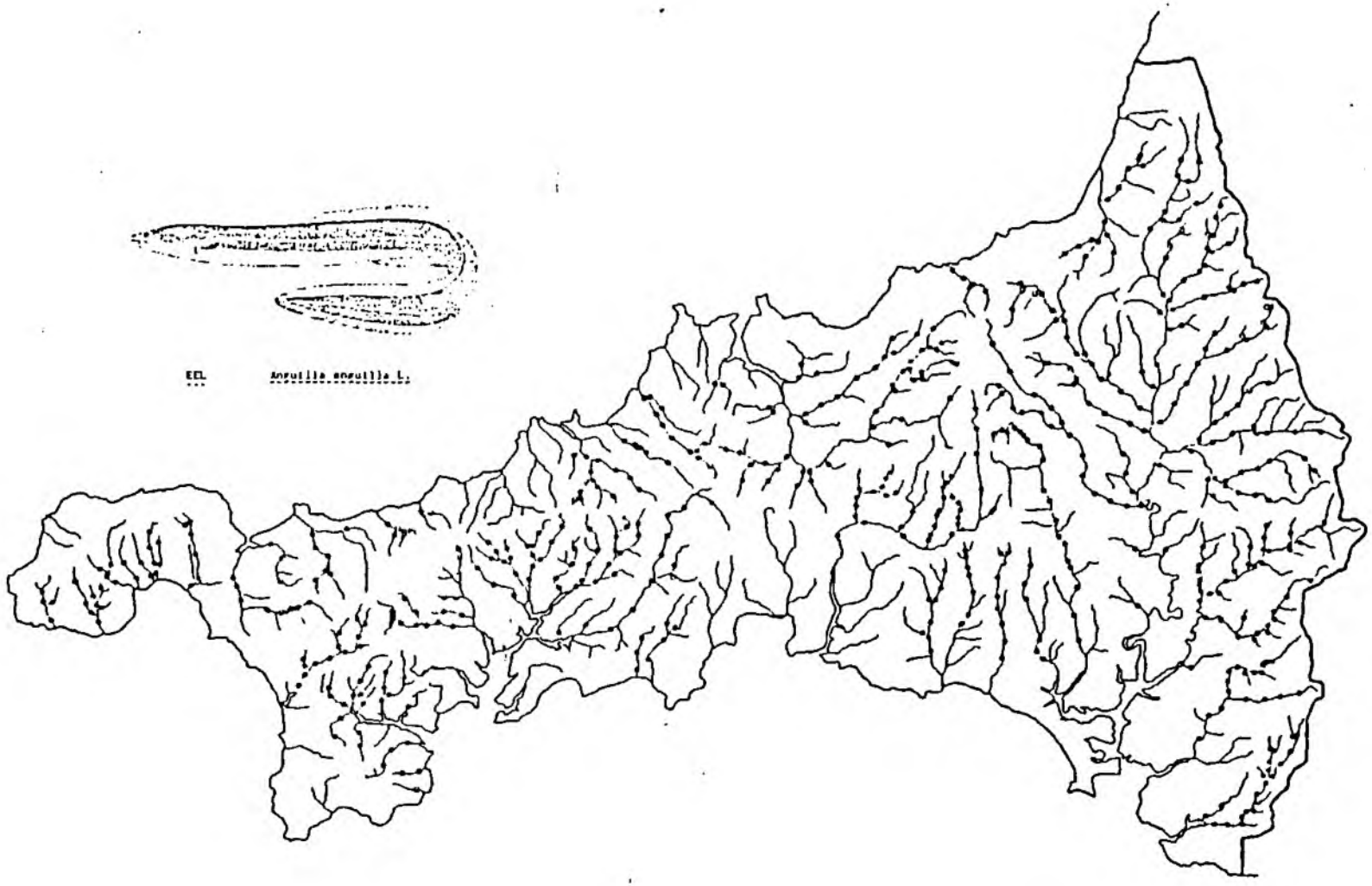
Notes :

- The stone loach is slender bodied, with a cylindrical anterior body and a flattened tail. The head is rounded and there are six barbels around the mouth. There is no spine beneath the eye.

- The stone loach is an inhabitant of stony streams and rivers, but it is also found lakes with gravel shores. A nocturnal fish that spends the daytime hidden under stones and in dense weed-beds. It feeds on benthic invertebrates, mainly crustaceans, insect larvae and worms.

- The stone loach spawns from April to June. The pale yellow eggs (0.5mm dia.) are shed in several batches and are attached to weeds and stones in running water. The eggs hatch in 14-16 days, at temperatures from 12-16°C. The young mature after 2-3 years, ie. approx. length 8-12 cm, and may live to 7-8 years old.

FIGURE 8.



Eel Anguilla anguilla L

Notes :

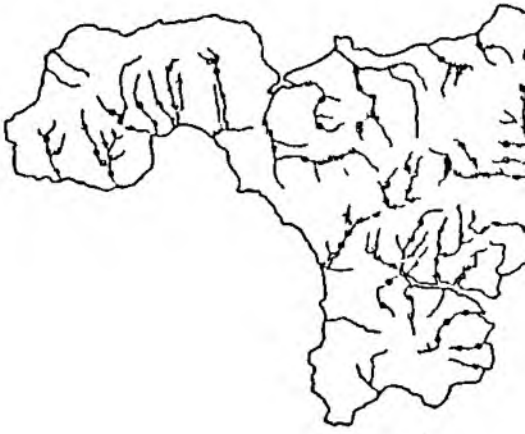
- The eel has an elongated, cylindical body. Minute scales are embedded in the skin. It has one pair of pectoral fins, but no pelvic fins. The long dorsal and anal fins merge with the tail fin. The coloration of the freshwater stage is muddy-brown dorsally and yellowish/golden on the sides and ventrally. As the eel reaches maturity the back remains dark and the belly becomes silvery. The young eel, ie. elver, is almost transparent when it first enters freshwater.

- The eel is common and an inhabitant of almost all types of freshwater and estuarine environments. The species survives in the sea and exhibits a catadromous life cycle.

- The eel is believed to breed in mid-Atlantic during March-June. Clear eggs (1.6mm dia.) have only been found in the Sargasso Sea. Leaf-shaped larvae (lepto-cephali) are transported to Europe on the ocean currents, taking approx. 3 years. The larvae metamorphose in the coastal waters before entering the rivers as elvers. The freshwater stage is the feeding and growing phase and as the older eel matures sexually it migrates downstream, returning to the sea. Maturing takes 7-15 years in freshwater. Very few mature eels have been caught in the ocean and certain life history details have to be elucidated. The adults are believed to return to the spawning grounds in the Sargasso Sea.

FIGURE 9.

BULLHEAD Cottus gobio L.



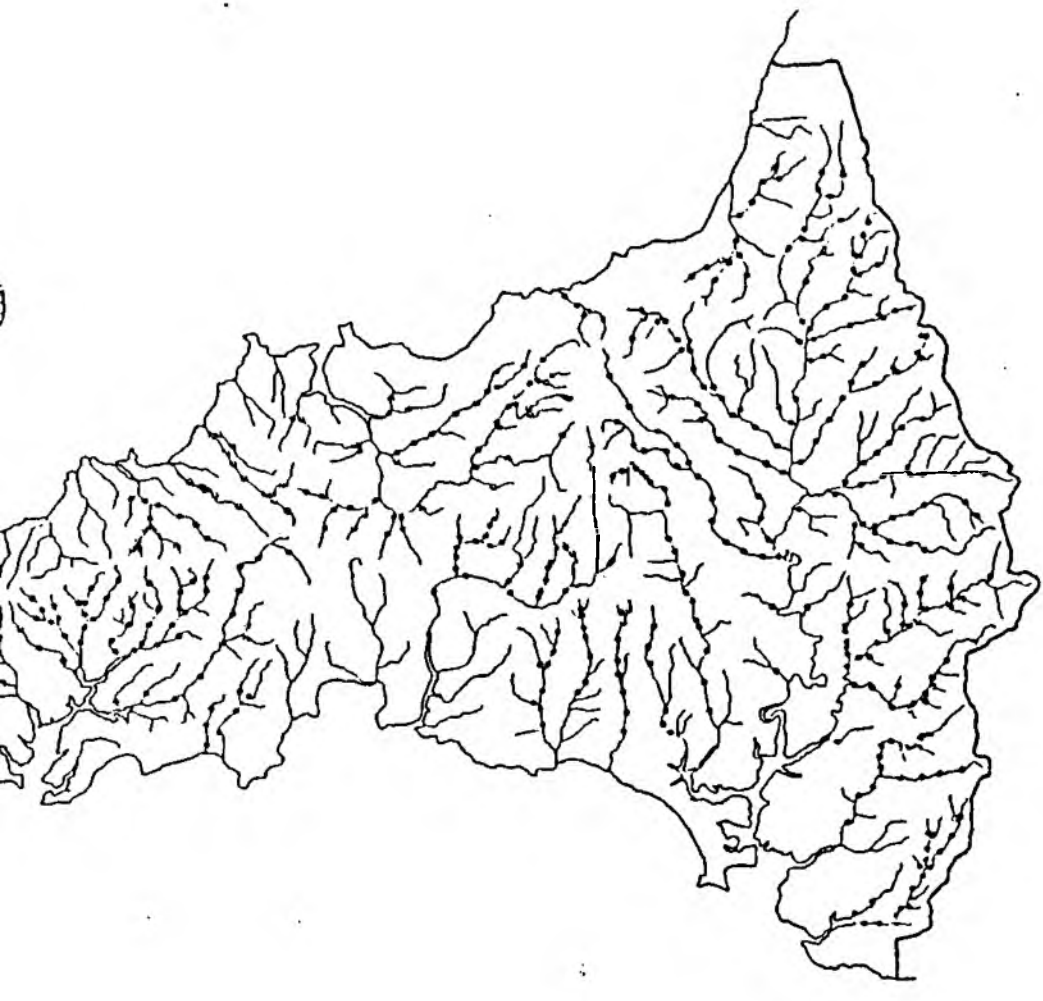
Bullhead *Cottus gobio L*

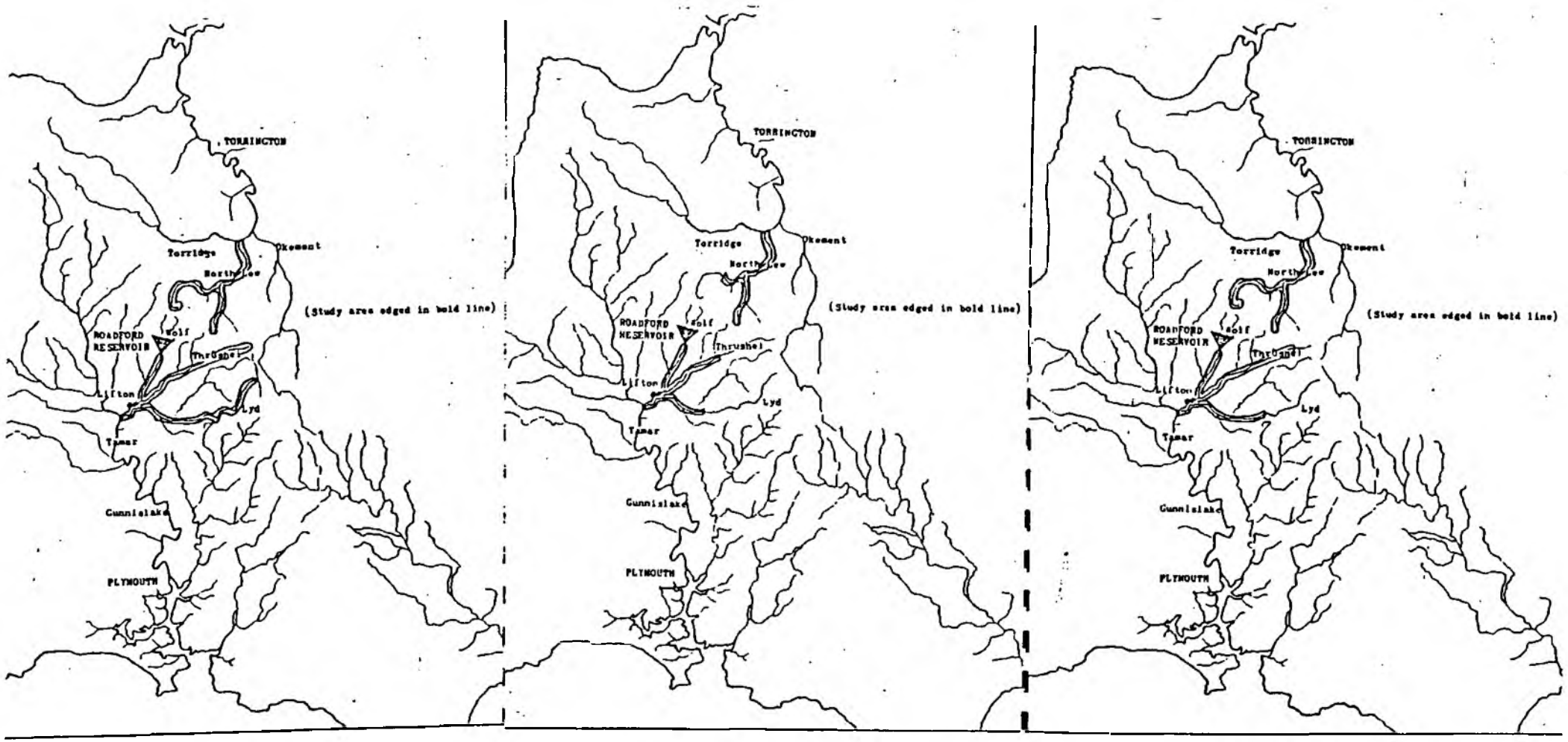
Notes :

- The bullhead is a small freshwater fish with a broad flattened head and a relatively short spine on each pre-operculus. The lateral line continues to the caudal fin, although the pores are not visible beyond the second dorsal fin. The coloration varies enormously and it is dependent on the surrounding habitat. Generally, the dorsal surface is brown or greenish-brown and mottled, while the ventral side is paler.

- The bullhead is found in stony streams/rivers and occasionally large lakes. It is mainly found in shallow waters, but can survive in deep water to 9 metres. It becomes active at night when it forages over the river bed, feeding on crustaceans and insect larvae. During daytime the bullhead hides under rocks and in vegetation.

- The bullhead spawns from March-May in a cavity excavated beneath a large stone. The eggs (2.3mm dia.) are attached in clumps to the underside of the stone and are guarded by the male for 20-25 days until hatching commences. The young become sexually mature in the second year and rarely survive beyond 3 years old.





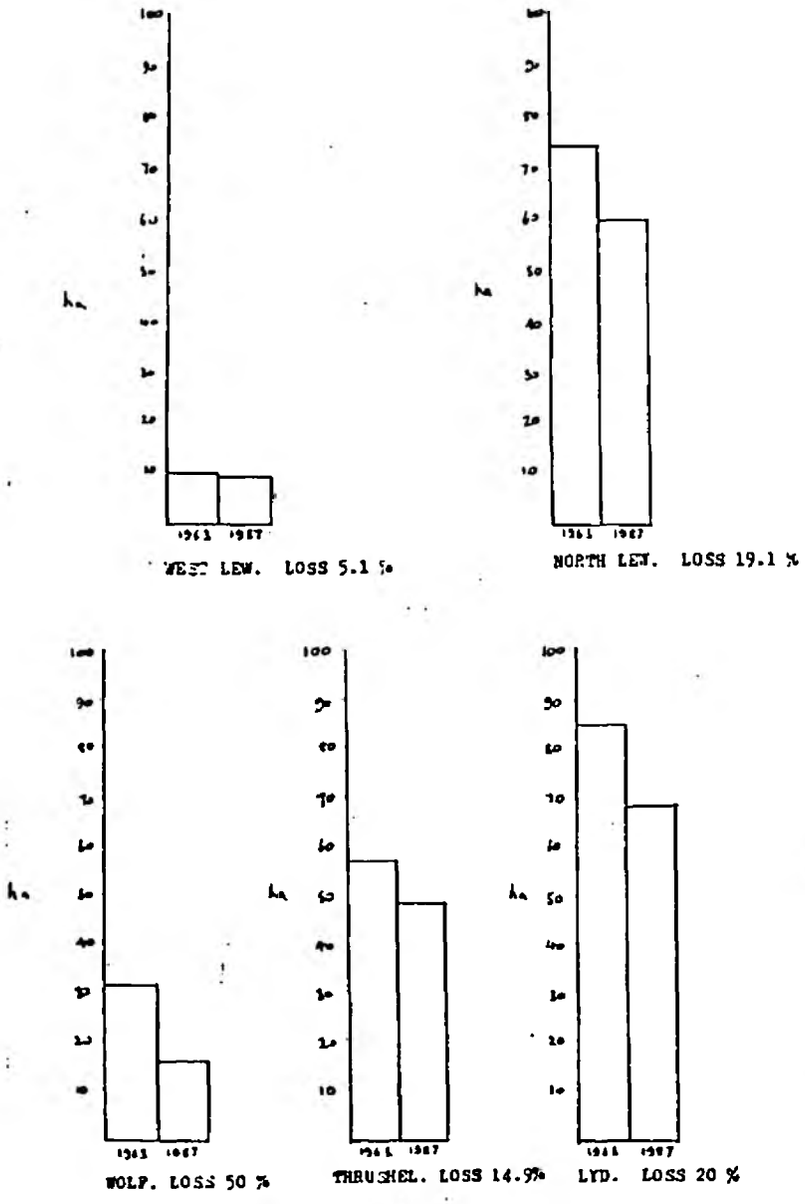
ROADFORD RIVERS STUDY AREA

EXTENT OF RIVER CORRIDOR (CHANNEL & BANKS) SURVEY

EXTENT OF PHASE 1 HABITAT SURVEY

FIGURE D6.2a Extent of survey areas of Heath (1989)

LOSS OF BROADLEAVED WOODLAND IN THE RIVER VALLEYS
FROM 1963 TO 1987 (SEE 2.1 FOR METHOD)



LOSS OF WETLAND/ROUGH GROUND IN THE RIVER VALLEYS
FROM 1963 TO 1987 (SEE 2.1 FOR METHOD)

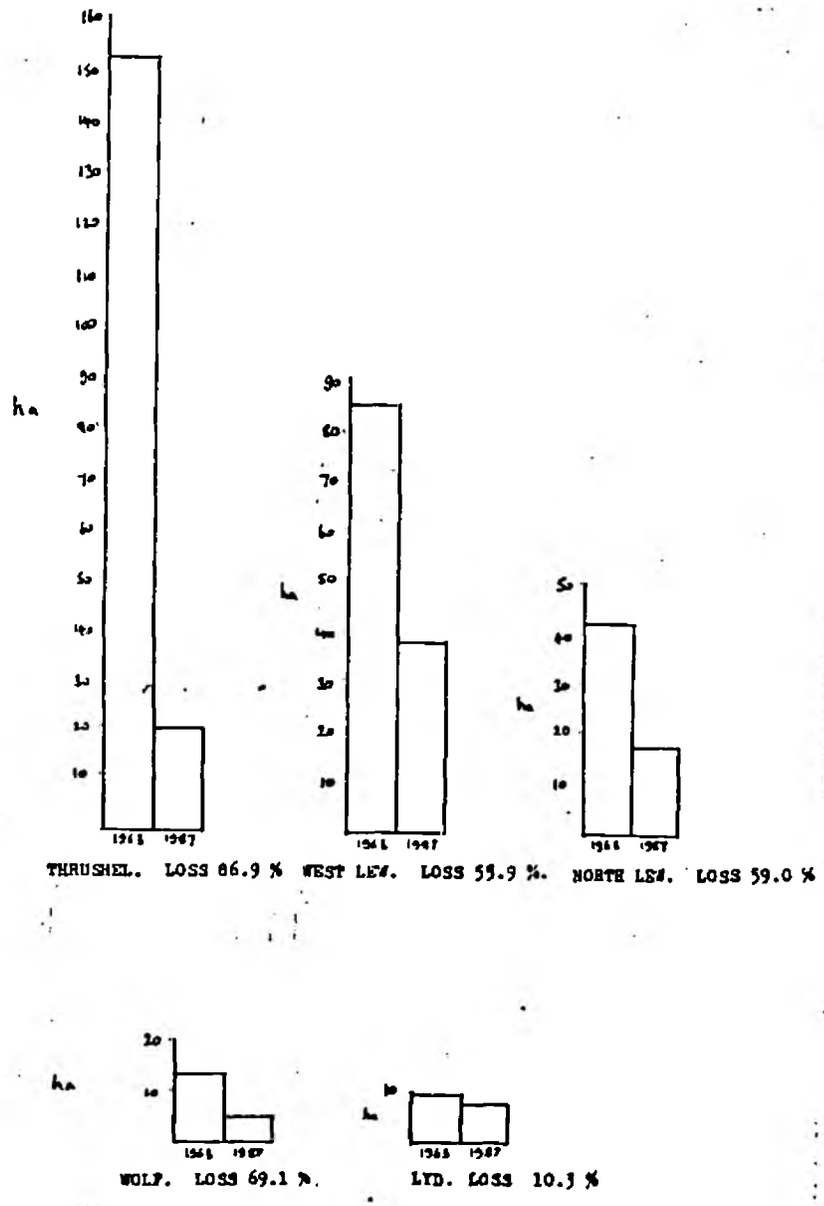


FIGURE D6.2b Land-use and habitat loss in the Lew (Torridge system), Wolf, Thrushel and Lyd (Heath; 1989)

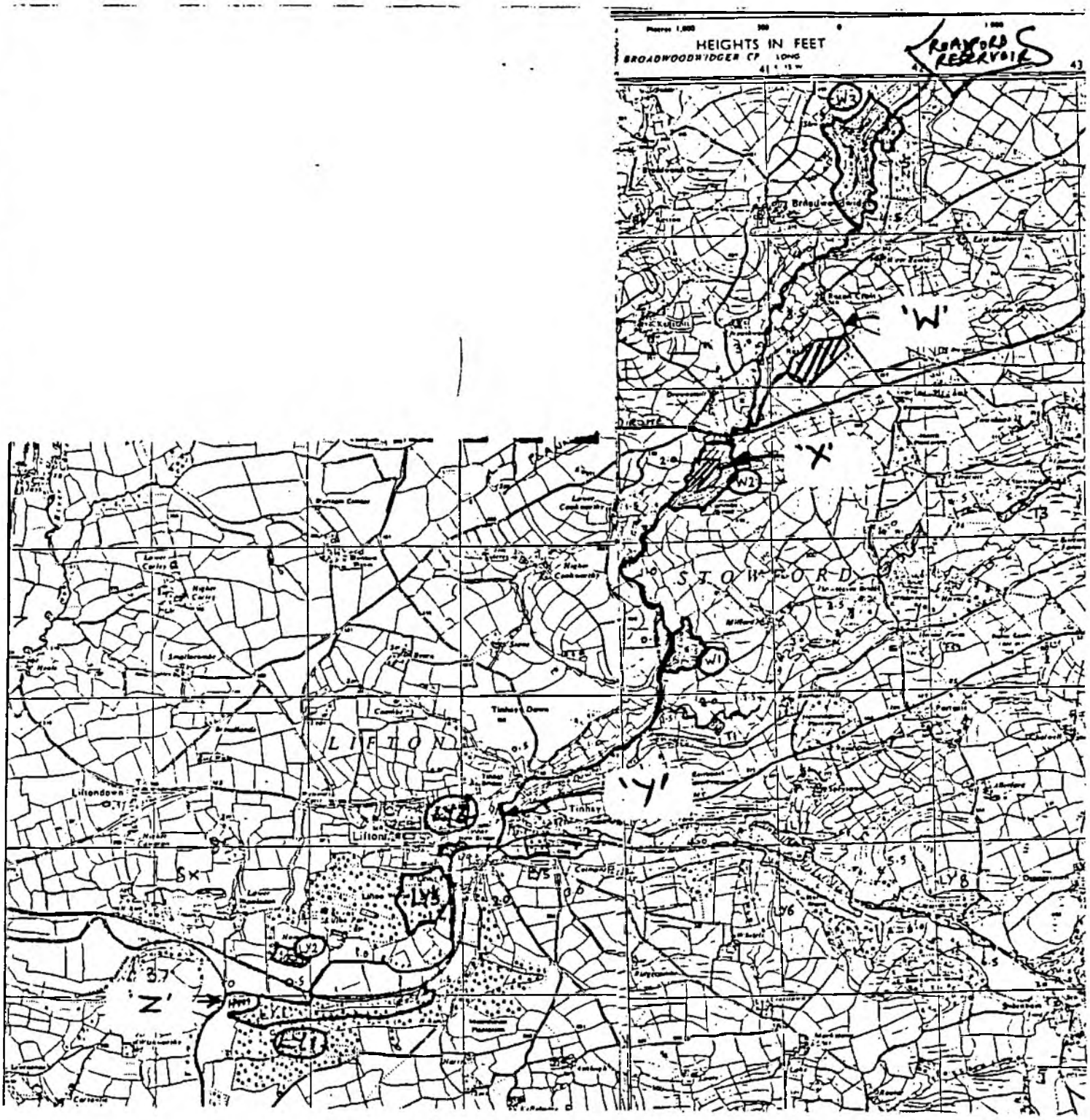
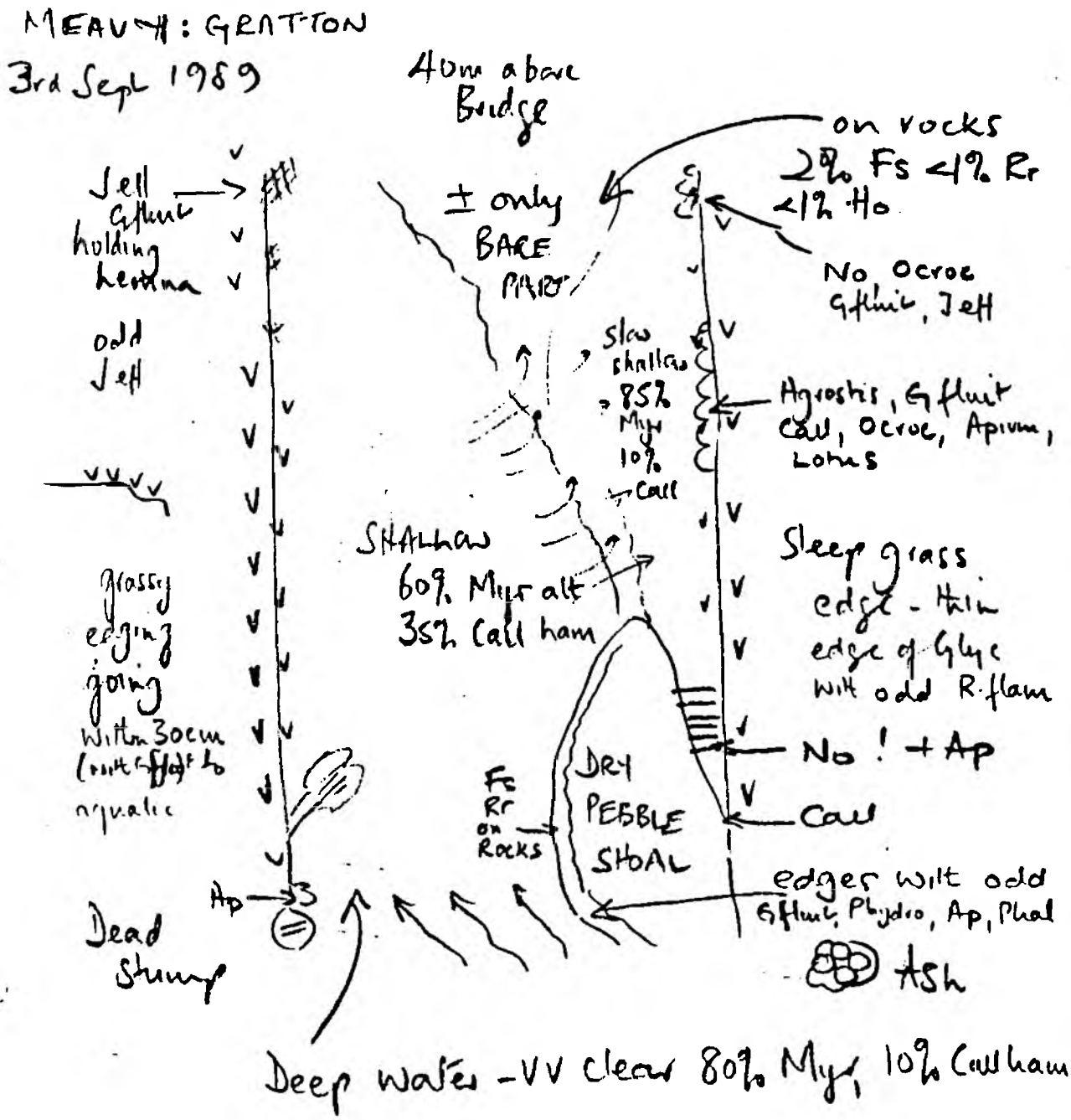
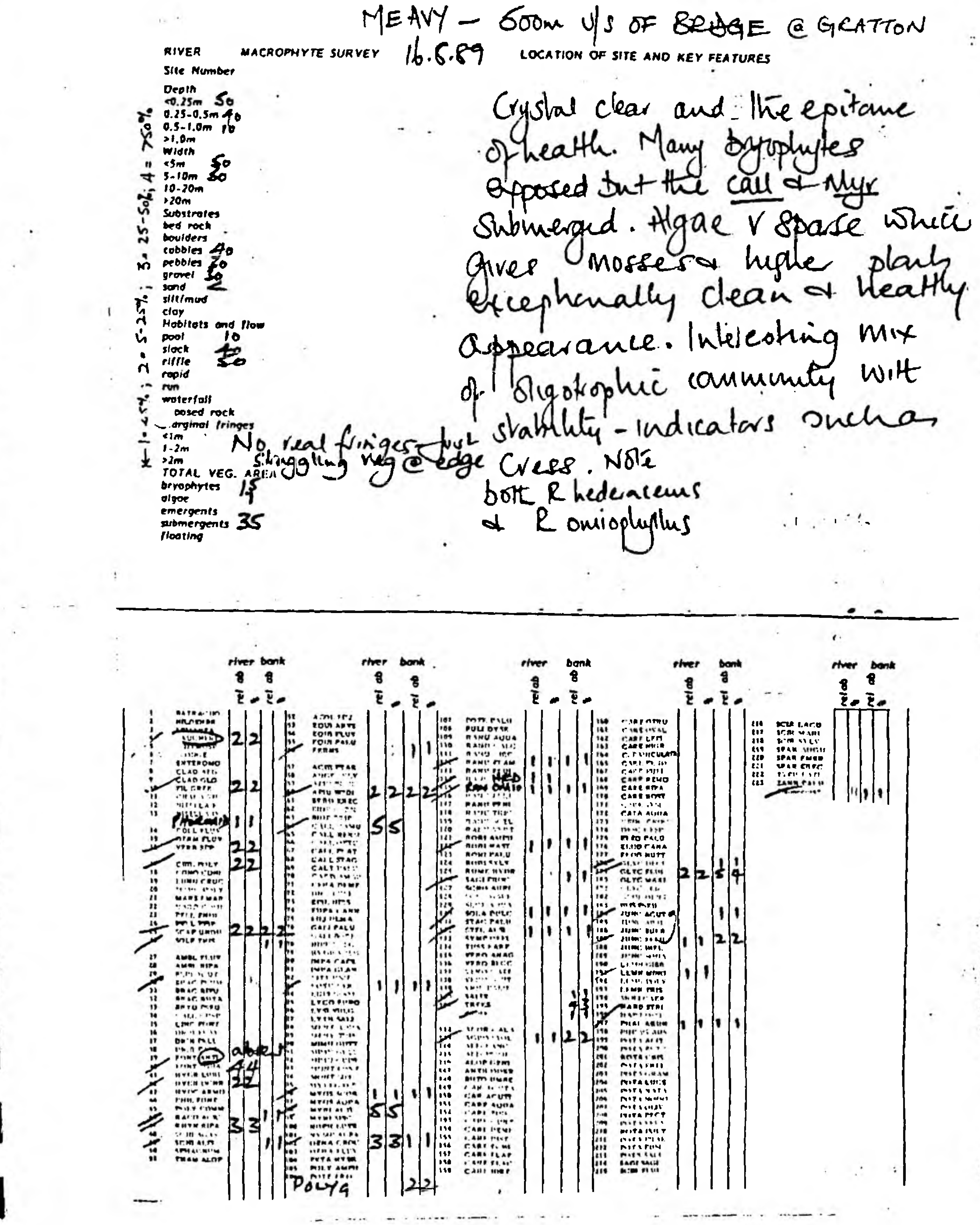


FIGURE D6.2c Location and extent of the seven 'key sites' identified by Heath (1989) in the Lyd sub-catchment - his sites are W1-3 and Ly1-4. W, X, Y and Z are sites identified in in Exeter University's studies - see text for details.



Amazing combination of cobbles & pebbles and accreted VVV clean coarse sand. Superbly clean and healthy plants. Plankton with considerable organic detritus but v clean & no obvious algal filaments in drift

FIGURE D3b Sketch of a 25m stretch of the R Meavy upstream of the Gratton road bridge during the 1989 drought (from Holmes in report of Halcrow to NRA SWRegion). Note variety of species in such a short stretch of river and abundance of rooted aquatics such as Myr alt (Alternate-flowered Water-milfoil) and Call ham (Spanner-leaved Water-starwort). For key see Appendix.



MEAVY – 600m U/S OF BRIDGE @ GRATTON

RIVER MACROPHYTE SURVEY 16.6.89 LOCATION OF SITE AND KEY FEATURES

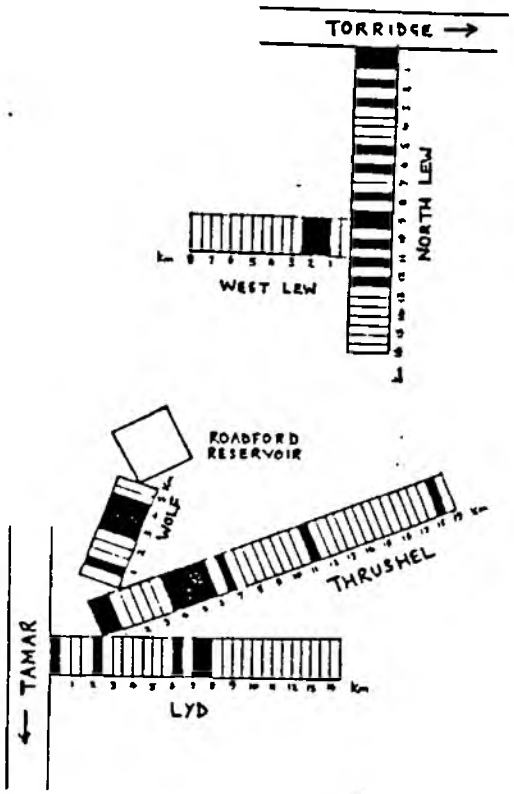
Site Number
Depth
<0.25m 50
0.25-0.5m 40
0.5-1.0m 10
>1.0m
Width
<5m 50
5-10m 50
10-20m
>20m
Substrates
bed rock
boulders
cobbles 40
pebbles 20
gravel 30
sand 2
silt/mud
clay
Habitats and flow
pool 10
slack 10
riffle 50
rapid
run
waterfall
exposed rock
marginal fringes
<1m
1-2m
>2m
TOTAL VEG. AREA
bryophytes 15
algae
emergents
submergents 35
floating

1 = <5%; 2 = 5-25%; 3 = 25-50%; 4 = >50%

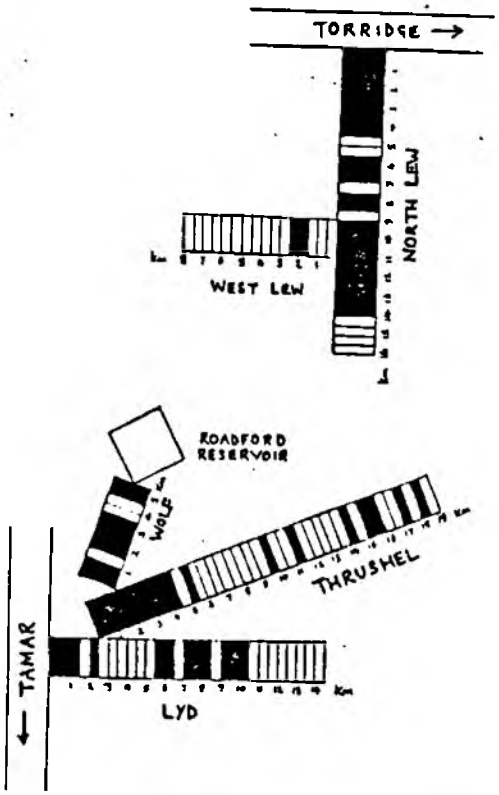
No real fringes but straggling veg @ edge

Crystal clear and the epitome of health. Many bryophytes exposed but the Call & Myr submerged. Algae v sparse which gives mosses & higher plants exceptionally clean & healthy appearance. Interesting mix of oligotrophic community with stability-indicators such as Cress. Note both R hederaceus & R omiophyllus

FIGURE D3c Macrophytes surveyed from a 0.5km length of the River Meavy upstream of Gratton Bridge during the drought of 1989 (from Holmes in Halcrow report to NRA SWRegion). Reference to the key will indicate that for such a long length of river Call hamu (Spanner-leaved Water-starwort) and Myri alti (Alternate-flowered Water-milfoil) are unusually abundant. For key see Appendix.



DISTRIBUTION OF OTTER RECORDS (SPRAINTS AND TRACKS) 1988



DISTRIBUTION OF OTTER RECORDS (SPRAINTS AND TRACKS) 1987

FIGURE D6.3a Details of otter usage in the Lyd catchment determined by Heath (1989).

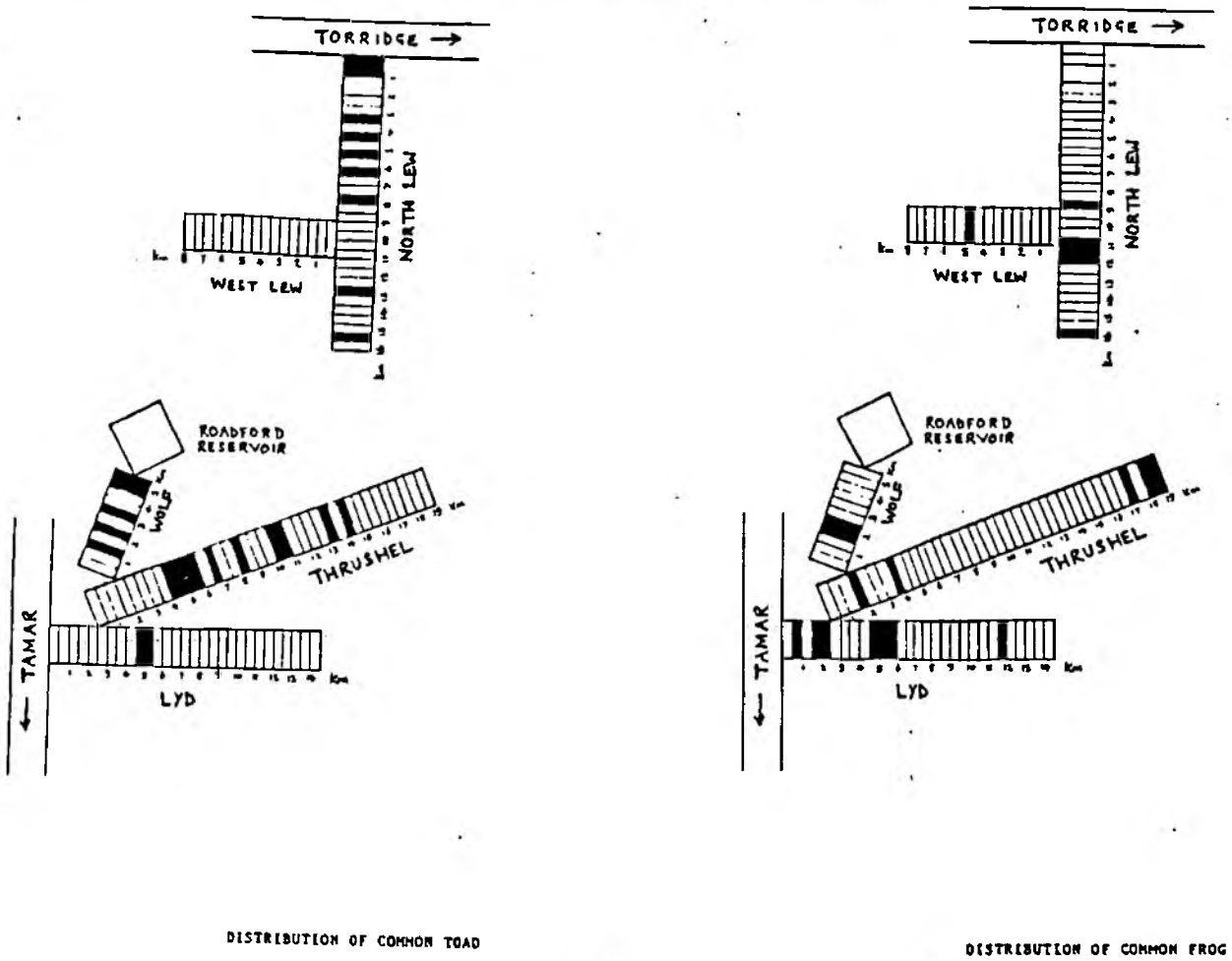
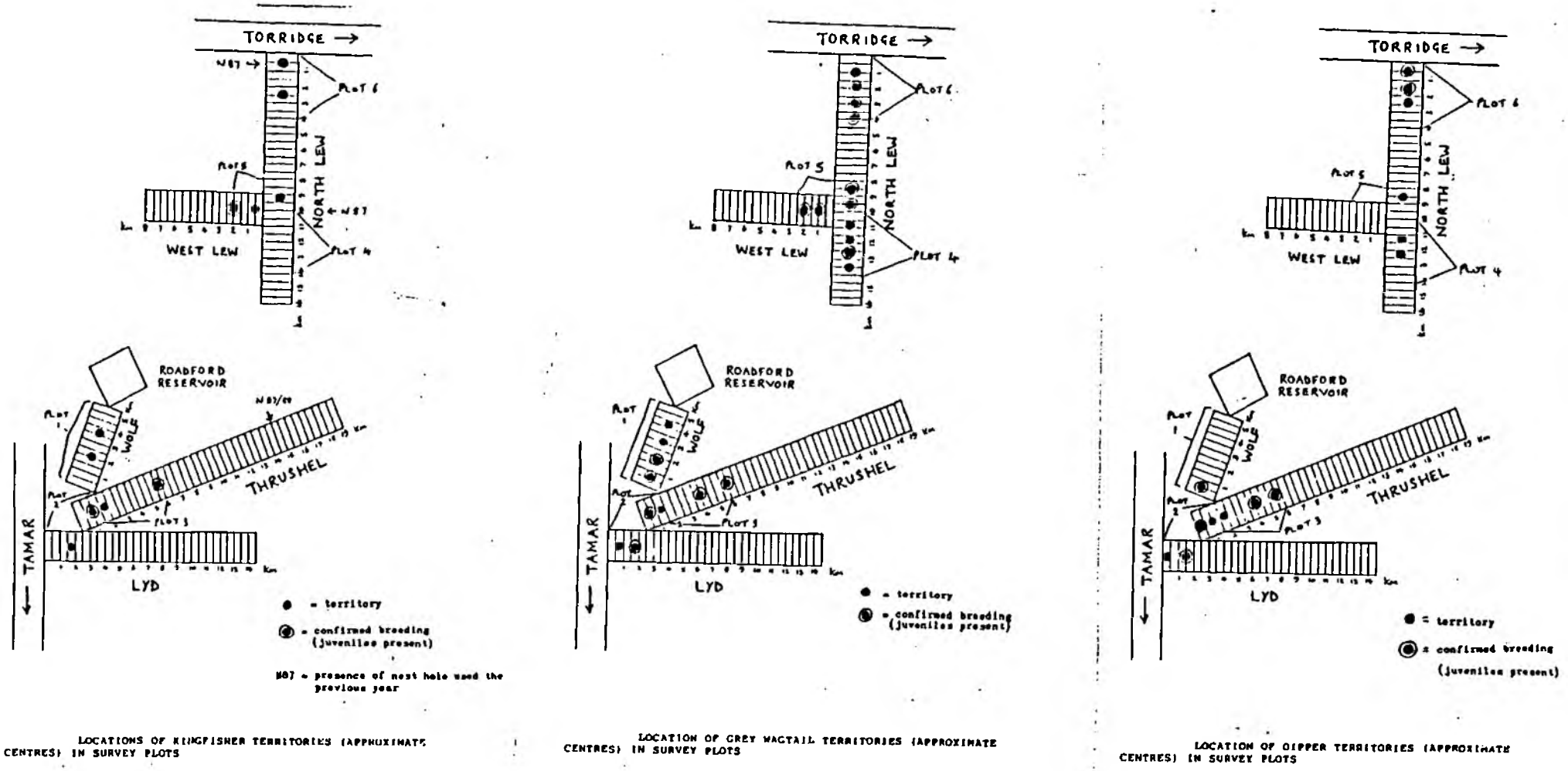


FIGURE D6.4a Distribution of common frog and common toad in the Lyd catchment (corridor) determined by Heath (1989). Note that toads were associated with the river channels but frogs were not.

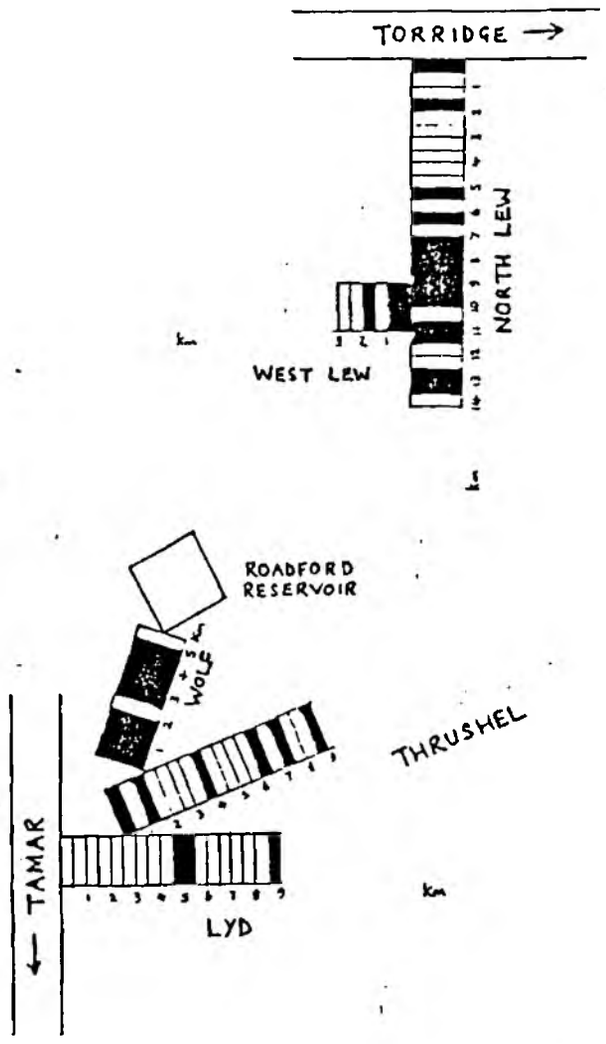


LOCATIONS OF KINGFISHER TERRITORIES (APPROXIMATE CENTRES) IN SURVEY PLOTS

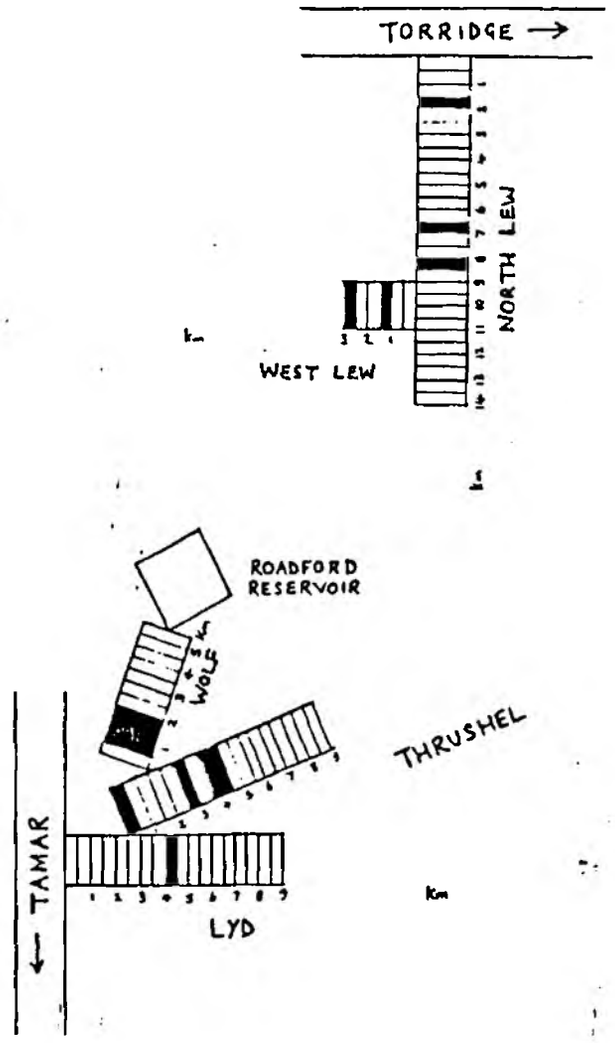
LOCATION OF GREY WAGTAIL TERRITORIES (APPROXIMATE CENTRES) IN SURVEY PLOTS

LOCATION OF DIPPER TERRITORIES (APPROXIMATE CENTRES) IN SURVEY PLOTS

FIGURE D6.5a Breeding distribution of kingfisher, grey wagtail and dipper in the Lyd catchment and the Torridge Lew system as determined by Heath (1989).

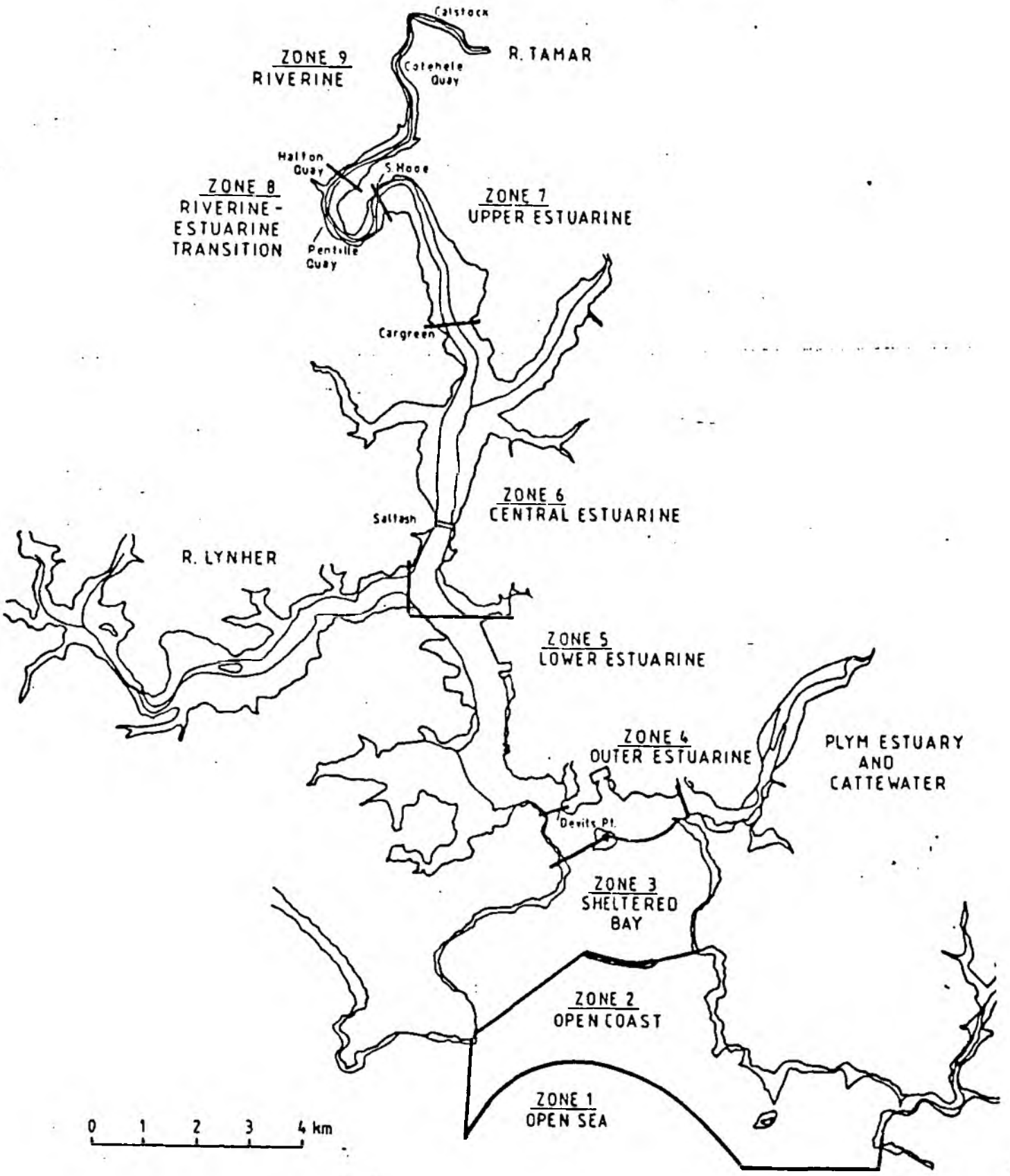


DISTRIBUTION OF SPANNER-LEAVED WATER STARWORT (CALLITRICHE HAMULATA) IN THE RIVER CHANNEL



DISTRIBUTION OF WOOD CLUB-RUSH (SCIRPUS SYLVATICUS) IN THE RIVER CHANNEL

FIGURE D6.7a . Distribution of Callitriche hamulata and Scirpus lacustris in the Torridge Lew and Lyd system (from Heath; 1989).



Major ecological zones in the Tamar and Plymouth Sound

FIGURE D9a Zones of ecological interest identified in the OPRU survey and literature review of the Tamar estuary (from OPRU; 1986).

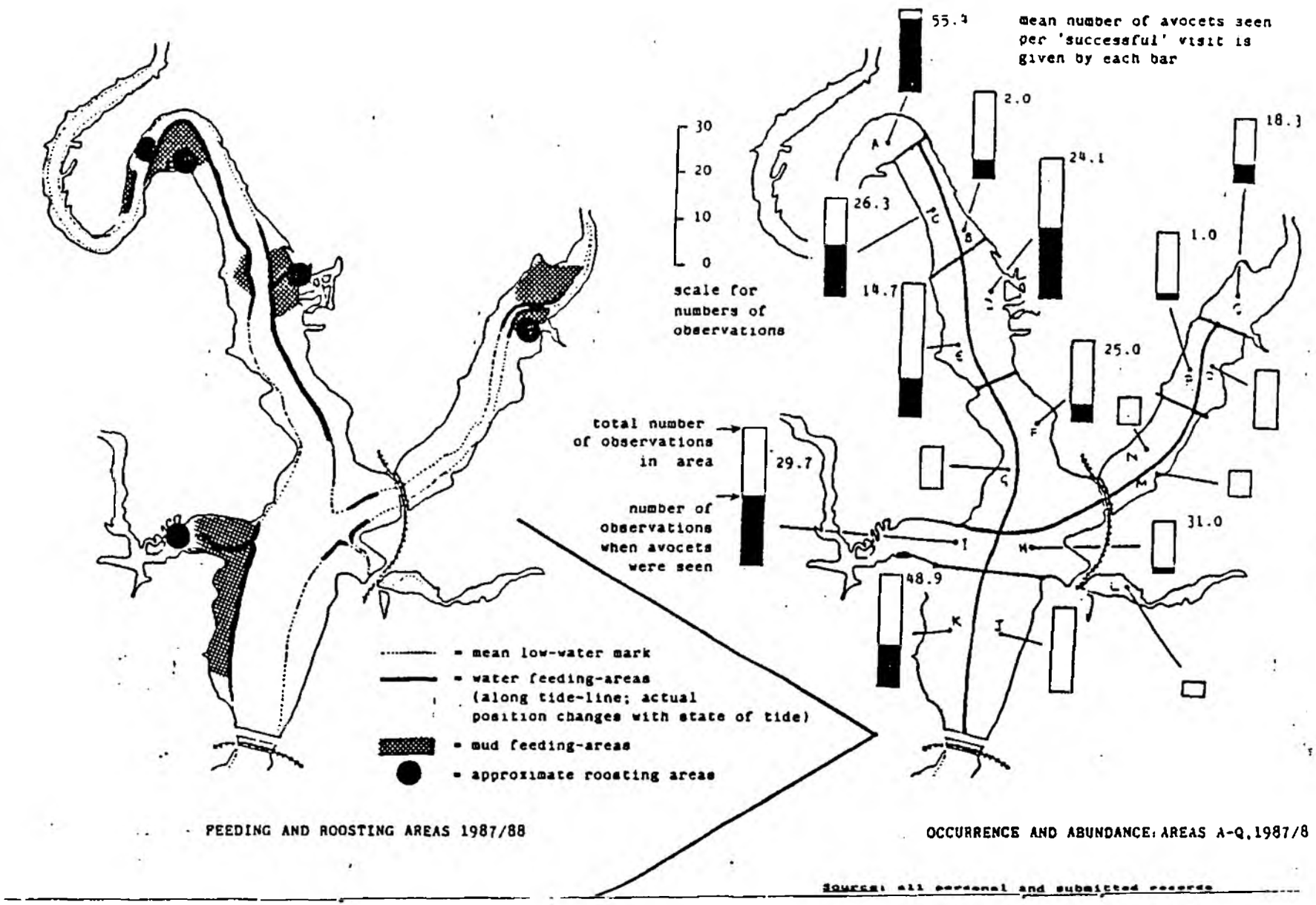
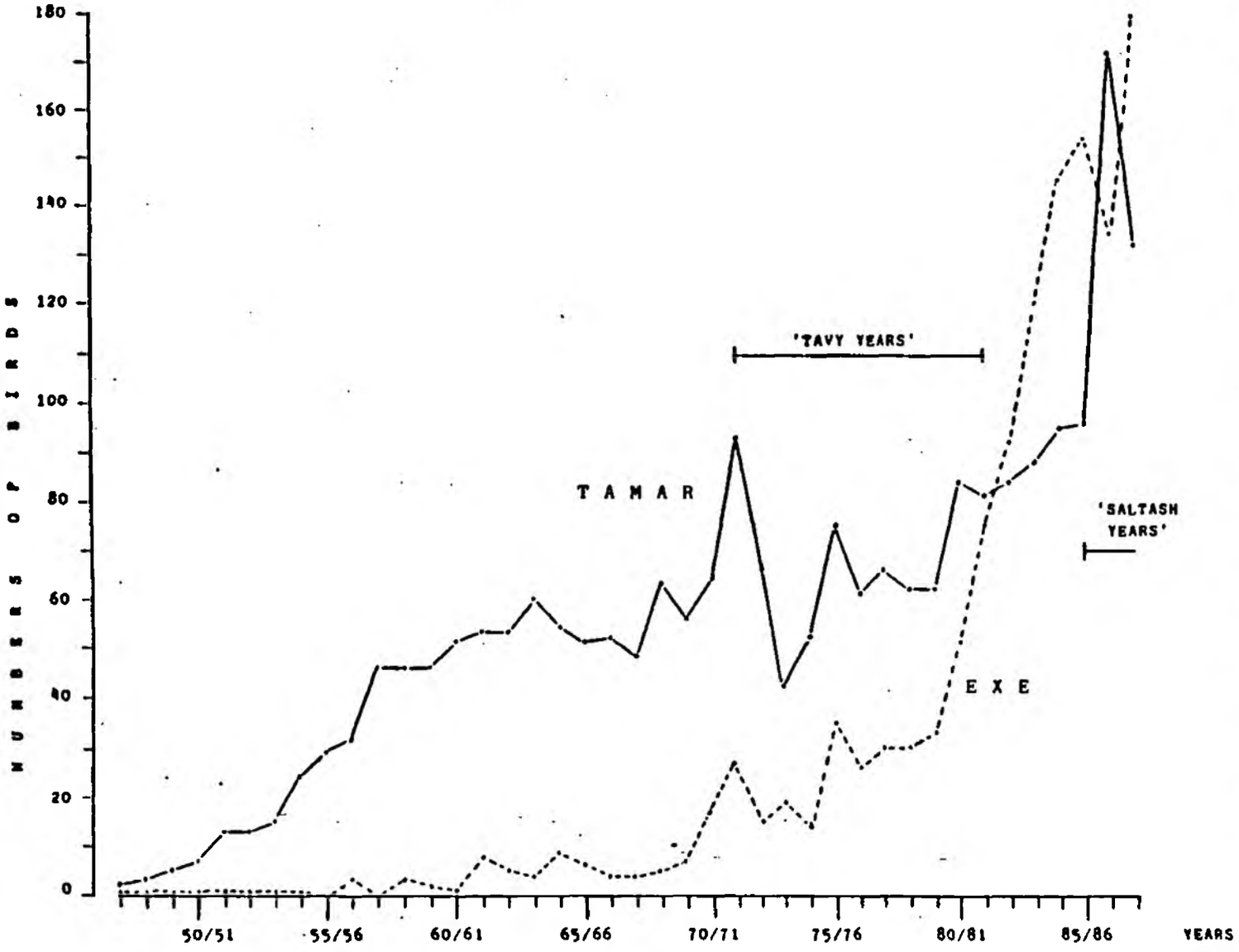


FIGURE D9b Main areas on the Tamar where avocets are observed and noted to feed and roost (from Reay; 1988).



PEAK NUMBERS OF AVOCETS RECORDED FOR EACH WINTER (1947/48 - 1987/88) FOR THE TAMAR AND EXE ESTUARIES

Source: Penhallurick (1969)
The Devon Bird Report
Birds in Cornwall
present study

FIGURE D9c Avocets and the Tamar - 1947 to 1988 (from Reay; 1988).

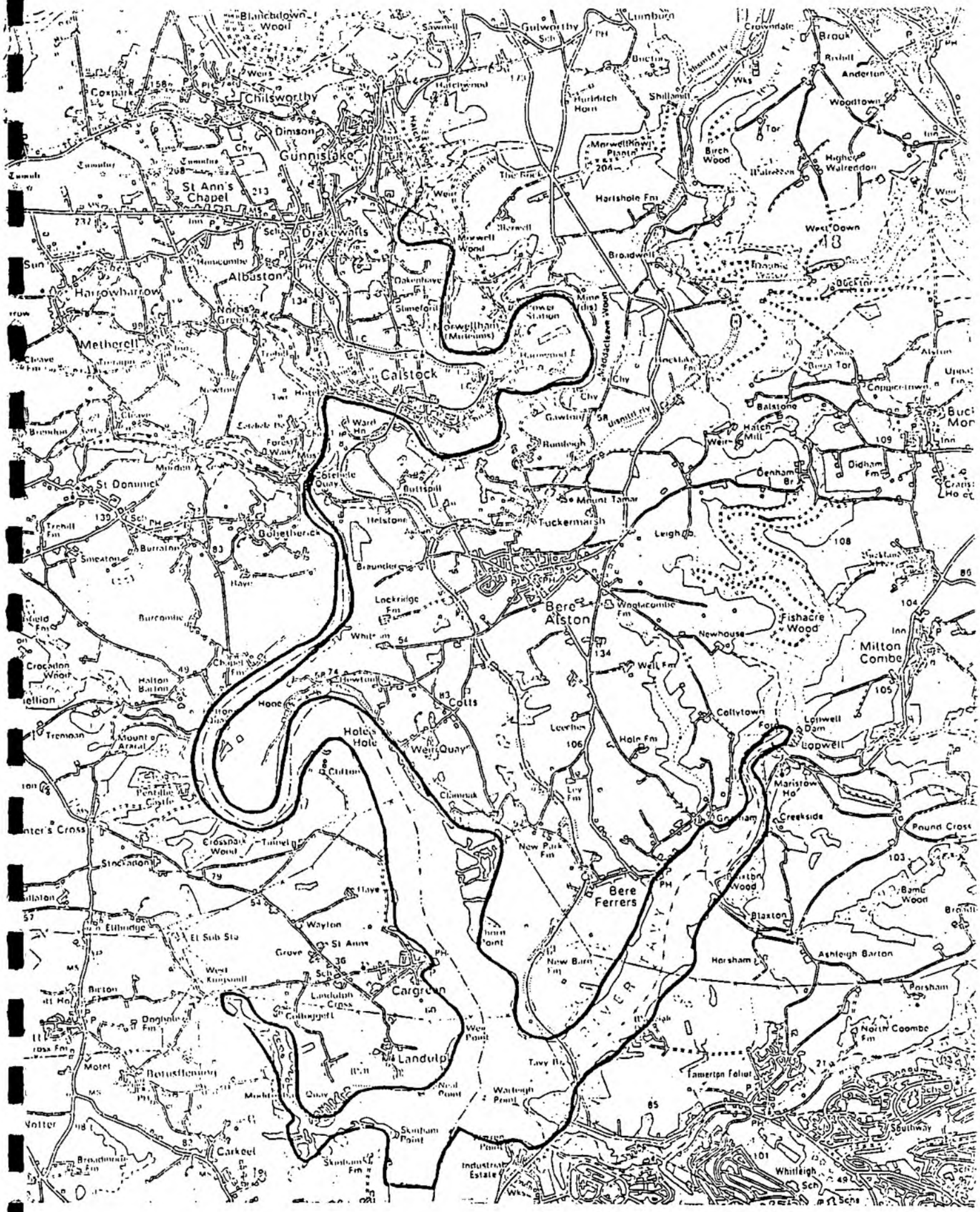


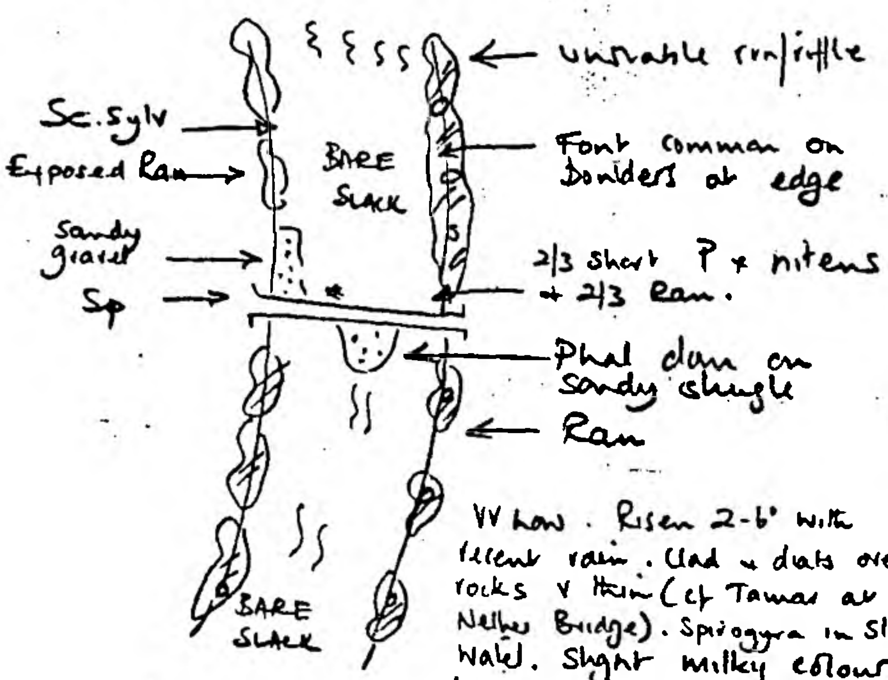
FIGURE D9d Possible boundary of the Tamar SSSI (Subject to further survey and consultation with owners and authorities).

RIVER TORRIDGE U/S STW

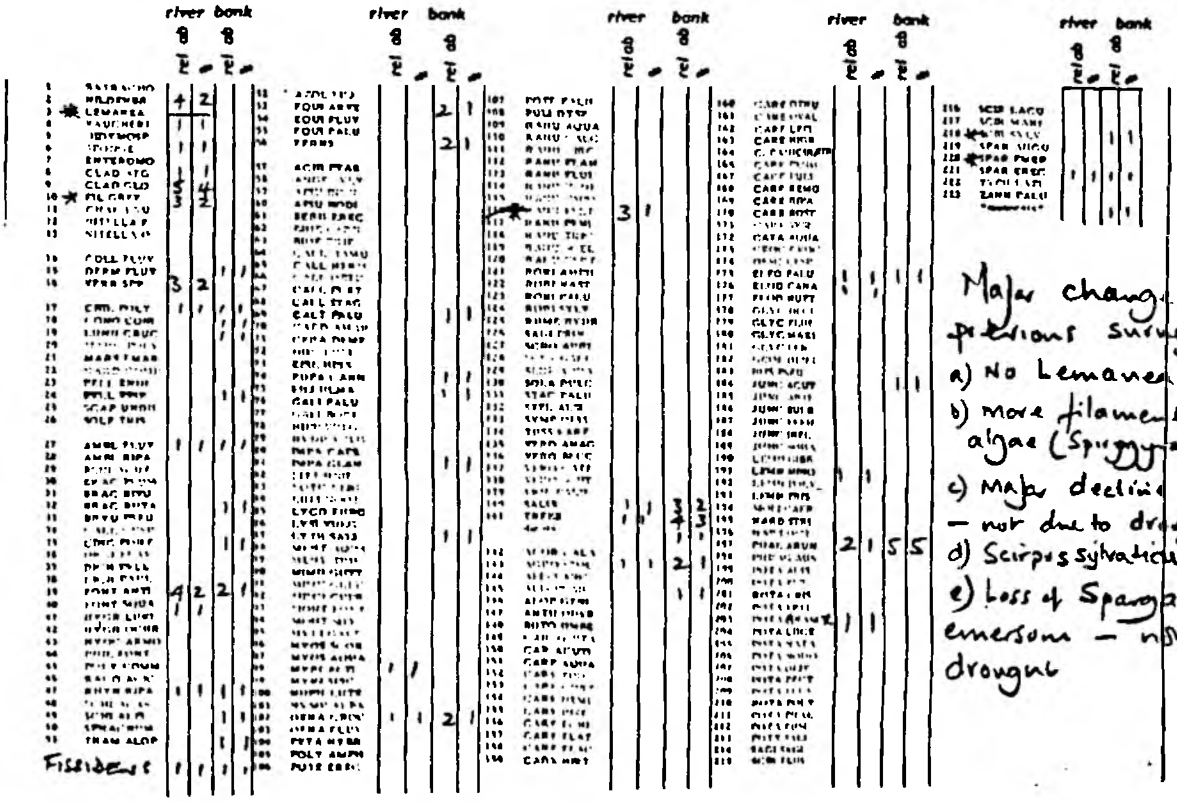
RIVER **MACROPHYTE SURVEY** 17.8.89 **LOCATION OF SITE AND KEY FEATURES**

1 = <5%; 2 = 5-25%; 3 = 25-50%; 4 = >50%

Site Number
Depth
<0.25m
0.25-0.5m
0.5-1.0m
>1.0m
Width
<5m
5-10m
10-20m
>20m
Substrates
bed rock
boulders
cobbles
pebbles
gravel
sand
silt/mud
clay
Habitats and flow
pool
slack
riffle
rapid
run
waterfall
posed rock
orginal fringes
<1m
1-2m
>2m
TOTAL VEG. AREA
bryophytes
algae
emergents
submergents
floating



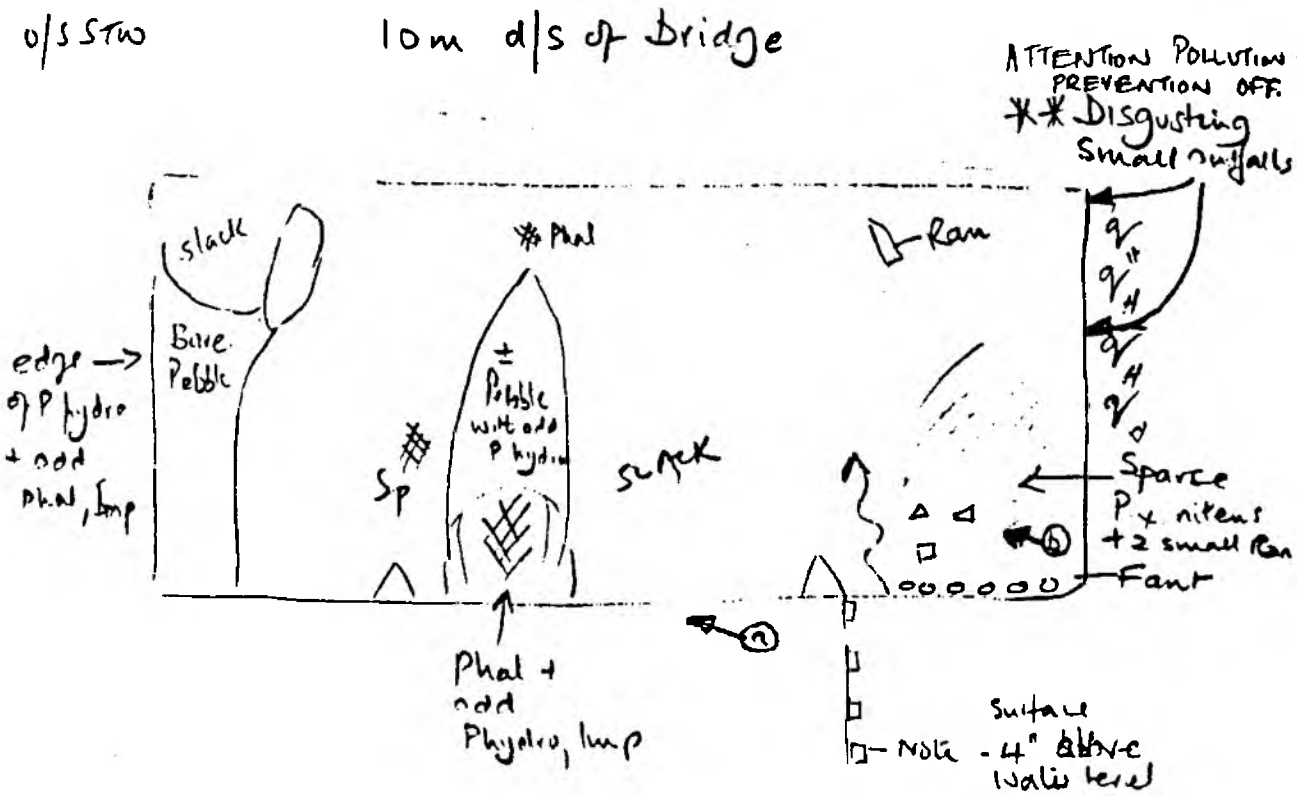
VV low. Risen 2-6" with recent rain. Clad + diats over rocks v thin (cf Tamar at Nether Bridge). Spirogyra in slack water. Slight milky colour but no indication of high plankton because no hint of green.



Major changes from previous survey:-(*)
a) No Lemanea (seasonal)
b) more filamentous algae (Spirogyra in slacks)
c) Major decline in Ran. — not due to drought
d) Scirpus sylvaticus found
e) Loss of Sparganium emersum — not due to drought

FIGURE D11a Macrophytes surveyed from a 0.5km length of the River Torridge either side of the road bridge at Town Mills above Torrington. From Holmes in drought report of Halcrow to NRA SWRegion. Comments are made concerning differences from previous surveys and whether these differences can be related to drought affects. Note record of Sc. sylv. (Scirpus sylvaticus) on left bank and rare hybrid P x nitens on right bank. For key, see Appendix.

Site: U/S Torrington at Town Mills Date: 1st Sept 1989



RB Mixed edge of Phal, Imp P. hydro on Rocky edge - Rocks with Font & Ang

Water with some debris and many small algal filaments - no animals.

Intake generally clean. Filamentous algae common on rocks. Mixed Clad + Oedog? ≥ 50% with Melosira? Slacks with bright green mats of Spirogyra.

Figure D11b Sketch of a 10m reach of the R Torridge upstream of Torrington STW and the water supply intake taken during the drought of 1989 (from Holmes in report of Halcrow to NRA SWRegion). The site is immediately downstream of the road bridge at Town Mills. Note sparse macrophytes but presence of rare P. X nitens. For key see Appendix.

RIVER TORRIDGE D/S STW

RIVER MACROPHYTE SURVEY 17.8.89 LOCATION OF SITE AND KEY FEATURES

Site Number

Depth
<0.25m
0.25-0.5m
0.5-1.0m
>1.0m

Width
<5m
5-10m
10-20m
>20m

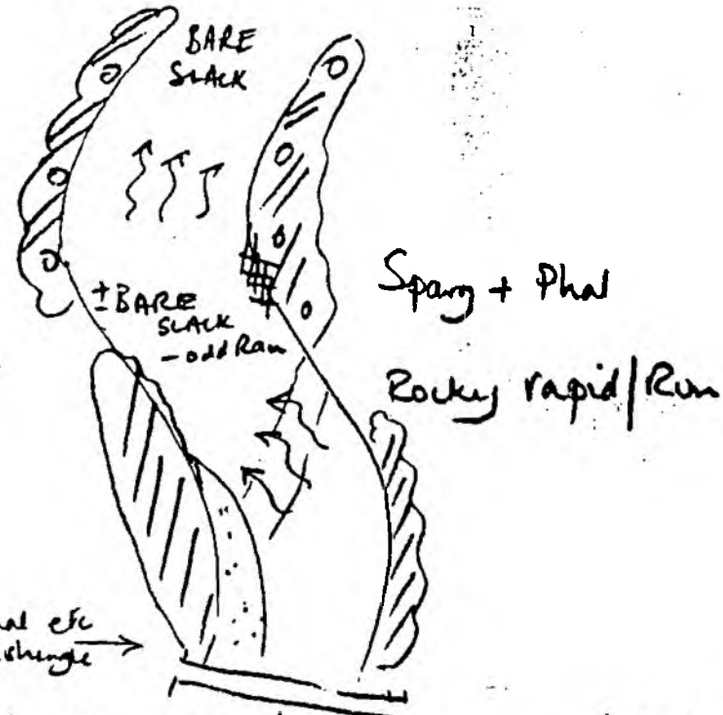
Substrates
bed rock
boulders
cobbles
pebbles
gravel
sand
silt/mud
clay

Habitats and flow
pool
slack
riffle
rapid
run
waterfall
exposed rock

Marginal fringes
<1m
1-2m
>2m

TOTAL VEG. AREA
bryophytes
algae
emergents
submergents
floating — 60% !

1 = <1%; 2 = 1-5%; 3 = 5-25%; 4 = >25%



Appears to have risen c 4 in over low-flow level but was even higher in past week. Cladophora smothers all stones — major change from u/s. Massive amounts of Spirogyra in slacks. Running slightly milky with abundant fil algae & lemna drifting.

	river	bank				river	bank				river	bank				river	bank				river	bank		
1 RATRACHO					52 ACOL FEJ					107 POTE PALU					160 CARE DIVU					216 SCIR LACU				
2 * HELOSHER	7	7			53 EQUI ARVE					108 PULI DYSE			1	1	161 CARE OVAL					217 SCIR MARI				
LEMAMEA					54 EQUI FLUV					109 RANU AQUA					162 CARE LEPI					218 * SCIR SILV			1	1
* VAUCHERI	1	1			55 EQUI PALU					110 RANU [illegible]			1	1	163 CARE NIGR					219 SPAR ERECU				
DIDYMOSP					56 EQUIS					111 RANU [illegible]					164 C. PANICULATA					220 * SPAR EMER				
6 SPIRO										112 RANU FLAM					165 CARE PSEU					221 SPAR EREC	1	1	2	1
7 ENTEROMO					57 ACHE PTAR					113 RANU FLUI					167 CARE PULI					222				
8 CLAD ARG					58 ANGI [illegible]					114 RANU SCEL					168 CARE ECHI					223 ZANN PALU				
9 CLAD GLO	5	5			59 [illegible]					115 RANU [illegible]					169 CARE RIPA									
10 * PELORHY	4	4			60 APIU NODI					116 RANU [illegible]					170 CARE ROST									
11 CHARACEA					61 BERU EREC					117 * RANU PENT	1	1			171 CARE [illegible]									
12 NITELLA F					62 [illegible]					118 RANU TRI					172 CATA AQUA									
13 NITELLA [illegible]					63 [illegible]					119 RANU [illegible]					173 [illegible]									
STIGEO	1	1			64 [illegible]					120 RAN [illegible]					174 [illegible]									
14 COLL FLUV					65 COLL [illegible]					121 RORI AMPH					175 ELEO PALU									
15 DERM FLUV	7	7			66 [illegible]					122 RORI MAST					176 ELEO CANA	1	1							
16 * VERR STR					67 CALL [illegible]					123 RORI PALU					177 ELEO MUTT									
					68 CALL STAG					124 RORI SYLV					178 GLYC [illegible]									
17 CHA. POLY	1	1	1	1	69 CALL [illegible]					125 RORI [illegible]					179 GLYC FLUI									
18 CHAR CORI					70 [illegible]					126 SALI PRIN					180 GLYC MAXI									
19 LIMN CRUC			1	1	71 [illegible]					127 SCRO AUQU					181 GLYC [illegible]									
20 [illegible]					72 [illegible]					128 [illegible]					182 [illegible]									
21 MARS [illegible]					73 [illegible]					129 [illegible]					183 [illegible]									
22 [illegible]					74 PUPA [illegible]					130 SOLA DULC					184 JUNC ACUT									
23 PELL [illegible]					75 [illegible]					131 STAC PALU					185 [illegible]									
24 PELL PHP			1	1	76 GALI PALU					132 STEL ALSI					186 JUNC BUFO									
25 SCAP UNDU					77 [illegible]					133 SYMP OFFI					187 JUNC EFFU									
26 SOLP TYM					78 [illegible]					134 TUSS FARF					188 JUNC INFL									
					79 [illegible]					135 VERO AMAG					189 JUNC [illegible]									
27 AMBL FLUV					80 IMPA CAPE					136 VERO BECC					190 LUZU [illegible]									
28 AMM RIPA	1	1	1	1	81 INUL GLAN					137 [illegible]					191 LEMN MINO	1	1							
29 [illegible]					82 [illegible]					138 [illegible]					192 [illegible]									
30 BRAC [illegible]					83 [illegible]					139 [illegible]					193 LEMN TRIS									
31 BRAC RIVU					84 [illegible]					140 * MALIS	1	1	3	2	194 [illegible]									
32 BRAC RIPA			1	1	85 LYCO EUROP					141 * TRPAS			3	2	195 HARD STRA									
33 RHYD FLU					86 LYS [illegible]		1	1		[illegible]				1	196 HAP [illegible]									
34 [illegible]					87 LYSI VULG		1	1							197 PHAL ARUN	2	1	5	5					
35 CENC PENY					88 [illegible]					142 MYRI ALTE					198 [illegible]									
36 [illegible]					89 [illegible]					143 [illegible]	1	1	1	1	199 [illegible]									
37 DRIM [illegible]					90 MIMU GUTT					144 [illegible]					200 * [illegible]	1	1							
38 [illegible]					91 [illegible]					145 [illegible]			1	1	201 ROTA CRIS									
39 FONT ANTI	1	1			92 [illegible]					146 ALOP GENI					202 [illegible]									
40 FONT SQUA					93 [illegible]					147 ANTI DONR					203 [illegible]									
41 HYGR LURI					94 [illegible]					148 BUTO UMBE					204 [illegible]									
42 HYGR [illegible]					95 [illegible]					149 [illegible]					205 [illegible]									
43 HYPN ARMO					96 MYOS [illegible]					150 CAP ACUTI					206 [illegible]									
44 [illegible]					97 MYOS AQUA					151 CAPP AQUA					207 [illegible]									
45 POLY [illegible]					98 MYRI ALTE					152 [illegible]					208 [illegible]									
46 PAL [illegible]					99 [illegible]					153 [illegible]					209 [illegible]									
47 RHYN RIPA					100 MUPH LUTE					154 [illegible]					210 [illegible]									
48 SCIU [illegible]					101 [illegible]					155 CARE DIST					211 [illegible]									
49 BRY ALB					102 [illegible]	1	1	2	1	156 CARP [illegible]					212 [illegible]									
50 SPHAGNUM					103 [illegible]					157 CARE FLAT					213 [illegible]									
51 FRAN ALDR					104 PETA HYBR			2	1	158 CARE [illegible]					214 [illegible]									
POLYGONUM			4	3	105 POLY AMPH					159 CARE HIRT					215 SCIR [illegible]									
					106 POTE ERIC																			

MAJOR CHANGES FROM BEFORE:—

a) Impossible to det encrusting algae as smothered by Clad.

b) massive density + cover of Clad & Spirogyra

c) Ranunculus declined

d) Pot. berchtoldii and Scirpus sylvaticus found

e) Sparganium emersum gone.

ONLY CHANGE ATTRIBUTABLE TO DROUGHT IS INCREASE IN ALGAL BIOMASS

FIGURE D12a Macrophytes surveyed from a 0.5km length of River Torridge downstream of the A386 road bridge below Torrington (from Holmes in drought report of Halcrow to NRA SWRegion). Comments are made concerning differences from previous surveys and a whether diferences can be related to drought affects. For key, see Appendix.

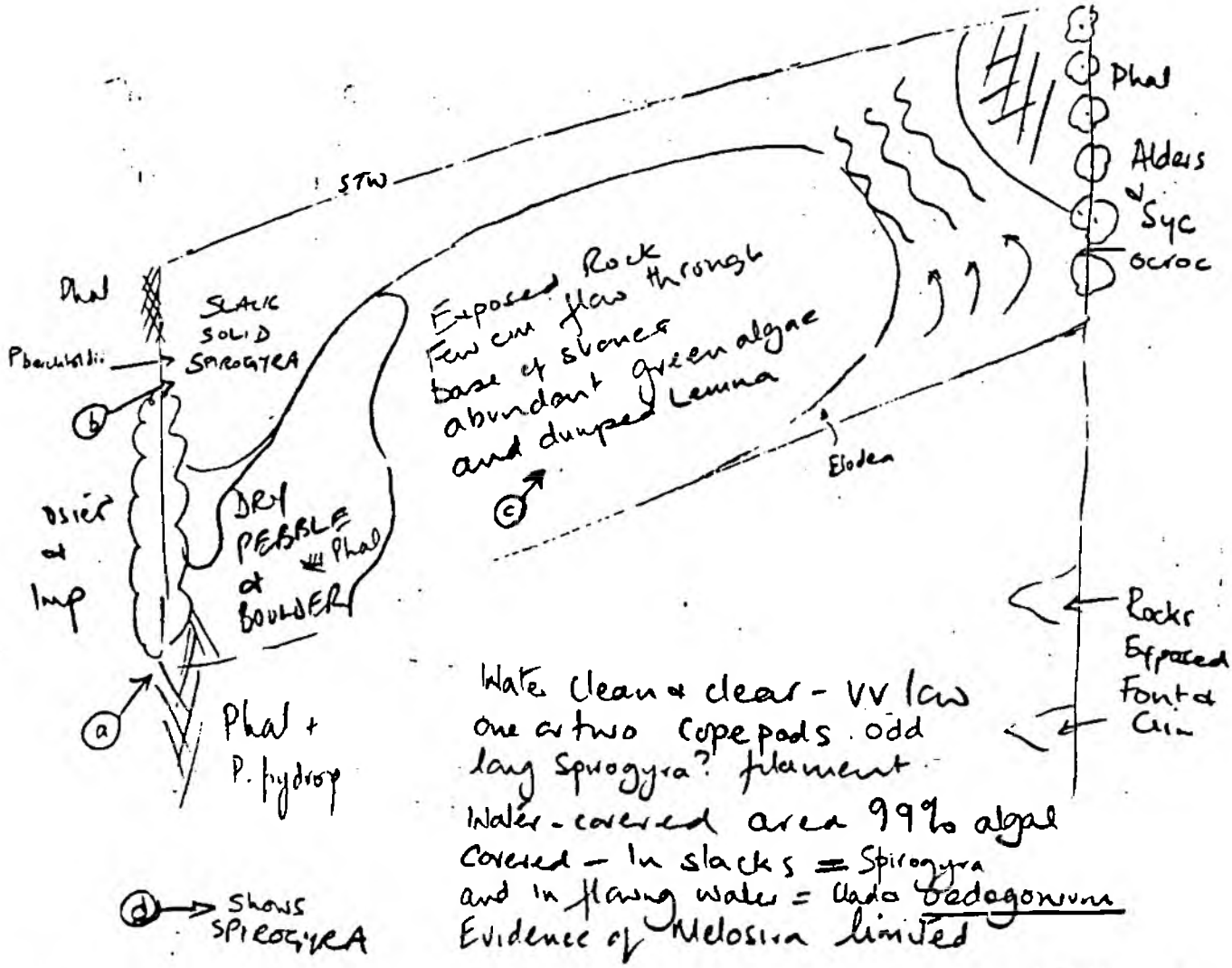


FIGURE D12b Sketch taken of a 25m diagonal reach of the Torridge downstream of the sewage works and river intake during the drought of 1989 (from Holmes in drought report of Halcrow the NRA SWRegion). It shows the unstable bed covered by filamentous alage. At the margins are reeds; note the location of P. berehtoldii on the left bank. For key to symbols see Appendix.

SITE LOCATION: Approx 50m downstream of the the A386 Bridge below Torrington.

DATE OF SURVEY: 1et September 1989

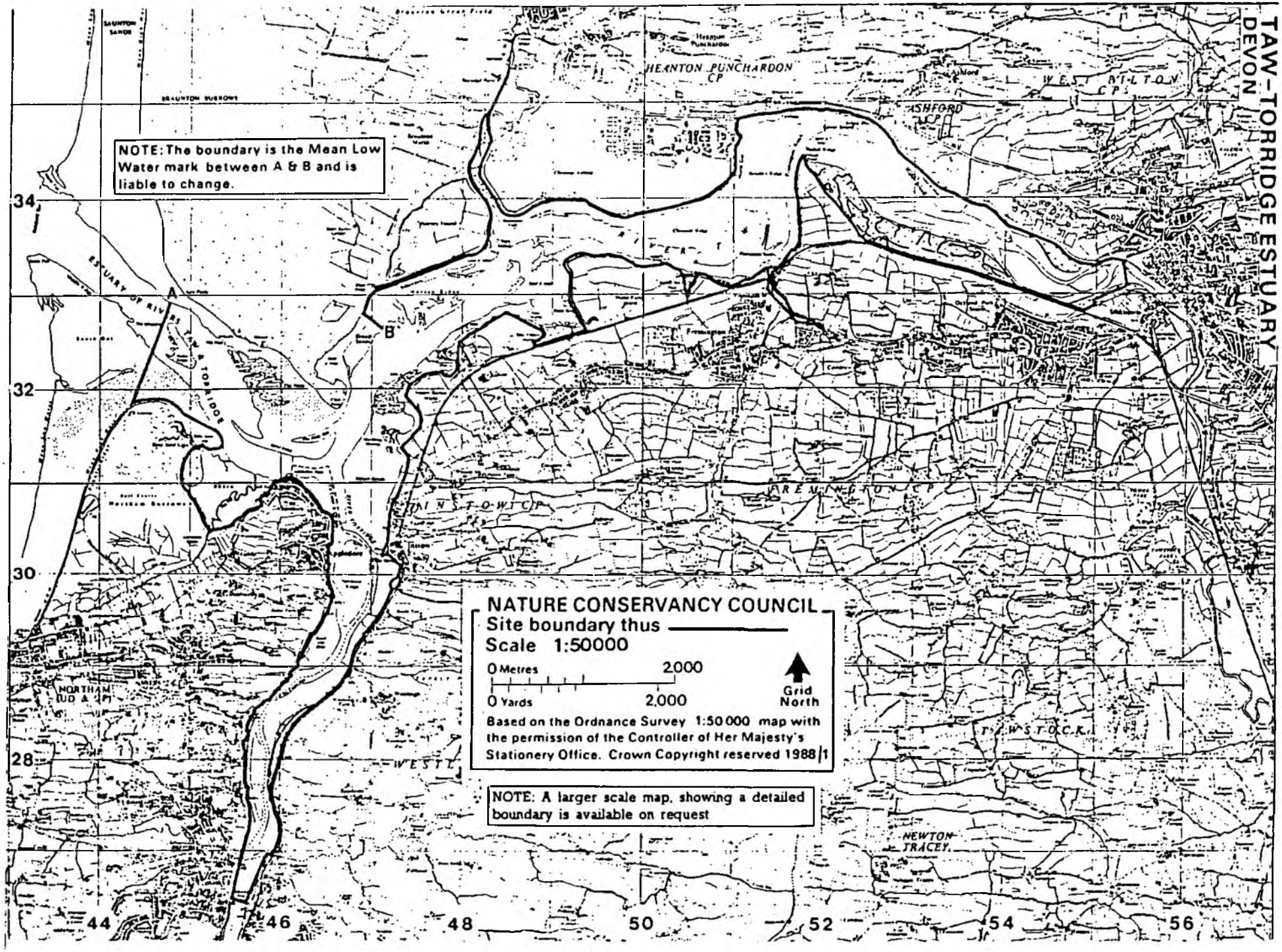
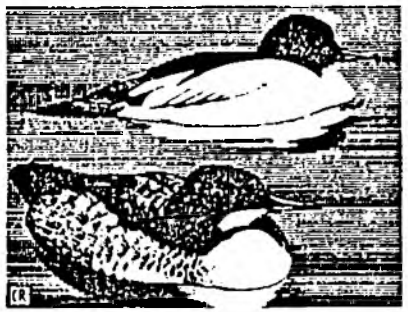


FIGURE D 13a Boundary of the Taw-Torridge Estuary SSSI

Goosander

Mergus merganser



Unlike the closely related Red-breasted Merganser *M. serrator*, the Goosander favours fresh water and is widespread inland in Britain (though not Ireland) in the winter months, occurring on many of the larger lakes and reservoirs. On the coast it occurs only locally at particularly sheltered localities.

Since first breeding in Perthshire in 1871, the Goosander has become a widespread breeding species both in Scotland and northern England, and in these areas the breeding distribution is reflected in the number of birds wintering. Considerable numbers also occur in most winters in Wales, central England and the London area. In contrast very few are seen in Ireland, where breeding commenced during the 1970s (*Breeding Atlas, Irish Bird Reports*). Only a few sites in Britain regularly hold more than 50 birds, the most notable being the Beauly Firth where up to 1,500 were recorded during the Atlas period.

In their studies in the north of England, Meek and Little (1977) have shown that Goosanders often do not move far from their natal areas in winter, and the same probably applies in Scotland. So it may be inferred that perhaps as many as three-quarters of the breeding population of Scotland and northern England, along with their surviving progeny (a total of perhaps 5,000, allowing one offspring per pair), winter in their general breeding area. Though Goosanders wintering in southern England doubtless include British birds, particularly in cold weather when inland waters further north are frozen, the few ringing recoveries suggest that many are from the Continent or Scandinavia, with recoveries in Sweden, Finland, NW Russia, the Netherlands and East Germany (Meek and Little 1977).

Goosanders will make hard weather movements when their wintering locations become frozen. The most recent of such influxes occurred in early January 1979 (Chandler 1981), when unusual numbers appeared in southern England. These would presumably have included British breeders, though the appearances of Smews *M. albellus* with the Goosanders in this influx shows that the source of many of the birds involved was the Continental shores of the southern North Sea, particularly the Netherlands.

Goosanders feed primarily on small fish, preferring water no deeper than 4 m. At some localities, birds may leave the water on which they roost to feed by day on nearby rivers, behaviour which can lead to the number of birds being under-recorded. In contrast the species' need to move when inland waters freeze makes some duplication of records over the winter period inevitable. However, since Goosanders are a conspicuous species and make only limited use of remote coastal areas, where Atlas coverage may have been less complete, a good proportion will have been recorded. The total winter population for Britain and Ireland in each of the 3 years was close to 8,000 with 5,000 of them being in northern England and Scotland. These numbers compare with estimates of the British winter population of about 5,000 made by Owen *et al* (1986), suggesting that there is some duplication in the *Winter Atlas* records, but showing that their figure of 5,000 is certainly not an overestimate.

In comparison, the northwestern European winter total is over 100,000 (International Waterfowl Research Bureau, unpublished).

R. J. CHANDLER

Total number of squares in which recorded: 1,008 (26%)

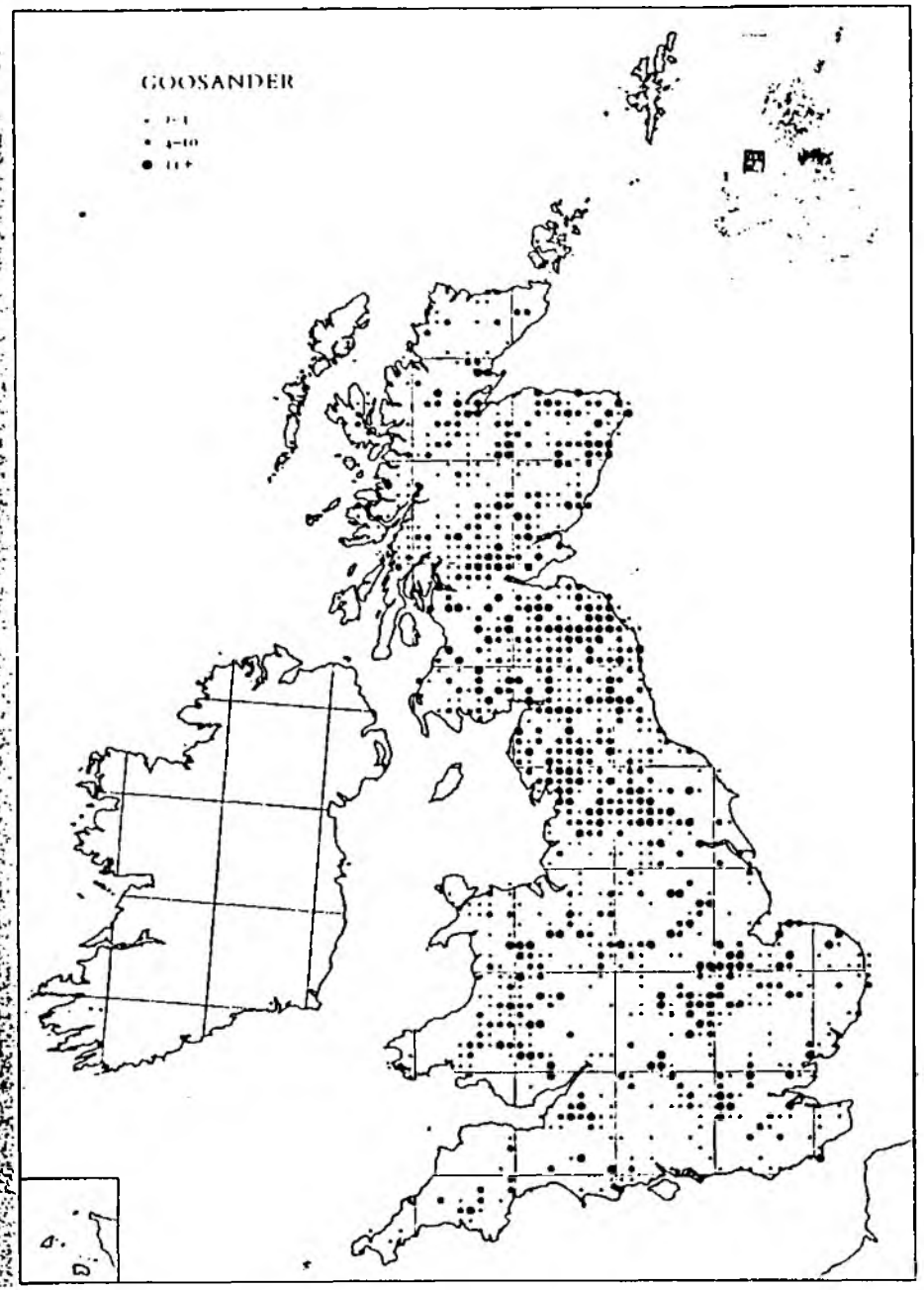
No. of birds seen in a day	Number (%) of squares: Britain	Ireland	TOTAL (incl. C.I.)
1–3	499 (50%)	3 (75%)	502 (50%)
4–10	303 (30%)	1 (25%)	304 (30%)
11+	202 (20%)	0 (0%)	202 (20%)

References

CHANDLER, R. J. 1981. Influxes into Britain and Ireland of Red-necked Grebes and other waterbirds during winter 1978/79. *Brit. Birds*, 74: 55–81.

MEEK, E. R. and B. LITTLE. 1977. Ringing studies of Goosanders in Northumberland. *Brit. Birds* 70: 273–283.

Breeding Atlas p 92

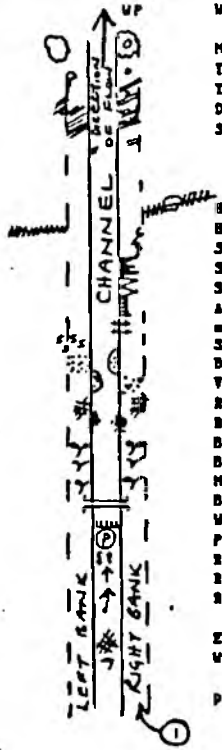


D15a Winter distribution of Goosander (from Lack; 1986) showing the regional importance of Burrator.

KEY TO SYMBOLS

TREES/SHRUBS

WW	White Willow
CW	Crack Willow
PCW	Pollarded Crack Willow
S. cin	Grey Willow
GW	Goat Willow
PCW	Pollarded Crack Willow
CW(P)	Crack Willow requiring pollarding
CCW	Coppiced Crack Willow
A	Alder
Br	Bramble
BT	Blackthorn
E	Elm
EB	Elderberry
HT	Hawthorn
M	Maple
Pop	Poplar
Syc	Sycamore
WP	White Poplar



Mature tree
Young tree
Trees amongst shrubs
Dense scrub/shrubs
Sparse scrub/bush

FEATURES

Hedges with trees
Hedges without trees
Slumping banks
Solid earth cliffs
Soft earth cliffs
Artificial banks
mud banks
Sand banks
Bare Shingle
Vegetated shingle
Reeds/sedges on bank
Reed/sedges at water margin
Bank flora dominated by herbs/ruderals
Bank flora dominated by grasses
Mixed flora on the banks
Bridge
Weir
Pool
Riffle
Rapid
Run

Emergent plants in channel
Water-lily

photographic record

A Arable land
IG Improved Grassland - Recent reseeding; poor herbs and grass
SIG Grassland previously improved, some common herbs and grasses present
SIP Pasture showing little sign of recent improvement; good herb and grass community and little or no rye-grass or invasive weeds
UP Unimproved pasture; indicators of ancient grassland present
Fence
Hedge removed

KEY TO SYMBOLS USED FOR PLANTS ON RCS MAPS

COMMON NAME	ABBREVIATION	LATIN NAME
Pool's Water-cress	Ap	Apium nodiflorum
Starwort	Call	Callitriche
Intermediate	ham	hamulata
Blunt-fruited	obt	obtusangula
Common	stag	stagnalis
Great Willow-herb	Ep	Epilobium hirsutum
Hemp Agrimony	Eup	Eupatorium cannibinum
Meadowsweet	Filip	Filipendula ulmaria
Indian Balsam	Imp g	Impatiens glandulifera
Gypsywort	Lyc	Lycopus europaeus
Purple Loosestrife	Lyth	Lythrum salicaria
Nettle	N	Urtica dioica
Water For-get-me-not	Myo	Myosotis scorpioides
Spiked Water-milfoil	M spic	Myriophyllum spicatum
Yellow Water-lily	Nuph	Nuphar lutea
Butterbur	Pet	Petasites hybridus
Amphibious Bistort	P amph	Polygonum amphibia
Crowfoot	Ran	Ranunculus
Fan-leaved	circ	circinatus
Brook	calc	calcareus
River	f	fluitans
Lesser Spearwort	flam	flammula
Celery-leaved Buttercup	scel	sceleratus
Great Yellow-cress	R a	Rorippa amphibia
Water-cress	No	Nasturtium officinalis
Water Figwort	Scroph	Scrophularia auriculata
Marsh Woundwort	Stach	Stachys palustris
Bittersweet	Sol	Solanum dulcamara
Comfrey	Symph	Symphytum officinalis
Blue Water-speedwell	V aa	Veronica anagallis-aquatica
Brooklime	V becca	beccabunga
Pink Water-speedwell	V cat	catenata
Marsh Foxtail	Alop	Alopecurus geniculata
Flowering Rush	But	Butomus umbellatus
Lesser Pond-sedge	Ca	Carex acutiformis
Tufted Sedge	C acuta	acuta
Great Tussock-sedge	C pan	paniculata
Pendulous Sedge	C pend	pendula
Remote Sedge	C rem	remota
Great Pond-sedge	Cr	riparia
Common Spike-rush	Eleo	Eleocharis palustris
Canadian Pondweed	E can	Elodea cannadensis
Nuttall's Pondweed	E nutt	nuttallii
Small Sweet-grass	G dec	Glyceria declinata
Flote-grass (Floating S-g)	Gf	fluitans
Reed Sweet-grass	G max	maxima
Plicate Sweet-grass	G plic	plicata
Yellow Iris	I	Iris pseudacorus
Sharp-flowered Rush	J acut	Juncus acutiflorus/articulatus
Soft Rush	J eff	effusus
Hard Rush	J inf	inflexus
Reed Canary-grass	Phal	Phalaris arundinacea
Common Reed	Phrag	Phragmites australis
Curled Pondweed	Pcrisp	Potamogeton crispus
Pennel Pondweed	Pect	pectinatus
Perfoliate Pondweed	Perf	perfoliatus
Arrowhead	Sag	Sagittaria sagittifolia
Common Club-rush	Sc	Scirpus lacustris
Wood Club-rush	Sylv	sylvaticus
Unbranched Bur-reed	Sea	Sparganium emersum
Branched Bur-reed	Sp	erectum
Bulrush (Reedmace)	T lat	Typha latifolia
Horned Pondweed	Zann	Zannichellia palustris

Site		Grid Reference
(10)	Okement Confluence	SS550071
(11)	Lockshill	SS552116
(12)	Warham	SS535151
(13)	Blinsham	SS517165
(14)	Town Mills	SS499184
(15)	Rothern Bridge	SS479197
	R. Okement	
(31)	Meldon	SX565924
(32)	Castle	SX584943
(33)	Brightley Bridge	SX598974
(34)	A3072 Bridge, Jacobstowe	SS592017
(35)	Hole Brook	SS585053
(36)	Iddesleigh Bridge	SS567057
(37)	Torridge Confluence	SS550071

6	Okement confluence	0.5	SS550071	1	7	61	12
7	Right bank tributary, Lockshill	0.5	SS552116	1	7	45	10
8	River meander, Warham	0.0	SS535151	1	7	30	10
9	A386 bridge, Great Torrington	0.5	SS499184	1	7	15	9
10	Right bank tributary, Weare Gifford	0.0	SS478215	1	7	O	12
	OKEMENT						
1	E Okement Farm	0.5	SS607909	1	2	396	0.7
2	A3072 Bridge, Jacobstowe	0.5	SS592017	1	4	91	3.5
3	Torridge confluence	0.5	SS550071	1	5	61	10

TABLE D1i Site locations of macrophyte surveys on the Torridge system downstream of Meldon. The upper list refers to sites surveyed in 1986 and the lower ones in 1979 (both by Holmes). Data from the former are given in Table D1iii.

	TAMAR						THRUSHEL				LYD				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
algae															
Batrachospermum															
Hildenbrandia rivularis															
Lemanea fluviatilis															
Vaucheria															
Ephydatia (River sponge)															
Cladophora aegagropila															
Cladophora glomerata agg. (Blanketweed)															
Stigeoclonium															
other filamentous algae															
lichens															
Verrucaria spp.															
liverworts															
Chiloscyphus polyanthos															
Conocephalum conicum															
Lunularia cruciata															
Marchantia polymorpha															
Pellia epiphylla															
Riccardia multifida															
Scapania undulata															
Solenostoma triste															
Porella pinnata															
mosses															
Amblystegium fluviatile															
A. riparium															
Brachythecium plumosum															
B. rivulare															
B. rutabulum															
Cinclidotus fontinaloides															
Fontinalis antipyretica															
F. squamosa															
Dichodontium pellucidum															
Ocinoficeras fontanum															
Orthotrichum spp.															
Fissidens rufulus															
F. viridulus															
Hygrohypnum ochraceum															
Philonotis fontana															
Polytrichum commune															
Rhynchostegium riparioides															
Schistidium alpicola															
Thamnobryum alopecurum															
Stringua															
VASCULAR CRYPTOGAMS															
Equisetum arvense (Creeping Horsetail)															
'Ferns'															
FLOWERING PLANTS - DICOTYLEDONS															
Chiun palustris															
Achillea ptarmica (Sneezewort)															
Angelica sylvestris (Wild Angelica)															
Apium nodiflorum (Fool's Water-cress)															
Bidens tripartitus (Tripartite Bur-marigold)															
Callitriche hamulata (Intermediate Water-starwort)															
C. stagnalis (Common Water-starwort)															
Eupatorium cannabinum (Hemp agrimony)															
Filipendula ulmaria (Meadowsweet)															
Galium palustris (Common Marsh-bedstraw)															
Impatiens glandulifera (Indian Balsam)															
Lotus uliginosus (Greater Birds-foot-trefoil)															
Lycopus europaeus (Gipsywort)															
Lythrum salicaria (Purple-loosestrife)															
Mentha aquatica (Water Mint)															
Myosotis scorpioides (Water Forget-me-not)															
Myriophyllum alterniflorum (Alternate Water-milfoil)															
Oenanthe crocata (Hemlock Water-dropwort)															
Potentilla erecta (Tormentil)															
Ranunculus ficaria (Lesser Celandine)															
Rorippa nasturtium-aquaticum (Water-cress)															
Scrophularia auriculata (Water Figwort)															
Sparganium erectum (Bur-reed)															
Stachys palustris (Marsh Woundwort)															
Stellaria alsine (Bog Stitchwort)															
Symphytum officinale (Comfrey)															
Veronica beccabunga (Brooklime)															
Viola palustris (Marsh Violet)															
Valerianella locusta (Lamb's Lettuce)															
Salix spp. (Willow & Sallows)															
other trees															
other herbs															
Mentha aquatica															
MONOCOTYLEDONS															
Agrostis stolonifera (Creeping Bent)															
Alisma plantago-aquatica (Water-plantain)															
Alopecurus geniculatus (Marsh Foxtail)															
Asplenium ruta-muraria (Wall Rue)															
Carex elata (Star Sedge)															
C. panicea (Carnation Sedge)															
C. pendula (Pendulous Sedge)															
C. riparia (Bank Sedge)															
Dactylorhiza purpurella (Common Spotted-orchid)															
Elodea canadensis (Canadian Pondweed)															
Glyceria declinata (Small Sweet-grass)															
G. fluitans (Floating Sweet-grass)															
Juncus articulatus agg. (Jointed Rush)															
J. bufonius (Toad Rush)															
J. bulbosus (Bulbous Rush)															
J. effusus (Soft Rush)															
Poligon amphibium (Purple Water-grass)															
Potamogeton crispus (Curly Pondweed)															
Sparganium erectum (Unbranched Bur-reed)															
other monocotyledons															
Carex hirta															
TOTAL NUMBER OF TAXA RECORDED	38	24	28	26	45	45	23	13	33	36	30	26	31	33	33	40

Table D111 Macrophytes of the Tamar Catchment from Holmes (1987) For key see end of Appendix A.

← MAIN RIVER → | ← OKEMENT

	10		11		12		13		14		15		31		32		33		34		35	
	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B
Hildenbrandia rivularis	32		21		32		32		42		42											
Lemanea fluviatilis	21		11		21		11		32								54		42			
Vaucheria sp(p.)			11		11		11		11		42											
Freshwater sponge	21		32		43		11		32													
Cladophora aegagropila	21		32		54		32		32													
C. glomerata	11		21		11		32		32		52										51	
'Filamentous greens' Blue green algae felt											11		51		23 55		21		21		11	
Dermatocarpon fluviatilis				11						11					11	11	11	11				
Verrucaria spp.	21		32		32		11		32								11	11	11	11		
Chiloscyphus polyanthos	11	11	11	11	21	43	11	11	11	11	11	11							11	11		
Conocephalum conicum		11								11						11				21		
Lunularia cruciata		11		11		11				11		11						21				
Marchantia polymorpha																		21		11		
Marsupella emarginata													11	21								
Nardia compressa													21	11								
Pellia endiviifolia																						
P. epiphylla		11		11		11		11		11		11	11	21	32		43		32			
Riccardia	11	11																				
Scapania undulata													51	42			11	32	11	11		
Solenostoma triste													11	11		21		21		11		
Amblystegium fluviatile					11	11			11	11												
A. riparium					11	11	11	11			11	11									11	21
Blindia acuta						11							21	11								
Brachythecium plumosum														11		11		43		11		
B. rivularia																		11	11	54		
B. rutabulum		11		11		11		11		11		11								11		
Bryum pseudotriquetrum														11		11		11				
Calliergon cuspidatum																						
Cinclidotus fontinaloides		11		32		11				11												11
Dichodontium flavescens														11		11						
D. pellucidum														11		11						
Fissidens	11	11			11	11			11	11												
Fontinalis antipyretica	11	11	21	11	22		42		32		11										11	11
F. squamosa	32		32		43		42		21						11	11	44	32	53			
Hygrohypnum ochraceum																	32	32	42	21		
Hyocomium armoricum																21		11		11		
Polytrichum commune														21								

TABLE D1iii Macrophytes of the Torridge system downstream of Meldon. For interpretation of abundance, see key at the end of Appendix A.

Table D1iii continued

	10		11		12		13		14		15		31		32		33		34		35	
	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B
Racomitrium aciculare													11	52		21	11	32				
Rhynchostegium riparioides	32		32		32	21	53										32	11	42	32	11	11
Schistidium agassizii																						
S. alpicola									11						11							
Sphagnum spp.																						
Thamnium alopecurum		11		32		32			11						11	52	11	43		11		
Equisetum arvense		11		11		11		11		21		11		11				21		11		21
E. fluviatile																						
E. palustre																						
'ferns'		32		21		21		11		21		11		21		21		32		32		11
Angelica sylvestris																						
Apium nodiflorum																				11		
Callitriche hamulata	11		11		11		11															
C. stagnalis	11	11				11																
Caltha palustris		11						21		11												
Epilobium hirsutum																						11
Eupatorium cannibinum		11				11				11				11				11		11		
Filipendula ulmaria		11		11				11		11										11		
Galium palustre																						
Impatiens glandulifera		11				11		21		21		21										
Lycopus europaeus		11																				
Lysimachia vulgaris						11						11										
Lythrum salicaria		11		11		11		21		11												
Mentha aquatica		11																				
Mimulus sp(p.)																						
Myosotis scorpioides																						
Myriophyllum alterniflorum			11		21		21		11													
Oenanthe crocata	11	11	11	21	21	32	21	32	11	21	11	21			11	42	11	32	11	54	11	11
Petasites hybridus						11						21										
Pulicaria dysenterica																						
Ranunculus aquatilis?																						
R. flammula													11	11		11						
R. fluitans																						
R. hederaceus																						
R. peltatus hybrid	53		52		43		53		52		42											
Rorippa nast.-aquaticum																						
R. sylvestris		11																				
Sagina procumbens																				11		11
Scrophularia auriculata																						

Table D1iii continued

	10		11		12		13		14		15		31		32		33		34		35	
	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B
Solanum dulcamara						11												11			11	11
Stachys palustris		11																				
Stellaria alsine																						
Veronica beccabunga																				11		
Salix spp.		11		11		11	11	32	11	32	11	32	11	32	21		21		21		11	32
Trees		44		44		55	11	44	11	43		32		21	42		43		32		11	43
Other dicotyledons		11		11		11		11		11		11		11		32		11		21		11
Agrostis stolonifera	11	32	11	21	11	11	11	11	11	21	11	11							21	32	41	43
Alisma plantago-aquatica	11	11					11			11												
Alopecurus geniculatus		11																				
Anthrothanthum oderatum														32								
Carex echinata														11								
C. remota				11				11								11		11		11		11
Deschampsia cespitosa														11				11				
Eleocharis palustris								11	11	11												
Elodea canadensis	11					11				11		11										
Glyceria fluitans	11	32																		11	31	21
Iris pseudacorus		11					11	11														
Juncus acutiflorus		21		11														11		11		11
Juncus bulbosus																						
J. effusus		11												11				11		11		
Molinea caerulea														11								
Nardus stricta														11								
Narthecium ossifragum																						
Phalaris arundinacea	11	55	11	55	11	55	21	55	21	55	21	55		11		11	11	21		11	51	55
Potamogeton gramineus / nitens							42		21													
P. polygonifolius																						
Scirpus sylvaticus																						
Sparganium emersum			11						11		21											
S. erectum	11	11					11	11	11	11	11	21										
Other monocotyledons		11				11		11		11		11		11		52		43		32	11	43
No. of taxa recorded	48		83		40		36		42		26		29		23		32		35		21	
Site Classification	C2iii		C2iv		B4iv		C2iii		C2i		B4iv		D3ii		C2iii		C2iv		C2iv		C3iv	

SPECIES		RIVER CATCHMENT	TAMAR	WOLF	WOLF/THRUSHEL CONF.-THRUSHEL/LYD CONF.	THRUSHEL/LYD CONF.-LYDFOOT	TAVY	PLYM	MEAVY	TORRIDGE	WEST OKEMENT	OKEMENT	TAW	DART
ATLANTIC SALMON	Salmo salar		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SEA TROUT/BROWN TROUT	Salmo trutta		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RAINBOW TROUT	Salmo gairdneri		X	X	X	X	✓	X	X	✓	X	X	✓	✓
GRAYLING	Thymallus thymallus		✓	X	✓	✓	X	X	X	X	X	X	X	X
BREAM	Abramis brama		✓	X	X	X	X	X	X	X	X	X	X	X
MINNOW	Phoxinus phoxinus		✓	✓	✓	✓	✓	X	X	✓	X	✓	✓	✓
DACE	Leuciscus leuciscus		✓	X	X	X	X	X	X	✓	X	✓	X	X
GUDGEON	Gobio gobio		X	X	X	X	X	X	X	✓	X	X	X	X
STONELOACH	Neomacheilus barbatulus		✓	✓	✓	✓	✓	X	X	✓	X	✓	✓	✓
EEL	Anguilla anguilla		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
THREE-SPINED STICLEBACK	Gasterosteus aculeatus		X	X	X	X	X	X	✓	✓	X	X	X	X
BULLHEAD	Cottus gobio		✓	✓	✓	✓	✓	✓	X	✓	X	✓	✓	✓
FLOUNDER	Platichthys flesus		X	X	X	X	X	✓	X	X	X	X	X	X
BROOK LAMPREY	Lampetra planeri		✓	✓	✓	✓	✓	✓	X	X	X	X	X	X
YEAR OF SURVEYS			1984	1989	1988 1989[&]	1988 1989[&]	1989	1989	1989	1986	1986	1986	1988	1987

TABLE D1iv Distribution of fish within river catchments. Note the year of survey is often different from that mapped in Figure D1f

SPECIES	HABITAT AND STATUS IN DEVON (Merritt 1983)	DISTRIBUTION OF SURVEY RECORDS (KILOMETRE SECTION) WOLF	THRUSHEL	LYD	NORTH-LEW	NORTH-LEW (WEST)
1. Beautiful Demoiselle (Calopteryx virgo)	Stoney streams & rivers Widespread	1,2,3	1,2,3,4, 5,7,8,9, 10.11,13, 16,19,15	1,2,5,7, 8,9,12	1,2,3,4, 5,6,10, 12,13	3
2. Large Red Damselfly (Pyrrhosoma nymphula)	Wide range of wetland habitats. Widespread.			6	2,4,5,6, 13	5
3. Blue-tailed Damselfly (Ischnura elegans)	Ponds, canals, rivers. Widespread and common.					5,6
4. Common Blue Damselfly (Enallagma cyathigerum)	Ponds, rivers, canals. Common.			6,9	2	5,6
5. Azure Damseslfly (Coenagrion puella)	Wide range of wetland habitats. Widespread and common.				2	5,6
6. Southern Hawker (Aeschna cynaea)	Ponds, lakes. Fairly wide-spread except in uplands.	3	4,2,11, 9,16,15	7,9,6	9,10,14, 14,16	6
7. Emperor Dragonfly (Anax imperator)	Ponds, lakes. Rather local.				2	6
8. Golden-ringed Dragonfly (Cordulegaster boltonii)	Stoney streams and rivers. Widespread and common.	2,3	2,9,19	5,6,7,9, 13	2,6,8,9, 10,12,13, 14	2
9. Broad-bodied Chaser (Libellula depressa)	Ponds. Widespread & not uncommon outside high moors.	2,4	4,11	4,6	2	5,6
10. Four-spotted Chaser (Libellula quadrimaculata)	Moorland & heathland pools. Rather local elsewhere.		15			6,8
11. Keeled Skimmer (Orthetrum coerulescens)	Restricted to sphagnum bogs and flushes. Nationally scarce.				2	6
12. Common Darter (Sympetrum striolatum)	Variety of wetland habitats. Widespread.		4	6	7,14	5,6

TABLE D6.1z Odonata observed during the surveys of Heath (1989) on the Lyd catchment and the Lew system (tributary of the Torridge). The numbers in the columns refer to 0.5km lengths where present; for locations see Figure D6.3a.

KEY SITES SUMMARY - WOLF

SITE	NOTES	POTENTIAL IMPACT OF ROADFORD SCHEME	OTHER KNOWN IMPACTS
W1 MILFORD QUARRY	Disused quarry with ponds, woodland, scrub and grassland habitats. Small heronry. Wet river-edge flushes.	Possible effects on wet river-edge areas if water-table lowered.	Dumping of refuse and farm wastes
W2 COOMBE	Large complex of habitats including marshy grassland, dry and wet woodland. Extensive fringing habitats within river channel. Grassland area is Exeter University Target Area.	Possible effects on grassland and wet woodland areas if water-table lowered and peak spates removed.	Proposed new A30 route cuts through northern part.
W3 SLEW WOOD	Large woodland block extending up to reservoir site. SWW-owned. Good dense cover adjacent to river. Remnants of ancient upland oakwood and heath amongst coniferized areas. Wet flushes and cut-offs in valley floor.	No major threat, providing no further clearance work is envisaged below present construction site. Excellent opportunities for beneficial management by SWW (DWT has submitted management recommendations). Cut-off pools could be affected but these heavily shaded and silted anyway.	Annual mink-hunt works upstream from Broadwood. Access should be denied.

KEY SITES SUMMARY - LYD

SITE	NOTES	POTENTIAL IMPACT OF OF ROADFORD SCHEME	OTHER KNOWN IMPACTS
LY1 GATHERLEY WOOD & HARTS	Large woodland site, providing important habitat for birds and mammals, including otter which make regular use of the area. The site is ancient but canopy is mainly post-war regeneration. One interesting wet woodland area at eastern end, remote from river.	Probably negligible.	Undergoing extensive coniferization programme, but riverine strip to be retained.
LY2 LIFTON PARK POND	Wooded pond with heronry and adjacent marshy grassland. Only site in the survey for *Carex riparia*, a regional rarity.	Probably negligible.	
LY3 LIFTON WOOD	Large woodland site - ancient but canopy severely altered by past felling/re-planting. Good site for birds and mammals.	Negligible.	Part of site has approval for Forestry Grant Scheme Could be coniferized.
LY4 LIFTON OLD WORKS	Neglected field, providing dense riverside habitat. Some marshy grassland.	SWW-owned? Good potential for beneficial management.	

TABLE D6.21 Description of key terrestrial sites identified by Heath (1989). For locations, see Figure D6.2c.

- RIVER BRYOPHYTES RECORDED

A - Abundant
B - Bank
F - Frequent
LB - Lower Bank
O - Occasional
R - Rare
S - Subaerged/Splash zone

Sampling Site

SPECIES		WOLF 1	WOLF 2	WOLF 3	WOLF 4	THRUSHEL 1	THRUSHEL 2	LYD 1	LYD 2	LYD 3	LYD 4	N.LEW 1	N.LEW 2	N.LEW 3	W.LEW 1
Fontinalis antipyretica	S	LF			LA								F		LA
F.squamosa	S	LA		O				LF	A	F					
Brachythecium rutabulum	S				O	F			O				F	F	F
B.plumosum	S											A		A	
B. rivulare	S	LA			F		O	LA		F		F		F	F
Cinclidotus fontinaloides	S							F	O						
Rhynchostegium riparoides	S	LA		F	O		A	LA		F	F	A		O	
Hygrohypnum luridum	S	O								O	LF				
Amblystegium fluviatile	S	O						F							
Nardia compressa	S										R				
Scapania undulata	S										O				
Orthotrichum rivalare	S										LF	R			
Acrocladium cuspidatum	S	LA	F	A											
Riccardia pinguis	S	R													
Chiloscyphus polyanthos	LB/S			F				F/LA	LF	F				O	
Atrichum crispum	S	R													
A.undulatum	S				O										
Plagiochilla porelloides	LB	LF			LF										
Conocephalum conicum	LB	LA	F	F	F	A	O	F				LA			
Lunularia cruciata	LB			F		F		F				F			
Plagiomnium undulatum	LB	LF	O									O			
Rhizomnium punctatum	LB	O		R											
Homalia trichomanoides	LB			F											
Dichodontium pellucidum (var.fagimontanum)	LB				R			O						O	
Leskea polycarpa	LB	O													
Eurhynchium praelongum	LB	LA	F	F		O	LF	LA			O	F	A		F
Lophocolea cuspidata	B									O					
Hypnum lindbergii	B											O			
Mnium hornum	B		F	O				O				O			
Thuidium tamariscinum	B		O	O											
T.delicatulum	B		O												
Hookeria lucens	B			R											
Isothecium myosuroides	B	O		O											
Thamnobryum alopecurum	B			F				LA					O		
Rhodobryum roseum	B	O													
Pellia epiphylla	B							O							

TABLE D.71 Bryophytes recorded from the Lyd and Torridge Lew systems by Heath (1989).

Description of survey methodology and data presentation

MACROPHYTE SURVEY METHODS

Macrophytes from 0.5km lengths are surveyed using a checklist of species.

The survey at each site includes the whole river and immediate banksides from one side to the other. There are, therefore, separate records for those macrophytes found in the river, and similarly for those found on the bank. Such a separation of records was an attempt to distinguish between those species which occured more or less permanently submerged, albeit their basal parts, and those that are subjected to only periodic submergence. The former are referred to as 'river' records and the latter as 'bank' records. To make the separation of these records objective, I attempted to keep to the following guidelines when defining the limits of the River. At the sides of the river all parts of the substratum were included which were likely to be submerged for more than 85% of the year. The 'bank' can be usually defined as that part of the side of the river (or islands) which are submerged for more than 50% but less than 85% of the time. In general terms, therefore, 'river' records are reserved for those macrophyes which occur in the region of the river which is rarely uncovered, and those shallow sections which have an upper limit that may be exposed for a maximum of 50 days in any year. 'Bank' records are for those plants that occur above the limit of the 'river' plants, and are thus out of the water for more than 50 days in any one year, yet will be submerged, or partially so, during mean flow periods. The upper limit of the 'bank' excludes all the areas of the bank which are submerged during the 150 days of each year when river flows are at their highest. In most cases such estimates involve guesswork, but at least the adoption of a particular submegence level does allow a greater flexibility in the interpretation of data and possibly a clearer insight into the ecology of individual species and communities at different sites.

The macrophyte survey thus only records the presence or absence of species on a checklist and limits itself to the channel and base of the banks.

The results from the surveys have been tabulated for information. This shows that wherever a species was present within a 0.5km site it has been indicated by a double set of numbers, these are either in the column marked 'R' for river or 'B' for bank. In the case of marginal plants it is not uncommon for the species to be recorded in both habitats.

To show which species in each 0.5km were most common, two estimates of abundance were given for each of the macrophytes found in each of the lengths surveyed. The first figure in each column refers to the relative abundance of one species against another; this only gives an indication of which species were the most common but does not indicate how abundant

each one was. The second figure of abundance is a subjective assessment of abundance based on the percentage of the river bed or bank covered by each macrophyte. Both are on scale 1-5.

To interprete the Table of Results an example of the type of information presented in the Table is given beow for two adjacent 0.5km sites.

	UPSTREAM 0.5km		DOWNSTREAM 0.5km	
	River	Bank	River	Bank
Sp A	55		55	
Sp B	11	11	11	11
Sp C	32	54		
Sp D	32	54	33	55
Sp E	43		45	

The figure in each column represents the relative abundance of the species (on scale 1-5) in either the river or the bank and the second figure represents a cover valule on a scale:

1	=	covering less than 0.1% of stream or bank
2	=	covering between 0.1-1% of stream or bank
3	=	covering between 1-5% of stream or bank
4	=	covering between 5-10% of stream or bank
5	=	covering more than 10% of stream or bank

In the example above, therefore;

Species A is dominant in both 0.5km lengths in the river, it covers more than 10% of the river but does not occur on the bank.

Species B is rare, present in both river and bank habitats in both lengths and does not exceed 0.1% cover.

Species C Present only in upstream 0.5km length, is co-dominant with species D on the banks by covering 5-10%, is frequent relative to other species within the river and covers between 0.1-1%.

Species D Present in both upper and lower 0.5km lengths, is again dominant on the banks. Although relative to other species it is at the same frequency in both sites in the lower site the actual areas of the rive it covers is between 1-5% and not less than 1% as it is in the upper site.

Species E Sub-dominant in the river but the actual cover is less than 5% in the upper site and more than 10% in the lower site.

APPENDIX D2

HALCROW

ROADFORD OPERATIONAL AND ENVIRONMENTAL STUDY

STAGE 1: ECOLOGICAL STUDIES.

Environmental Impact Assessment of Roadford Reservoir and its operation on the downstream macroinvertebrate communities of the River Tamar system.

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26 February 1990

CONTENTS

D6.1.1 INTRODUCTION
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D6.1.1A As part of the Roadford Operational and Environmental Study, an environmental assessment of Roadford Reservoir on the downstream macroinvertebrates has been undertaken.
The objectives of the macroinvertebrate study are:

1) to analyse the macroinvertebrate data existing for the Rivers Wolf, Thrushel, Lyd and Tamar and, together with a literature review, to assess what the impacts of the scheme will be in relation to predicted changes in water quality, substrate and hydrological aspects, including hydroelectric power (HEP) generation.

2) to consider what community changes are likely to occur, identifying those species which are most vulnerable and those which will benefit.

3) to consider the relative importance and conservation value of the species in the context of their catchment, regional and national distribution.

4) to consider the consequence of significant changes in total biomass of the macroinvertebrate populations on other river fauna.

These objectives will be addressed within the overall concept of an "Environmental Impact Assessment" study (EIA).

Many environmental factors are known to influence the composition and abundance of stream invertebrates. However, temperature, flow, water chemistry and their indirect and interacting effects may be considered the major factors controlling the macroinvertebrates downstream of reservoirs. Substrate is also an important factor but it largely depends on the flow regime and local geology (Ward & Stanford 1979; Brooker 1981).

While it is convenient to take a simplistic approach and consider each of the major controlling factors separately, it must be remembered that any changes in community structure are likely to be the result of a complex interaction of several environmental variables.

D6.1.1B River flow
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Roadford is primarily a water supply reservoir and will be used both as a regulation release and direct supply reservoir. Secondarily, demands will be placed on the water for recreational, HEP generation and environmental purposes, including the use of a fisheries reserve. As a consequence of the various operational scenarios, artificial discharge variations will occur. These will involve fluctuations of water depth and velocity having "unnatural" rates of change, duration and frequencies. Until such time as the demand horizon has been met, a considerable range of combinations of release duration, magnitude, frequencies and sequences is inevitable.

It is recognized that the effects of Roadford and its operation on the flow regime will generally be most marked immediately downstream from the reservoir. Changes to the natural flows will result from the introduction of a compensation flow (9 Ml/d) and patterns of regulation releases for supply and HEP purposes (Annexes D6.1Ai and D6.1c/d).

Water chemistry

Storage of water in open reservoirs induces physical, chemical and biological changes in the stored water. Many factors influence the quality of reservoir discharges, but those factors that control stratification, and hence releases of different water quality from the various draw-off levels, are particularly important.

The success of Roadford as a river regulating reservoir hinges on it being destratified in the summer period. Control of thermal stratification in the water column will suppress important associated problems, reduce anoxic conditions, inhibit ammonia production, control iron and manganese resolution and limit phosphorus release from the sediment.
The destratification equipment (two lines and compressors) and the use of multilevel draw-offs, together with detailed water quality monitoring of the reservoir will enable the best water quality to be released to the River Wolf and reduce the chance of non-compliance in the receiving waters. Overall it is anticipated that the operation of Roadford as a regulating reservoir will be relatively trouble-free.

With the present inflow of nutrients Roadford will be a mesotrophic reservoir. The mesotrophic state of Roadford Reservoir must be maintained by the adoption of a catchment management policy. The long retention time is a valuable asset and should not be negated via increase in nutrient export from the catchment.

Sedimentation and channel morphology

Approximately 90% of the sediment load will be trapped in the new reservoir, at least during the early years. The clear-water reservoir releases may lead to erosion of the river bed immediately downstream of the reservoir. Flow regulation will reduce flood magnitudes and the ability of the discharge to transport sediments. It should be appreciated that channel changes downstream of Roadford Reservoir may take a considerable time to be completed, certainly not less than 5 years.

During the construction phase of Roadford Reservoir, the sediment loading to the River Wolf downstream of the reservoir site increased. Signs of siltation were found up to the confluence of the R. Wolf with the R. Thrushel (W14, Milford), as the deposits progressively migrated downstream. The effects on the invertebrates will continue to be monitored in the early years of impoundment, but the impact will be reduced with increasing distance from the reservoir site.

Water temperature

The degree of thermal modification in the receiving stream due to impoundments depends primarily on the thermal stratification pattern of the reservoir, the release depth, the retention time, and reservoir operation (Ward & Stanford 1979).

Deep-release reservoirs, where water is drawn from the cold hypolimnion, induce fairly consistent thermal changes in the downstream river. The diel and seasonal fluctuations in temperature are reduced, the spring rise in

water temperature is delayed (summer-cold conditions) and the autumn fall in water temperature is delayed (winter-warm conditions).
The influence of surface-release dams on the temperature of the receiving waters is similar to that of natural lakes, although reservoir retention times are often less. Elevated summer temperatures were observed in previously cold-water streams (Fraley 1979; Ward & Short 1978).

The impact of the modified temperature regime will be local to the reservoir with temperatures reaching ambient within a relatively short distance.

Mineralization and manganese deposits

During the construction phase of Roadford, a large area of the lower reservoir basin was excavated. The natural weathering of the unweathered material resulted in elevated levels of *e.g.* iron, manganese, aluminium and sulphates in the drainage waters of the quarry area which, although capped and land-scaped, discharged to the River Wolf.
Manganese loading has been oxidized by the natural turbulence of the river over the riffles and the oxide deposited on the river bed. Under the present conditions, the area most vulnerable will be the first 1.5 km downstream from the reservoir. This is seen as a temporary problem associated with the first years of operation.

The potential increase in manganese due to thermal stratification and associated problems is a separate issue, but one that can be controlled by prevention of stratification in the reservoir.

D6.1.2 MAJOR TAXA OF THE LYD SUB-CATCHMENT

Since 1985 quantitative cylinder samples have been taken in spring and autumn on those stretches of the Rivers Wolf, Thrushel and Lyd due to be affected by the construction and subsequent impoundment of Roadford reservoir. In addition five sites were sampled on the River Tamar (Hilton 1986; Ingelrelst 1987, 1988). Previous surveys using qualitative kick samples were carried out in 1982 and 1984 (Logan 1982, 1984).
In June 1989, eight sites -corresponding to the routine cylinder sampling sites W9, W11, W12, W14, T1, T4, L1 and L5- were chosen to investigate the occurrence of macroinvertebrates in pools, tree roots and submerged macrophytes (Ingelrelst 1989b) (Annexes D6.1i and D6.1Aiv).

The benthic river fauna in the R. Wolf, Thrushel and Lyd is typical of similar rivers in the South West. Two species however are of regional importance: the stonefly *Amphinemura standfussi* and the caddis *Athripsodes bilineatus*.

From 1985 onwards, 170 taxa were found in the whole of the Lyd catchment (including 21 taxa collected in the pools, tree roots and submerged macrophytes that were never found in the cylinder samples [Annex D6.1iv]).

The quantitative data used for the EIA were collected for the period 1985-spring 1989 from the sites W4-W14, T3-T5 and L4-L5, plus one site sampled in 1987 at the actual dam site (Annexes D6.1a and D6.1Aii/iii). The relative abundances given below are for those sites only:

<u>Mollusca</u>: 6 families, 8 taxa, 1.9% of the benthos abundance in spring and 6.4% in autumn. Only *Potamopyrgus jenkinsi* and *Ancylus fluviatilis* are well represented.

<u>Oligochaeta</u>: 28.1% of the benthos in spring and 37% in autumn. Tubificidae are dominant.

<u>Ephemeroptera</u>: 6 families, 14 taxa, 25.6% of the benthos in spring and 14.2% in autumn. The dominant species are *Rhithrogena semicolorata*, *Baetis rhodani* and *Ephemerella ignita*.
In the spring of 1989, highly significant increase of *Caenis rivulorum* at the most heavily silted site (W7), immediately downstream of the dam. Conversely, *R. semicolorata* decreased downstream of the dam.

<u>Plecoptera</u>: 6 families, 18 taxa, 4.8% of the benthos in spring and 3.8% in autumn. *Leuctra fusca*, *L. geniculata* and *Chloroperla torrentium* are the most abundant.
In the spring of 1989, overall decrease of stoneflies downstream of the dam down to the confluence with the Kellacott Stream (except at W8).

<u>Elminthidae</u>: 4 species, 4.4% of the benthos in spring and 9.8% in autumn. *Limnius volckmari* is dominant, then *Elmis aenea*.

<u>Hydropsychidae</u>: 4 species, 2.9% of the benthos in spring and 5.9% in autumn. *Hydropsyche siltalai* is by far the most abundant species, then *H. pellucidula*.
Low occurrence downstream of the dam.

Polycentropodidae: 3 species, 0.15% of the benthos in spring and 0.26% in autumn. *Polycentropus flavomaculatus* is the most abundant.
Relatively high density at W7 immediately downstream of the dam.

Rhyacophilidae: 2 species, 0.53% of the benthos in spring and 0.62% in autumn. *Rhyacophila dorsalis* is virtually the only species present.

Other caddis: Glossosomatidae: 2 taxa, 2.3% of the benthos in spring, 2.1% in autumn. *Agapetus* is dominant.

Limnephilidae: 8 species, 0.12% of the benthos in spring and 0.25% in autumn.

Lepidostomatidae: 1 species *Lepidostoma hirtum*, 0.21% of the benthos in spring and 0.21% in autumn.
Confined to the lower reaches of the R. Wolf, to the R. Thrushel and R. Lyd.

Brachycentridae: 1 species *Brachycentrus subnubilus*, 0.15% of the benthos in spring and <0.1% in autumn.
Confined to the lower reaches of the R. Wolf, to the R. Thrushel and R. Lyd.

Chironomidae: 8.3% of the benthos in spring and 4.2% in autumn.

Simuliidae: 15.2% of the benthos in spring and 5.4% in autumn.
Low occurrence downstream of the dam.

Hynes (1970) rightly stresses that for no obviously catastrophic reason there can be considerable changes in the faunal composition of the benthos from year to year. This variability occurs in the Lyd catchment as well (Ingelrelst 1987, 1988, Tables 4 and 5) and should not be ignored when making use of the abundance data.

Several species collected from pools, tree roots and submerged macrophytes were never captured in riffles before, especially among the beetles and water bugs. Three new mayflies (Baetidae) were discovered. The damselfly *Agrion virgo* occurred regularly in tree and grass roots. One caddis of local importance, *Adicella reducta*, was also found in tree roots (Annexes D6.1iv and D6.1Aiv).

Other species were more abundant in those biotopes than in riffles such as the snails *Lymnaea peregra* and *Potamopyrgus jenkinsi*, the mayflies *Ephemerella ignita* and *Habrophlebia fusca* and the caddis Polycentropodidae, Limnephilidae, Lepidostomatidae and Brachycentridae.

D6.1.3 EFFECT OF IMPOUNDMENT ON DOWNSTREAM MACROINVERTEBRATES, AND IMPACT ASSESSMENT OF ROADFORD RESERVOIR

D6.1.3A River flow

The direct effects of flow are in many cases inseparable from the indirect effects resulting from changes in the substratum and water quality.

* In the upper reaches of the catchment, the increase and stabilization of low discharges during the summer months may bring an increase in the area of shallow riffles (this will be the case for instance at sites W10 and W12) which generally support greater densities of macroinvertebrates than deeper pools (Annex D6.1e). The net result will be a greater overall productivity at those sites. At higher flows however, riffle-pool sequences will be engulfed, which can result in a reduction in overall population numbers (Trotzky & Gregory 1974).

* Natural spates and floods where bedload transport is involved can have a dramatic effect, leading to a considerable reduction in abundance of most taxa (Hynes 1970; Irvine 1985; Petran & Kothé 1978). In the Wolf catchment, the floods that occurred during the autumn of 1987 clearly demonstrated the above impact. By contrast, both the density and relative abundance of Eiminthidae (riffle beetles) and of molluscs increased compared to their spring value (Ingelrelst 1988).

A reduction of peak discharges (spates less severe and frequent) is expected downstream of a dam and this is beneficial to the bottom fauna. However, the elimination of spates also leads to increased siltation.
Regulation of the Tees by Cow Green Reservoir led to the elimination of daily maximum discharges >8 times the annual mean and to a marked decrease in the frequency of discharges >5 times the annual mean. This pattern holds true throughout the year, despite the fact that 80% of this discharge in some winter months is uncontrolled flow down the spillway (Armitage 1976, 1977; Crisp 1977).
However, in a preliminary analysis of the flow regime of regulated rivers in the U.K., Bussell (1979, in Brooker 1981) showed that this reduction of the magnitude of the discharge was measured immediately downstream of the impoundment but was not perceptible at lowland sites.
This effect on the Wolf due to regulation by Roadford Reservoir is unlikely to persist further down the confluence with the rivers Thrushel or Lyd.

Annex D6.1iii presents the annual summary of river flow for a typical year (1980) at Combepark Farm on the River Wolf, just downstream from the dam. If one compares those values with the recommended flows for HEP operation (Annexes D6.1Ai and D6.1c/d) it appears that the effect of regulation will be one of increasing the seasonal (at least in spring and summer) and annual daily mean flow (DMF) and increasing the seasonal (at least in autumn and winter) flow constancy.

Ward (1976b) reviewed the effects of flow patterns below large dams on stream benthos and noted that more seasonal flow constancy could compensate for the adverse effects of daily flow fluctuations.

With the absence or reduction of destructive spates downstream of the dam, the tendency will be for greater bank and bed stability, leading to greater plant growth and mosses and algae cover. These changes would in general be favourable to benthic invertebrates, *e.g.* Oligochaeta, Chironomidae, grazing snails such as *Lymnaea*, the mayflies *Ephemerella ignita* and *Caenis rivulorum*, the caddis Hydropsychidae and the shrimp *Gammarus*.
In the Tees below Cow Green Reservoir, these plants have been put forward as a possible reason for striking increases in the numbers of *Nais* spp. (worms) and chironomid midges (Orthocladiinae) after regulation, but also for the scarcity of the mayfly *Rhithrogena semicolorata* (Armitage 1976).

During the surveys in conjunction with Roadford, the caddis *Hydropsyche siltalai* was consistently found in large numbers wherever samples were taken in mosses - Lifton Gauge (L5) on the Lyd in the autumn of 1987 (Ingelrelst 1988) and Cross (33) on the Torridge in the spring and autumn of 1987 (Ingelrelst 1989a).

The most adverse effects of flow regulation are likely to result from large and rapid (within minutes) flow variations downstream of HEP generation dams, particularly when they are associated with short-term changes in water quality and temperature linked with fluctuations in draw-off location. Examples abound in the literature, especially from North America, but the recommended flows at Roadford Reservoir (Annexes D6.1Ai and D6.1c/d) bear no comparison with the flows described for some of those huge schemes. The operational strategy is different as well, for most North American schemes are deep-release reservoirs. To give an example, Fisher & Lavoy (1972) studied the distribution of macroinvertebrates on a bar 425 m long and 70 m wide, 10 km below Turner's Fall dam in Massachusetts. The bar was completely submerged under high flow and exposed during low flow, representing a "tidal" amplitude of about 1 m. Few invertebrates, except chironomid midges, were recorded in the tidal zone.

Natural spates can rise very quickly but recede more slowly than artificial releases, especially in the lower stages. Abrupt increases or reductions in discharge must be prevented, the changes should be gradual. Ward (1976b) noted that adverse effects of daily flow fluctuations could be overcome by more seasonal flow constancy, attributing this phenomenon to a more stable substrate.

Stability of the substrate and algal growth increased after impoundment of Cow Green Reservoir on the Tees, although very high flows (23.4 cumecs) did occur when the reservoir overflowed down the spillway. These high flows do not however carry the coarser particles, which settle in the reservoir, and consequently do not have a marked scouring effect on the river bottom (Armitage 1976).

* Flow perturbations have been shown to cause both immediate and delayed (nocturnal) increases in invertebrate drift (Brooker & Hemsworth 1978; Corrarino & Brusven 1983, in Irvine 1985; Elliott 1967a,b; Pearson & Franklin 1968).

Scullion & Sinton (1983) investigated the effects of artificial freshets in two impounded rivers in mid-Wales. The releases had insufficient force to initiate bed-load movement. A six-fold increase in flow in the River Tywi (1.8 to 10.9 cumecs) was maintained for 3 days in May at a riffle 3.2 km downstream from Llynne Brianne Reservoir and then reduced to 5.9 cumecs. A three- to four-fold increase in flow in the River Elan (1.2 to 4.1 cumecs) was maintained for two days in June at a riffle 4.8 km downstream from Caban

Coch Reservoir and then reduced to 1.4 cumecs.
Total abundance and the densities of many major benthic taxa and species were reduced but the differences were not significant. The relative abundance of major taxa did not change in the River Elan but in the River Tywi there was a relative decrease in the stoneflies and a corresponding increase in the chironomid midges. The numbers of drifting invertebrates increased substantially but were back to pre-freshet levels four hours later.
The drift was dominated by Chironomidae (65%) and stoneflies (25%). The midges responded immediately to the increase in discharge but stonefly drift increased later, during the night.

Irvine (1985) investigated the effects of successive flow perturbations. The discharge in a stream was augmented fivefold and then returned to its original state three times between 17:00 and 21:00 in one day. This treatment was repeated on four successive days each week for three weeks. Each period of increased flow lasted 45 min with 45-min low flow periods between. Flow fluctuations occurred virtually instantaneously.
There was a decline in the density of all major benthic taxa except molluscs, a decrease in the relative abundance of worms and an increase in the proportion of riffle beetle larvae and chironomid midges. Invertebrate drift density increased significantly during the first flow variation after several months of stable flows, but the increase was less with each successive fluctuation. Many of the invertebrates displaced probably had been resident in sloughed off filamentous algae. The three taxa common in attached algae (worms, chironomid midges and caddis larvae) were also numerous in the drift. At the end of three weeks of varying flows, fluctuations had no effect on the density of drifting invertebrates except for terrestrial insects. This was attributed to depletion of the benthos, which was partly the result of loss of invertebrates to drift, but some taxa probably migrated downwards into the substrate (hyporheic zone) to avoid scouring (Poole & Stewart 1976).

Only a small proportion of the benthos (<0.01% in Elliott 1967a,b; 0.027% in Irvine 1985) is usually found in the drift. Elliott (1967b) showed that the invertebrates were in the drift for a short period of time and travelled only a short distance if conditions allowed a quick return to the benthos. He concluded that drift was a passive phenomenon, strongly correlated with the amount of water flowing down the stream. Other studies however showed that invertebrates actively entered the water column (Müller 1963b, in Elliott 1967b). Kohler (1985) found that active drift was a component of the mayfly *Baetis* food searching behaviour. Active drift would also account for increases in drift sometimes observed with decreases in flow (Anderson & Lehmkuhl 1968; Minshall & Winger 1968).

During the first 12 months of the filling phase, which started on 20 October 1989, the River Wolf downstream of Roadford dam will receive a constant compensation flow of 9 Ml/day (0.10 cumecs). Various combinations of higher maintained flows and hydrogeneration releases will occur in the following 12/24-month period. It is clear that the first releases for supply or HEP generation will increase the invertebrate drift density, although an equilibrium will eventually take place. The loss of invertebrates through drift will be compensated by the material (invertebrates and plankton) drifting from the reservoir.

* During the construction of a reservoir sediment input into the river downstream from the works inevitably increases. A representative rate of erosion of construction works relative to forest=1 is 2000 (grassland relative to forest is 10) (Canter 1983). High sediment loads have an adverse effect on macrophytes and benthic macroinvertebrates (Armitage 1984; Cline &

Ward 1984).

Sediment conservation practices used at Roadford dam site reduced the input into the stream. A recommended suspended solids concentration (SSC) of 45 mg/l which should not be exceeded by construction site run-off was exceeded at the dam site by natural flood events for 13% of the time in 1986 and 11% in 1987. At Broadwood (site W11) these figures were 11% of the time in 1986 and 5% in 1987 (FBA 1988). Samples taken between 22/09 and 06/10/1987 in the Wolf catchment revealed obvious signs of siltation of the surface riffle gravels within a 300 m reach of the dam site. A substantial quantity of fine sediments had accumulated in the intervening pools, consisting mainly of medium sand (Petts 1987). The sedimentation study of October 1988 again showed elevated concentrations of fines local to the dam site with approximately 18% finer than 2mm. Highest concentrations occurred in the lower (15-30 cm) layer. Since the 1987 survey the proportion finer than 1mm at the local sites has increased from 10% to 13% of the substrate by weight. At sites further downstream from the works, and at the control sites, the proportion of fines has remained unchanged or has declined over the same period. The 1988 survey demonstrated that the construction works have had an impact on the spawning gravels for at least 3 km, possibly 5 km, downstream of the dam (Petts 1988).

During the macroinvertebrate sampling in the spring of 1989 (routine cylinder samples and special habitats survey in pools, tree roots and submerged macrophytes [Ingelrelst 1989b]), signs of siltation were found up to the confluence of the R. Wolf with the R. Thrushel (site W14, Milford). An impoverished invertebrate fauna typical of slow-flowing, silted areas has now developed downstream from the dam down to the confluence with the Kellacott Stream (sites W7-W12), and to a lesser extent further down to the confluence with the R. Thrushel (sites W13-W14) (Annex D6.iv). There has been a decrease in the numbers and diversity of stoneflies, although *Leuctra geniculata* and *L. fusca* were largely unaffected. The density of the mayfly *Rhithrogena semicolorata* was overall lower but that of the closely related *Ecdyonurus* did not change. The second site downstream of the dam (W8) was rich in stoneflies (8 species) and the abundance of *Rhithrogena* was not depleted, but no particular reason could be found. Other faunal changes were the absence or notable reduction of the caddis *Rhyacophila dorsalis* and *Hydropsyche siltalai* and of blackfly larvae (Simuliidae). Changes were most significant at the most heavily silted site, immediately downstream of the dam (W7). There was a significant increase in the numbers of the mayfly *Caenis rivulorum* (1280 individuals/m^2) and 19 water-mites (Hydracarina) were captured whereas these are otherwise very rare in the samples.

When the reservoir becomes fully operational and regulation releases are made to the River Wolf, the upper layer of silt and sand will be washed away to be re-deposited in areas of low current velocity. Deeper layers of the substrate may remain silted to some extent since that silt will be less easily flushed out. Siltation of the substrate is considered a temporary problem as long as remedial action is taken in the first 12-18 months of impoundment. Compaction of the sediment will otherwise result. The ingress of fine sediments into the substrate and the compaction therein are more significant to fish than surface silting (FBA 1988). It is detrimental to the benthic fauna by clogging interstitial spaces, thus reducing substrate heterogeneity, which in turn reduces species diversity.

Most effects of Roadford Reservoir (temporary low flows and siltation, temperature changes, flow patterns) will be local to the dam and with

greatest impact immediately downstream of the reservoir.
During the present conditions of low flows (9 Ml/d) and resulting siltation, the input of the relatively small Kellacott Stream already proved to be beneficial to the invertebrates and fish. Spates emanating from this small catchment have resulted in flows of 300 to 400 Ml/d (DMF) at the Wolf confluence. The confluence of the R. Thrushel and R. Lyd will further help to mitigate any adverse effects of regulation.
It is then unlikely that the operation of Roadford will have any visible detrimental effects on the macroinvertebrate populations of the R. Tamar.

D6.1.3B Water chemistry

* Gross deoxygenation and the generation of hydrogen sulphide in the hypolimnion of an impoundment will severely affect invertebrates immediately downstream of deep-release reservoirs (Davies 1979, in Brooker 1981) but generally equilibration will be rapid and the effects local. Low levels of dissolved oxygen will commonly be accompanied by relatively high concentrations of iron and manganese, both in soluble form and associated with particles. Local settlement of the particulate phase may occur and form deposits on the river bed, as was observed downstream of Caban Coch Reservoir in mid-Wales. Total iron and manganese concentrations were much higher in the regulated River Elan than those recorded in natural streams of the catchment. Compared to the nearby unregulated River Wye (Brooker & Morris 1980), there were fewer caddis, mayflies and beetles or they were absent completely (Inverarity et al. 1983; Scullion et al. 1982).

  It is probable that iron and manganese concentrations in Roadford Reservoir will be high enough to be troublesome if deoxygenation occurs (Collingwood 1987). Water in the reservoir however will be artificially mixed and thus prevent anaerobiosis. Detailed monitoring of water quality in conjunction with the operation of the destratification equipment and draw-off levels will reduce the risk of deterioration in water quality standards of the receiving waters.

* The production of plankton and algae in the reservoir enhances the production of filter-feeders (e.g. Simuliidae [blackflies] and the net-spinning caddis Hydropsychidae and Polycentropodidae) downstream of the dam. Deep-release reservoirs however may have reduced populations of filter-feeders downstream of the dam. Ward (1975, in Armitage 1978) suggested that hypolimnial plankton was not a reliable enough food source for the build-up of a fauna depending on suspended matter. In a study of differentially regulated sections of a Colorado mountain river, Ward (1976a) attributed the low numbers of Hydropsychidae below the dam to a reduction of particle size diversity due to the clarifying effect of the reservoir.

  Microcrustaceans completely dominated numbers and biomass in the drift below Cow Green Reservoir on the Tees. Despite that supply of zooplankton from the impoundment, filter-feeders were present in relatively low numbers but the reason for that was not clear. Simuliidae might have been at a competitive disadvantage for settlement with the very high densities of *Hydra* found below the dam. Hydropsychidae were rare before and after the reservoir was built. Low numbers of Polycentropodidae were possibly due to sampling in riffles only (Armitage 1976, 1978, 1979).

  The enriching effect of lake outflows does not persist very far because plankton usually settles rapidly (Armitage 1979; Keefer & Maughan 1985).

Below Cow Green Reservoir, the greatest losses in zooplankton occurred in the first 400 m below the dam (Armitage 1979). The persistence of plankton in the river will depend on factors such as species size, flow, temperature and the presence of vegetation. Cold weather and high flows caused the drift of organisms to extend much further downstream than usual (Keefer & Maughan 1985). Ward (1975, in Brooker 1981) showed that the downstream persistence of zooplankton was positively related to the magnitude of the river flow and negatively correlated with the species size.

Below Cow Green Reservoir, macroinvertebrate abundance and biomass were greatest about 200 m below the dam. Thereafter both parameters decreased and species diversity increased. Diversity was not significantly different 500 m below the dam from that in the unregulated tributary Maize Beck (Armitage 1978). Illies (1956, in Hynes 1970) found large changes in invertebrate biomass and species composition in a lake outflow within a distance as little as 20 m. Passive filter-feeders were dominant 15 m from the outlet whereas 215 m below the lake active feeders became dominant.

* It has been shown that the merging with unregulated tributaries rapidly improves water quality, temperature and food resources. This caused caddis populations and diversity downstream from an HEP dam in Idaho (U.S.A.) to increase and approach near normal levels (Brusven 1984; Munn & Brusven 1987).

Downstream of Roadford reservoir, the convergence of three rivers (Thrushel, Lyd and Tamar) will mitigate any adverse effects of regulation. Most effects of the operation of Roadford will be felt immediately downstream from the dam.

Stored water from a reservoir can be of considerable benefit in improving water quality should a discharge of farm wastes or chemicals occur in the downstream reaches (Armitage 1979; Brooker 1981). The potential adverse effects of a sudden discharge of water on the downstream fauna can be weighed up against the benefits of diluting the pollutants.

D6.1.3C Temperature

* The development of many stages in the life cycles of macroinvertebrates is known to be temperature dependent (Elliott 1972, 1978) and the downstream effects of impoundments on temperature regime are likely to be of considerable importance in determining benthic communities.

* Deep-release reservoirs in temperate, cold countries have drastic effects. The winter warm releases prevented ice cover formation within 20 miles from the outlet of a dam on the Saskatchewan River in Canada (the river freezes up from November to April at a control station). The number of species and abundance of mayflies and other insects were greatly reduced and the effect was still evident 70 miles downstream. While 19 species of mayflies were present upstream of the reservoir, none were recorded below the outlet and only 7 species were found 70 miles downstream of the dam . Those species lacked the environmental stimuli (t° sequence, total degree-days) necessary to cue developmental stages and thus could not succesfully reproduce (Lehmkuhl 1972).

* In regions with a more equable climate, such as Great Britain, the effects of winter warm conditions will be less drastic (Ward & Stanford 1979).

Water from Cow Green Reservoir on the Tees is drawn simultaneously from a top and bottom draw-off. The release did not have any gross discernible effect, although the water downstream of the dam was warmer in winter and colder in summer than in the control tributary Maize Beck. It is however possible that the timing of the life histories of certain taxa was altered (Armitage 1979).

Boon (1987) investigated the influence of Kielder Water (River North Tyne, NE England) on caddis populations downstream from the dam. The reservoir forms one of Europe's largest man-made lakes (3.6 times Roadford's surface area, maximum depth 52 m). The water downstream of the dam is warmer in winter and cooler in summer than unregulated streams in the region, with the maximum temperature delayed by about 1 month. Seasonal variations are reduced and these changes are noticeable for 15-16 km downstream. The growth rates of *Hydropsyche siltalai*, *H. pellucidula* and *Rhyacophila dorsalis* below the dam were accelerated during the winter and retarded in the summer, apparently correlated with the winter-warm, summer-cool discharges from the reservoir. The mean final weight of mature *H. pellucidula* larvae (unlike *H. siltalai* or *R. dorsalis*) was 30-55% greater below the dam than above it, and that difference was statistically significant.

The blackfly *Simulium*, the freshwater shrimp *Gammarus* and Chironominae midges replaced Baetidae (mayflies), Elminthidae (riffle beetles) and the caddisfly *Hydropsyche* downstream of a deep-release and stratified reservoir and this was attributed to changes in thermal regime (Hilsenhoff 1971). Similar faunal shifts have been reported from other rivers receiving cold water discharges with shrimps, chironomid midges and worms generally replacing beetles and mayflies (Blanz et al. 1969, Brown et al. 1967, in Brooker 1981; Lehmkuhl 1972).

* Despite great differences in stream size, macroinvertebrate communities below two surface-release dams in Montana and Colorado were similarly modified by regulation. The total invertebrate density increased, but species diversity was reduced. Stoneflies were severely affected, whilst Hydropsychidae (caddis) became the most abundant taxon (Fraley 1979; Ward & Short 1978).

Caddisfly production generally increases below surface-release dams due to increased food supply (plankton from the reservoir) and favourable water temperatures (Henricson & Sjöberg 1984; Parker & Voshell, 1983; Simmons & Voshell 1978). By contrast, hypolimnetic releases typically affect caddisflies in a negative manner (Hilsenhoff 1971; Zimmermann & Ward 1984).

* In stratified reservoirs, surface water releases will have less adverse effects on the invertebrate populations than the water drawn from the lower layers of the reservoir.

At Roadford, artificial mixing of the water body will allow draw-offs at various depths by reducing the temperature differential between the surface and lower layers. Artificially mixed water drawn from the surface of Roadford Reservoir will probably benefit the community as a whole, at least in terms of increased standing crops. This in turn will be beneficial to the fish. Increased standing crops would be at the expense of a reduction in species diversity. This is thought to be acceptable if it were to benefit the fish and considering the fact that those changes will not persist very far downstream of the dam (probably not further than the confluence with the Thrushel or the Lyd).

D6.1.4 Major taxa

D6.1.4A Mollusca (snails and mussels)

* Gastropoda (snails) are usually enhanced below impoundments with a more constant flow regime, even when short-term fluctuations are superimposed (Ward 1976b). Less extreme flows below Cow Green Reservoir on the Tees encouraged the development of large populations of molluscs, particularly *Lymnaea peregra* (Armitage 1976). Investigating the effect of flow increases on stream benthos, Irvine (1985) noted a decline in the density of all major taxa except molluscs.

One effect of impoundments on water chemistry is a pronounced smoothing of short-term ionic concentrations fluctuations which are typical of natural rivers. The fluctuations in outflowing water are smaller than those of the water entering the reservoir.
Where soft, nutrient-poor upland water is released from a reservoir to support low natural flows, especially in summer when ionic concentrations in river water are likely to be at their highest, considerable dilution and softening of the natural drainage may occur and influence the distribution of some macroinvertebrates, *e.g.* Mollusca and Amphipoda (shrimps), which have a minimum requirement for chemicals such as calcium (Edwards et al. 1978; Edwards & Crisp 1982). Freshwater snails can be separated into two groups according to the minimum calcium concentration they can tolerate (Macan 1977). One group comprises the hard water species, *i.e.* those species which are never or practically never found in soft water. From the snail standpoint water ceases to be soft at a concentration of calcium of about 20 mg/l (20 parts per million). The second group is made up of all those species which can tolerate soft water, although they will be found in hard water as well.

Sphaeriidae were shown to be more abundant than expected below reservoirs characterized by a reduced and near constant downstream flow. Reduced flows and silty stone surfaces are beneficial to these deposit feeders (Armitage et al. 1987).

Extence (1981) found *Lymnaea* resistant to prolonged stranding.
Lymnaea peregra made up 17% of the invertebrate abundance (243 individuals/m²) below an HEP dam in Sweden where zero discharge was allowed at night on average 15 days per month, with a corresponding drop in water level of about 1 m and velocities of 0-60 cm/sec. Below another dam with average daily flow fluctuations of 280-390 cumecs but a water level almost constant, the relative abundance of *L. peregra* was 10% (151 ind./m²) in the littoral area and 4% (173 ind./m²) in the middle area of the river (Henricson & Sjöberg 1984). The growth of benthic and filamentous algae increased after regulation below those two dams and this in turn enhanced the production of grazing invertebrates.

** The relative abundance of molluscs is 1.9% in spring and 6.4% in autumn (Annexes D6.1Aii/iii). Two species, *Potamopyrgus jenkinsi* and *Ancylus fluviatilis* are collected throughout the Lyd catchment, without being abundant. It was common however in tree roots samples and sometimes very abundant (T1 and L5) (Annex D6.1Aiv). *L. peregra* is rare in the samples but it turned up more frequently - without being common - in samples taken from tree roots or submerged macrophytes. Sphaeriidae are rare in the Lyd

catchment and did not increase in abundance downstream of Roadford Reservoir due to construction works.

During the autumn of 1987, heavy rain and subsequent major flooding considerably reduced the abundance of invertebrates, except that of molluscs and riffle beetles (Elminthidae) (Ingelrelst 1988), an effect similar to that observed by Irvine (1985).

All the snails from the Lyd catchment are soft water species and indeed mean calcium concentrations are < 20 mg/l (Annex D6.1ii). It is then unlikely that any dilution effect will affect the distribution of snails downstream of the reservoir.

*** Operation of Roadford Reservoir will result in a greater seasonal flow constancy below the dam. Spates will be less severe and frequent and this should benefit the mosses and algae due to subsequent greater bed stability. This in turn could lead to increased numbers of grazing snails.

Potamopyrgus may well increase in abundance during the filling of the reservoir, when flows downstream of the dam are low and constant and siltation occurs. Conversely, this will be detrimental to *Ancylus*.

The regulated conditions and resulting effects should not be detrimental to the molluscs as a whole, neither during the first years of filling of the reservoir nor when the reservoir will be fully operational (higher maintained flows and HEP releases).

D6.1.4B Oligochaeta (worms)

* A striking increase in the numbers of Naididae (*Nais* spp.) occurred after regulation below Cow Green Reservoir on the Tees (Armitage 1976, 1978, 1979). This was attributed to the increased standing crop of mosses and algae that resulted from greater seasonal flow constancy downstream of the dam.

The deposit feeders Naididae and Lumbriculidae were found to be more abundant than expected downstream of reservoirs with a reduced and near constant flow (Armitage et al. 1987).
Similar faunal changes were observed in the regulated River Elan. The Chironomidae and Oligochaeta were the dominant taxa in the riffle (53% and 26% respectively). The River Elan downstream of Caban Coch Reservoir receives a constant compensation flow of 1.4 cumecs and a substantial reservoir overspill in the winter. The temperature regime is altered by deep water releases and the river bed is covered by iron- and manganese-rich deposits (Scullion et al. 1982).

The density of worms increased downstream of deep-release reservoirs in Colorado. The thermal pattern was typically greatly modified (Zimmermann & Ward 1984).

The amount of information about the effects of regulation on worms is surprisingly scarce from all the papers consulted. Most workers concentrate on mayflies, stoneflies, the filter-feeding caddis, Chironomidae and Simuliidae.

** Oligochaeta (mainly Tubificidae) are usually the dominant group at the sampling sites in the Lyd catchment (28% in spring and 37% in autumn, Annexes

D6.1Aii/iii).

D6.1.4C **Gammaridae** (freshwater shrimps)

* *Gammarus pulex* was very abundant at the two closest sites (2 m and 240 m) downstream from Cow Green Reservoir on the Tees although it was not found in that area in a pre-impoundment survey. Large numbers of this species had colonized the reservoir and this facilitated their establishment downstream (Armitage 1978).

Despite big differences in location, limnological conditions in the reservoir, release depth, flow modification and many other factors, Ward & Stanford (1979) showed that Amphipoda (shrimps) were invariably enhanced below reservoirs, often appearing for the first time in unregulated rivers downstream of the regulated inflow. Ward (1974, 1976a) studied some regulated sections of the South Platte River, Colorado, and recorded increased densities of Amphipoda and Gastropoda associated with dense beds of submerged macrophytes. Zimmermann & Ward (1984) however, reviewing the effects of regulation downstream of 15 deep-release dams in Colorado, did not find these dense beds and their associated shrimps and molluscs.

Invertebrates such as *Gammarus* are expected to develop in rivers where flow is stabilized by impoundment (Brooker 1981). Similarly, Amphipoda were usually enhanced below reservoirs with a more constant flow, even when short-term fluctuations were superimposed (Ward 1976b). Bed load movement can result in reduced benthic populations and a more stable substrate should be beneficial to the majority of invertebrates, notable exceptions being some species of Naididae and Tubificidae (worms), which can actually be more abundant in areas of shifting substrate than in a stable substrate (Petran & Kothé 1978).

Armitage et al. (1987) reviewed the effects of reduced and near constant flow on the zoobenthos downstream of reservoirs in the U.K. Although Amphipoda were slightly more abundant in the regulated sites, the difference between their observed and predicted abundance (using 5 physico-chemical variables) was not significant.

Gammarus was favoured downstream of a deep-release reservoir and this was attributed to changes in thermal regime (Hilsenhoff 1971). A similar effect has been observed in other rivers receiving cold water discharges (Blanz et al. 1969, Brown et al. 1967, in Brooker 1981; Lehmkuhl 1972).
Ward & Stanford (1979) suggested that invertebrates such as *G. lacustris* which are able to complete their life cycle under constant thermal conditions (Smith 1973) may be favoured below dams.

Extence (1981) found *G. pulex* relatively sensitive to stranding.

** *Gammarus pulex* is uncommon in the Lyd catchment but was found at all sites, always in small numbers. In the spring of 1989 they were comparatively abundant immediately downstream of the dam (W7), in a slow-flowing and heavily silted environment.

*** The regulated conditions are unlikely to be detrimental to *G. pulex*. Rather, they are expected to increase downstream of Roadford reservoir.

D6.1.4D **Ephemeroptera** (mayflies)

* Mayflies are generally adversely affected - reduction in abundance and species diversity - downstream of deep-release reservoirs. This is attributed partly to changes in thermal regime (Blanz et al. 1969, Brown et al. 1967, in Brooker 1981; Hilsenhoff 1971; Lehmkuhl 1972; Ward & Stanford 1979). Temperature range changes from 0.5-21.0°C to 2.0-12.5°C together with high flows resulted in the complete failure of a summer generation of *Baetis* below Flaming Gorge Dam on the Green River, Utah (Pearson et al. 1968, in Brooker 1981).

Zimmermann & Ward (1984) reviewed the effects of 15 deep-release reservoirs in Colorado on the downstream fauna. The temperature regime was typically modified, with diel and seasonal fluctuations greatly reduced and the seasonal maximum substantially delayed. The temperature never reached 0°C in contrast with the unregulated reaches ice covered for several months of the year. The species diversity of mayflies was reduced but their abundance increased. The density of mayflies decreased below 2 surface-release dams.

Mayflies (grazers *e.g. Baetis* and filter-feeders *e.g. Isonychia*) increased below Lake Anna on the North Anna River, Virginia. Acid and metal mine drainage from a tributary used to depress diversity and abundance of the zoobenthos for a considerable distance downstream from the confluence of the two rivers. Now the tributary flows straight into the reservoir which acts as a sink for sediment and metals. As the reservoir discharges primarily surface water, this has proved to be beneficial to the invertebrate communities as a whole, and to mayflies and Mollusca in particular. Plankton from the reservoir and an increased standing crop of benthic algae below the dam further enhanced the mayflies and consolidated the dominance of caddis (Hydropsychidae and other filter-feeders). There is no restriction to the downstream flow except for a minimum compensation flow of 1.13 cumecs. A 35-year average discharge of the North Anna River was 10.76 cumecs (Simmons & Voshell 1978).

Armitage et al. (1987) used 5 physico-chemical variables to predict the presence and abundance of macroinvertebrate families at 30 regulated sites in the U.K. The regulation took the form of a reduced and near constant flow. Heptageniidae (= Ecdyonuridae) were less abundant than expected, due to increased siltation and algal growth below these dams.
Sand deposition in the River Camel however resulted in an increased abundance of *Rhithrogena semicolorata* (Nuttall 1972).

The enhanced growth of mosses and algae downstream of Cow Green Reservoir on the Tees was probably detrimental to *R. semicolorata*. Heptageniidae decreased in 1972 and 1973 but returned to their pre-impoundment level in 1975. They were never very abundant in that section of the Tees but were still abundant in the adjacent tributary, the Maize Beck. Baetidae did not show any definite trends within that period and Caenidae appeared to have increased in numbers. On the whole there was no reduction in the number of species (Armitage 1976, 1978).

Few mayflies occurred below Caban Coch Reservoir on the River Elan, mid-Wales. It was particularly deficient in Baetidae and Heptageniidae. Iron- and manganese-rich deposits accumulated on the bottom of the river have been put forward as the probable major cause (Brooker 1981; Scullion et al. 1982; Inverarity et al. 1983). Similar effects have been observed in rivers contaminated by ferric hydroxide (Letterman & Mitsch 1978).

Mayfly populations were usually reduced below HEP dams (Powell 1958, in Cushman 1985; Williams & Winget 1979). Trotzky & Gregory (1974) reported a decrease in the abundance of *Rhithrogena*, whereas *Paraleptophlebia* increased in abundance. The latter burrowed into the substrate during adverse periods. The river downstream of the dam was subject to rapid variations in flow (<8.5-170 cumecs, ~25% of bottom left dewatered at low flow, velocity 0.1-0.5 m/sec at bottom, with a 4-fold increase in <1 hour).

Pearson & Franklin (1968) found *Baetis* sp. to be resistant to stranding. Jensen & Jensen (1984) observed the effects of the lowering of the water level (~1 m in 1 hour) in a lowland stream in Denmark. Apparently all the active species, including *B. rhodani*, escaped by swimming towards the middle of the channel. Burrowing species such as *Ephemera danica* were more affected but many individuals did escape by leaving their burrows before the opening was left exposed.

Baetis spp. was absent however below a short-term regulated HEP dam where zero discharge occurred at night, about 15 days per month. The mayflies *Caenis rivulorum* and *Ephemerella ignita* were present, albeit in small numbers. It was suggested that species which overwintered as eggs or small nymphs deep in the substrate might be better preadapted to these regulated conditions since they were exposed to flow fluctuations for a comparatively short time (Henricson & Sjöberg 1984).

C. rivulorum was absent from the samples from December to March below Cow Green Reservoir on the Tees. There was a period of rapid growth from May to July and the emergence probably took place in June and July. The nymphs most probably overwintered deep buried into the substrate (Armitage 1976). *E. ignita* was confined to the summer months and hatched in July and August. The same life history pattern was reported from the Walla Brook on Dartmoor. The species overwintered in the egg stage and nymphs were present in the benthos from May to August (Elliott 1967a).

During periods of low flow, when algal cover was abundant, *E. ignita* was also found to be abundant in a canal downstream of a dam in France, where the minimum compensation flow of 30 cumecs could suddenly increase to >1000 cumecs (Gaschignard & Berly 1987).

** Mayflies are well represented in the Lyd catchment (25.6% in spring and 14.2% in autumn, Annexes D6.1Aii/iii). The diversity is high with 14 species in riffle areas, plus 3 additional species from the pools, tree roots and submerged macrophytes.
The most abundant species in spring are *Rhithrogena semicolorata* (40%), *Baetis rhodani* (27%), *Ephemerella ignita* (13%) and *Caenis rivulorum* (9%). In autumn *B. rhodani* (41%), *R. semicolorata* (34%) and *Ecdyonurus sp.* (18%) are the dominant species.

The life cycle of *E. ignita* in the Lyd catchment is similar to that observed below Cow Green Reservoir on the Tees (Armitage 1976) or in the Walla Brook on Dartmoor (Elliott 1967a). They are confined to the summer months, although individuals were captured at the end of September and even October (1 ind.) and beginning of December (1+1 ind.).

Sand and silt deposition in the River Wolf at those sites in the middle of the works (W5-W6, H4) did not appear to be detrimental to *R. semicolorata* or *Ecdyonurus*. However, there was an overall decrease in the abundance of *Rhithrogena* downstream of the dam (sites W7 and W9-W13) due to the low flows

and siltation encountered during the construction and pre-impoundment phase of Roadford Reservoir. *Ecdyonurus* appeared again largely unaffected (Annex D6.1v). Unlike *Rhithrogena*, they were captured in small numbers from the pools, tree roots and submerged macrophytes samples.

*** On the River Wolf, a noteworthy fact was the appearance in the spring of 1989 of high numbers of *Caenis rivulorum* at the most heavily silted site, immediately downstream of the dam (W7), where 192 individuals (1280 ind./m²) were captured. It was present at each of the more downstream sites on the Wolf as well, but no more than 9 individuals were collected at one single site. The Caenidae are typical of slow-flowing, silty conditions (Hynes 1970).

To conclude, the abundance of mayflies could increase downstream of Roadford Reservoir but the species diversity will probably be reduced.

During the first years after impoundment, when only the compensation flow will be released, species characteristic of slow-flowing, silty/sandy conditions will be favoured, such as *Caenis rivulorum* and *Ephemera danica*. Iron- and manganese-rich deposits in riffle areas immediately downstream of the dam will be detrimental to Heptageniidae and Baetidae. These are considered short-term effects only.

When the reservoir becomes fully operational, Heptageniidae are the most likely to suffer from regulation, resulting in reduced numbers of *Rhithrogena semicolorata* and *Ecdyonurus*. Although they are well adapted to life in rapidly flowing waters, they do not tolerate low flows and are negatively affected by macrophytes beds.
Conversely, the summer-growing species *Ephemerella ignita* and *Caenis rivulorum* are associated with macrophytes beds and are likely to increase.

D6.1.4E Plecoptera (stoneflies)

* Stoneflies were usually severely reduced below impoundments where the downstream flow was more constant (Ward 1976b; Ward & Stanford 1979). This was confirmed for the families Perlodidae and Chloroperlidae by Armitage et al. (1987) in their analysis of 30 regulated sites in the U.K. with a reduced and near constant flow. It appeared that the conditions at these regulated sites were also unsuitable for Perlidae and Taeniopterygidae, although their low occurrence and abundance barred detailed quantitative analysis. The families Leuctridae (mainly *Leuctra fusca*) and Nemouridae (mainly *Amphinemura sulcicollis*) were however unaffected by regulation but no particular reason could be found.

A constant compensation flow (except during reservoir overspill) and iron- and manganese-rich deposits on the river bed below Caban Coch Reservoir in mid-Wales was not detrimental to the stoneflies, unlike other major taxa groups such as the mayflies, caddis and beetles. In May their relative abundance was high and they were mainly represented by *Amphinemura*, *Leuctra*, *Chloroperla* and *Isoperla* (Inverarity et al. 1983). Scullion et al. (1982) found that the stoneflies were slightly more abundant downstream than upstream of the reservoir. Detritus-feeders such as *L. fusca* and *Protonemura meyeri* were important components of the riffle fauna.

The abundance of stoneflies generally decreased below HEP generation dams (Powell 1958, in Cushman 1985; Williams & Winget 1979). Trotzky & Gregory (1974) reported reduced populations of Perlidae below a reservoir with large and rapid fluctuations in flow, but the abundance of *Alloperla* (Chloroperlidae) increased. This taxon was able to burrow into the substrate during adverse periods. Other workers observed that, under conditions of rapid flow fluctuations, certain species able to burrow into the substrate (hyporheic zone) such as the Chloroperlidae increased in relative abundance (Radford & Hartland-Rowe 1971, in Ward & Stanford 1979; Ward & Short 1978). *Leuctra fusca* and *Amphinemura standfussi* made up 81% of the stonefly abundance below a short-term regulated reservoir in Sweden (Henricson & Müller 1979). These two species overwintered in the egg stage (diapause) and did not resume their development until late spring and it was suggested that therefore they avoided the adverse effects of flow fluctuations.
On the other hand, winter growing species such as *Leuctra hippopus*, *Taeniopteryx nebulosa* and *Nemoura cinerea* suffered from regulation and their numbers decreased.

Leuctridae were abundant during periods of low flow downstream of a dam in France. They were characteristic of irregular hydraulic conditions. The minimum compensation flow of 30 cumecs could suddenly be increased to >1000 cumecs (Gaschignard & Berly 1987).

Stoneflies are one of the groups most affected by deep-release reservoirs (Ward & Stanford 1979). The temperature downstream of such a reservoir in Montana was relatively constant around 7°C compared to a thermal amplitude in the unregulated reaches of 0-18°C. Stoneflies were reduced from 38 species to five (Stanford & Ward 1984). Only two stoneflies (*Alloperla* and *Isoperla quinquepunctata*) were commonly collected below deep-release reservoirs in Colorado.
The density of stoneflies slightly increased however below two surface-release dams (Zimmermann & Ward 1984).

Plecoptera were drastically reduced below a surface-release reservoir on the North Anna River, Virginia. A minimum compensation flow of 1.13 cumecs was required but otherwise there were no restrictions to the downstream flow. A 35-year average discharge of the river was 10.76 cumecs (Simmons & Voshell 1978). Similar severe reductions occurred below other surface-release reservoirs with fluctuating downstream flow. It was partly attributable to higher summer temperatures in these previously cold-water streams (Ward & Short 1978). An average increase of 3.4°C in a cold water stream below a shallow reservoir in Montana resulted in the disappearance of two species. Another species however was favoured in the warmer section, as it was not recorded from the upper unregulated reaches (Fraley 1979).
Small differences in temperature however seem to have little effect on the invertebrates downstream of surface-release dams (Saltveit et al. 1987).

Stoneflies showed a steady increase in the first five years after impoundment of the Tees by Cow Green Reservoir. Rapid flow over a heterogeneous bottom prevented accumulation of silt, helped in this flushing process by high discharges during winter overspill. The reservoir was well mixed and thus problems caused by deep releases did not occur. During the same period there was a small decrease in the number of stoneflies in an unregulated tributary, the Maize Beck (Armitage 1978, 1979).

Stoneflies are especially intolerant of introduced sediments and they are generally adversely affected by the addition of sand and silt during dam

construction (Cline & Ward 1984; Saltveit et al. 1987). Within the Leuctridae, Hynes (1941) found *L. nigra* typical of silty reaches, *L. geniculata* on stony substratum where silt collects and the other species on clean gravel. However, *L. nigra*, *L. geniculata* and also *A. sulcicollis* were immediately eliminated by sand deposition in the River Camel. *L. fusca* and *Protonemura meyeri* were largely unaffected (Nuttall 1972).

** The diversity of stoneflies is high in the Lyd catchment: 19 species were recorded. Their relative abundance is 4.8% in spring and 3.8% in autumn (Annexes D6.IAii/iii). In spring the most abundant species are *Leuctra geniculata* (31%), *Chloroperla torrentium* (23%), *Isoperla grammatica* (16%), *L. fusca* (9%), *Brachyptera risi* (8%) and *Amphinemura sulcicollis* (5%). In autumn the most abundant species are *Leuctra fusca* (73%), *Protonemura meyeri* (8%) and *Nemoura avicularis* (5%).

One species, which is rare (3 individuals in all) and localised in the catchment, is of regional importance. *Amphinemura standfussi* was captured at W11 in 1986 and at W8 and K3 in 1989. Although not listed in the British Red Data Book or the Nationally Notable species, it is nevertheless of interest through being scarce or having few published records.
The operation of Roadford Reservoir should not pose any particular threat to this stonefly as it is a summer-growing species which overwinters in the egg stage. The fact that it was captured at site W8 in 1989 suggests that the early years of operation of the reservoir and resulting siltation downstream of the dam would not be detrimental.

The number of stonefly species, together with the total number of individuals (in parentheses), collected in the River Wolf during the spring of 1989 from upstream to downstream was 6 (59) at W4, 5 (29) at W5, 4 (12) at W6, 2 (10) at W7, 8 (24) at W8, 1 (1) at W9, 1 (4) at W10, 2 (2) at W11, 3 (22) at W12, 6 (37) at W13 and 6 (24) at W14. It is clear that the introduction of silt and sand downstream from the dam and in the works area was in general detrimental to the stoneflies, both in terms of abundance and species diversity. The second site downstream of the dam (W8) however presented the highest diversity with 8 different species, although it is difficult to explain why. The above figures also show that the recovery is rapid, at least as far as the species diversity is concerned.
Leuctra geniculata appeared largely unaffected by siltation. Nine individuals were captured at the most heavily silted site, immediately downstream of the dam (W7). They were also found to be common in the pools - low velocity, silty stone surfaces - throughout the catchment. *L. nigra* is rare in the catchment (at least from the habitats investigated) and did not increase downstream of the dam due to the addition of silt. Silty reaches however were not specifically sampled.

*** It is predicted that the depressed values of species diversity and abundance due to increased siltation will remain low during the early years of operation of Roadford Reservoir, since only the compensation flow of 9 Ml/d will be released.
However, *L. geniculata* and *L. fusca* appeared so far largely unaffected and will be the dominant species during those first years. Siltation effects should be short-term and not permanent and will be greatest immediately downstream of the reservoir (W7-W12). The input of the unregulated Kellacott Stream will reduce the impact of siltation on the lower Wolf.

Iron- and manganese-rich deposits that settled in riffle areas immediately downstream of the dam would not be detrimental to the stoneflies.

Higher maintained flows and HEP releases will help to flush out the accumulated fine sediments from riffle areas. The abundance and diversity of stoneflies will probably still remain relatively low, because they are also very sensitive to large changes in flow and temperature. Deep HEP releases would be most detrimental.

However, species which combine the characteristics of overwintering as eggs or small nymphs and being able to burrow into the substrate, such as *Leuctra fusca* and *Chloroperla torrentium* - both distributed throughout the Lyd catchment - may well tolerate the regulated conditions and increase in numbers. Conditions of flow and substratum downstream of the dam should be favourable to *L. geniculata*, which also passes the winter in the egg stage and grows rapidly during late spring/early summer (Hynes 1941).

D6.1.4F **Elminthidae** (riffle beetles)

* Riffle beetles were severely affected by iron- and manganese-rich deposits downstream of Caban Coch Reservoir on the River Elan, some species sometimes completely missing from the samples. *Limnius volckmari* was probably the most tolerant species (Brooker & Morris 1980; Inverarity et al. 1983; Scullion et al. 1982).

The abundance of riffle beetles increased in the first five years of impoundment of the Tees by Cow Green Reservoir (Armitage 1978).

Elminthidae were negatively affected by deep-release discharges and this was put down principally to changes in thermal regime (Blanz et al. 1969, Brown et al. 1967, in Brooker 1981; Hilsenhoff 1971; Lehmkuhl 1972; Zimmermann & Ward 1984). Trotzky & Gregory (1974) reported reduced populations of Elmidae (= Elminthidae) below a deep-release reservoir where in addition large fluctuations in flow occurred.

Esolus parallelepipedus was very abundant in a canal downstream of a reservoir in France subjected to wide and rapid fluctuations in flow (sudden increases from 30 to >1000 cumecs) (Gaschignard & Berly 1987). Investigating the effects of flow fluctuations on stream benthos, Irvine (1985) observed a decline in the density of all major taxa except molluscs. The relative abundance of riffle beetles increased.

** The relative abundance of riffle beetles in the Lyd catchment is 4.4% in spring and 9.8% in autumn (Annexes D6.1Aii/iii). Four species occur in the catchment and *Limnius volckmari* is by far the most abundant one (86% in spring and 82% in autumn).

Heavy rain and subsequent major floods during the autumn of 1987 in the Lyd catchment reduced the density of the majority of taxa to an unusually low level compared to the spring figures. By contrast, both the relative abundance and density of Elminthidae and Mollusca were higher (Ingelrelst 1988). Similar effects were reported by Irvine (1985).

*** Probably because they live in the interstitial spaces within the substratum and therefore are not exposed to the full force of the current, the riffle beetles appear to be able to withstand flow fluctuations. There are several instances where their relative abundance and density increased under such conditions.

They may increase in numbers downstream from Roadford Reservoir. However there are likely to be short-term effects due to iron and manganese deposition in the riffle zones immediately downstream of the reservoir.

D6.1.4G **Trichoptera** (caddisflies)

Hydropsychidae:

* It is a well established fact that filter-feeders are usually favoured downstream of surface-water release dams due to the contribution of lake plankton as food source. Amongst caddis, the net-spinning Hydropsychidae and Polycentropodidae are well documented.

Parker & Voshell (1983) studied the production of 5 species of Hydropsychidae in the impounded North Anna River and in the non-regulated South Anna River (Virginia). Lake Anna is 17.6 times the area of Roadford Reservoir and is a shallow (mean depth 8 m, maximum depth 24 m), surface-release reservoir. Total production was highest at the site immediately below the dam, and this was attributed to the zooplankton released from the reservoir. They concluded that the very high densities of filter-feeders below the dam reduced the quality (size) of the plankton they fed upon, and consequently limited the production of other filter-feeders downstream.
High populations of filter-feeding caddis below surface-release dams are however not always present (Zimmermann & Ward 1984).

Boon (1987) investigated the influence of Kielder Water on the River North Tyne (NE England) on caddis populations downstream from the dam. At two stations below the dam, the relative abundance of *Hydropsyche siltalai* increased from 62% to 94% and simultaneously that of *H. pellucidula* decreased from 22% to 2%. Consequently, and although 9 out of 10 of the species recorded before impoundment were still present, the overall species diversity was reduced. *H. pellucidula* is more ubiquitous in terms of flow preference than *H. siltalai*, which selects faster flows (Boon 1978). Thus the change towards higher mean flows following impoundment favoured *H.siltalai* at the expense of *H. pellucidula*.

Hydropsychidae can be regarded as fast-flow specialists and often construct their nets on moss-covered bed rock in rapidly flowing water, where they can be very abundant (Edington & Hildrew 1981). Moss however is not colonized at high densities unless the water velocity is high, as was discovered by Edington (1968). He demonstrated that velocities below 10 cm/sec were frequently inadequate to sustain filter-feeders such as the net-spinning caddis. In the field *H. siltalai* (then named *H. instabilis*) was found in the water velocity range 15-100 cm/sec. Likewise in the laboratory net-spinning activity increased markedly between 10 and 20 cm/sec and was maintained at velocities above this.

The typical order of first appearance from source to mouth in sizeable, unpolluted rivers starts with *Diplectrona felix* and *H. instabilis* in the headwaters, follows with *H. siltalai*, then *H. pellucidula* and finishes with *H. contubernalis* and/or *Cheumatopsyche lepida* (Eddington & Hildrew 1981).

Both *H. siltalai* and *H. pellucidula* are univoltine (one generation per year) with egg-laying in summer. There is a rapid autumn growth period for *H.*

pellucidula and the majority of larvae overwinter in the 5th (last) instar. By contrast, most *H. siltalai* larvae overwinter in the 3rd instar, with a rapid growth resuming from March onwards (Hildrew & Eddington 1979 for the River Usk in South Wales ; Boon 1979 for the River North Tyne).

Boon (1987) observed that below the dam, the growth rates of both species were accelerated or retarded at certain times of the year, apparently correlated with the winter-warm, summer-cold discharges from the reservoir. The final weight attained by mature *H. pellucidula* (unlike *H. siltalai*) larvae was significantly (30%-55%) greater below the dam than above it.

Trotzky & Gregory (1974) studied the macroinvertebrate fauna below a deep-release, HEP dam. They found that insect populations generally increased further downstream from the dam. At one station where the flow near the bottom increased four-fold in less than one hour, very few Hydropsychidae larvae were found. They suggested that this may have been the result of the flushing and scouring effect of severe flow fluctuations due to HEP releases.

Wide fluctuations in discharge and abnormal temperatures were the probable causes of a sharp reduction in the abundance and species richness (Hydropsychidae were completely absent) of the caddis community below Dworshak Dam on the North Fork Clearwater River in Idaho. HEP generation imposed extreme flow variations, ranging from 41 to 266 cumecs annually, and with daily vertical fluctuations of about 2 m. The downstream effects were however rapidly ameliorated due to the mitigating influence on discharge and temperature of the merging of a larger non-regulated river, only 2.5 km below the dam. In the lower mainstem caddis densities approached those found above the reservoir. Daily fluctuations of the water level of 0.5-1 m took place in the lower mainstem (Brusven 1984; Munn & Brusven 1987).

Henricson & Sjöberg (1984) studied the zoobenthos below two short-term regulated HEP dams in Sweden. Both were surface-release reservoirs. Average daily flow fluctuations below the first dam ranged from 280 to 390 cumecs. Current speed in the middle of the river varied from 40 to 70 cm/sec. Filter-feeders together with scrapers dominated the fauna both in terms of density and biomass. The relative abundance of Hydropsychidae was about 2% (117 ind./m^2). No larvae were found in the littoral samples though. It could be argued that they do not readily colonize shore regions which are in a daily state of fluctuation, but the reason for their absence here is probably related to low water velocities, as the water level remained almost constant below the dam.
Below the second dam zero discharge occurred at night on average 15 days per month. Average daily flow fluctuations ranged from 50 to 140 cumecs. The zoobenthos below the dam was dominated by the same functional feeding groups but Hydropsychidae larvae were completely absent, most probably caused by the zero discharge.

Hydroelectric operations commenced recently at the Kielder dam on the River North Tyne. Generation takes place for 16 hours every day in winter and varies in summer according to storage level. A typical hydrograph during the winter of 1985/86 showed a rise in flow from about 2 to 17 cumecs over a 2-hour period each morning. Boon (1987) suggested that the new flow regime might well encourage the dominance of *H. siltalai* in the caddis community.

Although some filter-feeding caddis may benefit from regulation from surface-release reservoirs, most caddisflies are negatively affected by deep-release reservoir effects (Zimmermann & Ward 1984). Stanford & Ward (1981, in Munn & Brusven 1987) found Hydropsychidae absent below such a

reservoir. New species were added with increasing distance downstream, and they attributed their recovery to improved thermal and food conditions.

** In the Lyd catchment, Hydropsychidae make up 2.9% of the river fauna in spring and 5.9% in autumn (Annexes D6.1Aii/iii). This family represents 35% of the caddis in spring and 52% in autumn. *Hydropsyche siltalai* is by far the most abundant species (97% in spring and 86% in autumn).

A typical longitudinal distribution can be observed in the Lyd catchment. *H. pellucidula* (virtually the only other species) is absent from the headwaters. *C. lepida* is not recorded from the Lyd sub-catchment but does occur in the main Tamar.

H. siltalai was consistently found in large numbers on moss-covered stones/bedrock in fast-flowing water, for example at Lifton Gauge (L5) on the Lyd in the autumn of 1987 (Ingelrelst 1988) and at Cross (33) on the Torridge in the spring and autumn of 1987 (Ingelrelst 1989a).

The life cycle of the larvae is similar to that observed in other rivers. In the autumn samples, *H. pellucidula* larvae are fully grown whilst *H. siltalai* larvae are small. In the spring samples, most *H. siltalai* larvae are in the 4th instar.

*** Below Roadford Reservoir, the larger zooplankton biomass, greater seasonal flow constancy and higher daily mean flows, will all favour Hydropsychidae, especially *H. siltalai*. In addition, the new flow conditions will probably be profitable to benthic mosses and algae (greater bed stability), which in turn will benefit Hydropsychidae larvae.

Low flow periods however will be detrimental to the larvae. The minimum compensation flow below Roadford dam is set at 9 Ml/day, corresponding to a velocity of 15 cm/sec. This is probably too low for large populations of larvae to develop. However under the enhanced environmental flow regime associated with the HEP proposals (Annex D6.1Ai) the minimum flow will be higher, set up at 20 Ml/day (velocity = 21 cm/sec) or 34 Ml/day (velocity = 27 cm/sec).

To conclude, it is predicted that surface-water releases, greater seasonal flow constancy, higher daily mean flows and the flow regime imposed by HEP generation will be beneficial to Hydropsychidae (*H. siltalai*) larvae and their numbers would increase.
In the early years of operation of the reservoir, where only the compensation flow of 9 Ml/d will be released, low numbers of Hydropsychidae will occur downstream of the dam.

<u>Polycentropodidae</u>:

* Whereas Hydropsychidae live in fast flowing water, the net-spinning Polycentropodidae will be found in slow flowing or still water. They are exclusively predatory and use their nets to catch live prey, mainly larvae of chironomid midges, mayflies and stoneflies and, in the earlier instars, freshwater shrimps (Edington & Hildrew 1981).

Out of 100 *P. conspersa* nets in a small stream near Cardiff, 95 occurred in the range 0-10 cm/sec and 5 in the range 10-20 cm/sec but none was found at

higher velocities, although extensive stretches of rapids were present in the stream. In the laboratory, nets built in a flowing-water tank at 10 cm/sec disintegrated when the velocity was increased to 25 cm/sec (Edington 1968). Polycentropodidae larvae will be captured in small numbers in riffles because suitable, sheltered microhabitats can always be found, provided the flow regime maintains habitat diversity. Edington (1965, 1968) demonstrated that slow-flow species of net-spinning caddis occurred more frequently in rapids than fast-flow species in pools.

Polycentropodidae larvae did not increase in numbers below Cow Green Reservoir on the Tees, although that might have been expected. This could partly be explained by the sampling in riffles only, for *P. flavomaculatus* was found relatively abundant in pools (Armitage 1976, 1978). Polycentropodid larvae were most abundant in slowest-flowing water (10-26cm/sec). *Cyrnus trimaculatus* has appeared since the dam was built. *Neureclipsis bimaculata* also appeared after impoundment. This species is typically found in lake outflows where it catches drifting planktonic organisms (Edington & Hildrew 1981).

Polycentropodidae made up a substantial part of the total macroinvertebrate abundance below two short-term regulated HEP dams with surface-water release in Sweden (Henricson & Sjöberg 1984). *N. bimaculata* was much more abundant than *P. flavomaculatus*, and contributed to 23% of the zoobenthos in the littoral samples and 13% in the samples taken from the middle area below dam B, and respectively 20% and 11% of the zoobenthos below dam K. Zero discharge was permitted at night on average 15 days per month below dam B, corresponding to a lowering of the water level of about 1 m. Average variations in current speed ranged from 0 to 60 cm/sec. The results show that *N. bimaculata* is a species tolerant to variations in flow and water current.

Lillehammer & Saltveit (1984) investigated the effects of regulation at two sites downstream of a reservoir in Norway. The upper site was situated about 2 km below the dam and the lower site at about 18 km. Both stations had a swift current and levelled flow. At the upper site, *P. flavomaculatus* was the dominant caddis species (~60%) before regulation. After regulation it was virtually the only species present (~97%). A strong increase was recorded at the lower site as well, where its relative abundance went from ~15% to ~53%. This was attributed to the large amount of zooplankton drifting from the lake, but the reasons for that overwhelming dominance in fast-flowing waters were not discussed.

In a nearby regulated river with a 84% reduced waterflow, *P. flavomaculatus* was also the most abundant caddis species. It was thought to feed mainly on Chironomidae, which dominated the fauna composition.
This agrees with Armitage et al. (1987), who found that when regulation took the form of a reduced and near constant flow, Polycentropodidae were more abundant than expected. The reduced flows offered large areas of suitable habitats.

** Polycentropodidae are rare in the Lyd catchment. In spring they made up 1.8% of the caddis abundance and in autumn 2.3% (Annexes D6.1Aii/iii). Two species are regularly found: *Plectrocnemia conspersa* and *Polycentropus flavomaculatus*. In spring their respective relative abundance is 34% and 63%, and in autumn 10% and 90%.

P. conspersa usually occurs in small headwater streams and is replaced downstream by *P. flavomaculatus* (Edington 1968). This typical longitudinal distribution can be seen in the Lyd catchment as well, although it is not

always obvious due to the low numbers of individuals captured. This in turn could be due to sampling in riffles, though Polycentropodidae were found to be uncommon -but regular- in the pools investigated during the spring of 1989.

P. flavomaculatus appeared to have benefited from the silty and slow-flowing conditions encountered immediately downstream of Roadford dam (W7). Nine individuals were collected during the spring of 1989, together with one specimen of *Cyrnus trimaculatus*, which is usually found in the lower reaches of larger rivers (it is present in the main Tamar). This species was also captured from the tree roots sample at site W14 during the spring of 1989.

There is a third family of net-spinning caddis found in British rivers, the Philopotamidae, but they are rare in the Lyd catchment and are restricted to the rapids of headwaters and tributaries. Only two specimens of *Wormaldia* were found at Boldventure (H1), the headwater site on the Wolf (Hennard stream).

*** *Neureclepsis bimaculata*, a species usually found in lake outflows, could well appear immediately downstream of Roadford dam.

The availability of food and flow conditions below the dam will probably benefit the Polycentropodidae in the pools and other slow-flowing areas. Even in riffles a decrease in their abundance is not expected if they can find sheltered microhabitats. They should be better preadapted to periods of low flow (minimum compensation flow of 9Ml/day in summer/autumn) than *Hydropsyche*.

<u>Rhyacophilidae</u>:

* *Rhyacophila* larvae are probably the caddis most restricted to conditions of high current speed (Edington & Hildrew 1981). Scott (1958, in Boon 1978) found that they were most common in current speeds of 80-90 cm/sec. They are free-living predators and feed mainly on larvae of chironomid midges, blackflies and *Baetis* (mayfly).

Boon (1978, 1987) studied the influence of Kielder Water on the River North Tyne on the downstream populations of Hydropsychidae, Polycentropodidae and Rhyacophilidae. Three species, *Hydropsyche siltalai*, *H. pellucidula* and *Rhyacophila dorsalis* accounted for 98% of all larvae collected. The abundance of *R. dorsalis* increased after regulation below the dam, probably in response to the altered flow regime (frequent periods of moderately high, stable flows and elimination of extremely low flows) but also in response to the increase of hydropsychid larvae. Apparently correlated with the winter-warm, summer-cool discharges from the reservoir, the growth rate of the larvae below the dam was accelerated in winter and retarded in summer.

Trotzky & Gregory (1974) and Williams & Winget (1979) reported reduced populations of *Rhyacophila* as a result of fluctuating flows.

R. nubila was absent below a surface-release dam where zero discharge occurred at night, about 15 days per month. Below another dam with average daily flow fluctuations of 280-390 cumecs and corresponding fluctuations in current speed of 40-70 cm/sec, it was present (5 individuals/m^2) in the middle area of the river but not recorded from the littoral samples (Henricson & Sjöberg 1984).

Armitage et al. (1987) analyzed the data for 30 regulated sites with a reduced and near constant flow. Rhyacophilidae were less frequent than expected. The median water velocity was 25-50 cm/sec and areas of fast flow were limited.

** In the Lyd catchment, Rhyacophilidae (*R. dorsalis* is virtually the only species present) accounted for 6.4% of the caddis in spring and 5.5% in autumn (Annexes D6.1Aii/iii).

*** When Roadford Reservoir becomes fully operational, the higher daily mean flows and greater seasonal flow constancy downstream of the dam would benefit the Rhyacophilidae caddis. Long periods of low flows (compensation flow of 9 Ml/d only) will be detrimental, although they were captured during periods of very low flow and it is unlikely that they will be eliminated. They were also captured from all three habitats -pools, tree roots and submerged macrophytes- during the spring of 1989, although very rarely. As their prey taxa are likely to increase in numbers (Chironomidae, Simuliidae, Hydropsychidae), availability of food will not be a limiting factor.

Other caddis families:

* The caddis larvae increased in abundance below Cow Green Reservoir on the Tees, due particularly to *Brachycentrus subnubilus*, the only representative of the family Brachycentridae in Britain. This caddis is a filter-feeder and its high density at the sites situated 500 m and 900 m below the dam was probably due in part to the supply of plankton from the reservoir. Examination of the gut contents revealed that in the summer months when its density reached its peak, *B. subnubilus* fed mainly on algal filaments drifting from the reservoir. This together with a more constant downstream flow and reduced velocity allowed dense populations to develop (Armitage 1977, 1978).

The persistence of plankton in the river will depend on factors such as flow and the presence of vegetation. The downstream persistence of zooplankton was shown to be positively related to the magnitude of the river flow and negatively correlated with the species size (Ward 1975, in Brooker 1981).

The regulated reach of the North Fork Clearwater River (Idaho) below Dworshak Dam flows into a larger, unregulated river only 2.5 km below the dam. HEP operation results in daily vertical fluctuations of about 2 m in the regulated reach and 0.5-1 m in the main stem. The river below the dam undergoes extreme flow fluctuations ranging from 41 to 266 cumecs annually. Two *Brachycentrus* species (both filter-feeders) were recorded in the catchment. *B. americanus* was present only above the reservoir. *B. occidentalis* was present above the reservoir, absent in the regulated reach and present again in the main stem.
Only two species of caddis were found in the regulated reach immediately below the dam, including *Glossosoma* sp. (Glossosomatidae). In the lower main stem 11 caddis taxa were recorded (10 taxa were found at the station just above the reservoir). Taxa that were present above the reservoir, eliminated below the dam but present again in the main stem included the Hydropsychidae and *Lepidostoma* sp. (Lepidostomatidae).
The sampling sites situated immediately below the dam and in the lower main stem were 30 river km apart (Brusven 1984; Munn & Brusven 1987).

The case-bearing Limnephilidae and Lepidostomatidae were completely

eliminated at a station about 2 km below a reservoir in Norway. At about 18 km from the dam, two species of Limnephilidae were present, whereas five species were recorded at these two sites before impoundment. Limnephilidae are large particle feeders (shredders and scrapers) and it was thought that the increased winterflow after regulation might have prevented the accumulation of larger food particles (Lillehammer & Saltveit 1984).

Caddis with heavy or unwieldy cases have low mobility and they were shown to be sensitive to stranding. *Anabolia nervosa* (Limnephilidae) and *Silo pallipes* (Goeridae) for example had difficulty in escaping during short-term lowerings of the water level in a lowland stream in Denmark (Jensen & Jensen 1984).

** *Brachycentrus subnubilus* appeared in the cylinder samples in 1988 in the lower reaches of the Wolf (only recorded from site W14), in the Thrushel and the Lyd. Special habitats samples (pools, tree roots and submerged macrophytes) taken during the spring of 1989 revealed that this species was common in the Thrushel and Lyd. On the River Wolf it was captured at sites W14, W12 and W11 but not at W9.

Lepidostoma hirtum presents a similar distribution although a few individuals were captured in the headwaters of the Wolf in 1985 (Hilton 1986). The special habitats samples showed that this species was common in the Thrushel and Lyd. On the River Wolf, it was captured at site W14 but not at W12, W11 or W9.

Glossosoma sp. occurs in the Lyd catchment but is uncommon. The closely related genus *Agapetus* is much more widespread and abundant. Glossosomatidae make up 27.7% of the caddis abundance in spring and 18.6% in autumn (Annexes D6.1Aii/iii).

Limnephilidae are typically associated with slow flowing reaches or in sheltered microhabitats in riffles. They are not common in the Lyd catchment but this may be due to sampling in riffles only. Large limnephilid specimens were regularly captured from the pools, tree roots and submerged macrophytes.

The caddis *Athripsodes bilineatus* was captured at L4 during the cylinder sampling in 1989 and at W14, T1 and T4 during the special habitats survey in 1989. It turned up in all 3 biotopes investigated. This Leptoceridae caddis is local in Southern England (Wallace, pers. comm.). If it is present further up the River Wolf than site W14, individuals living in tree roots might be at risk. Further information about this species may be needed.

*** Glossosomatidae are scrapers, usually at thin algal layers. If the percentage of moss and algal cover increases below the dam (and it could increase due to more seasonal flow constancy and higher mean flows), *Glossosoma* and *Agapetus* could well decrease below Roadford reservoir.

B. subnubilus could increase downstream from Roadford dam due to the plankton drifting from the reservoir.

As a result of the flow regime downstream of the dam and of the reduction in particle food size, Limnephilidae caddis will probably decrease both in abundance and diversity. Those species collected mainly from tree roots and submerged macrophytes such as *Potamophylax* will be more vulnerable than those species that were also regular in pools such as *Halesus* and *Chaetopteryx*.

D6.1.4H **Chironomidae** (non-biting midges)

* Chironomidae are probably one of the taxa most tolerant of rapid and wide fluctuations in flow, even when this results in large areas of channel bed being periodically exposed. Ten kilometres below Turner's Fall HEP dam in Massachusetts lies a bar 425 m long and 70 m wide which is submerged during high flow and exposed during low flow. Few insects, except Chironomidae, were recorded in the "tidal" zone (Fisher & Lavoy 1972).
Below a surface-release, short-term regulated HEP dam where zero discharge occurred at night on average 15 days per month, chironomid midges were the most abundant taxon (34% of the zoobenthos in the middle of the river and 31% in the littoral zone) (Henricson & Sjöberg 1984).
Brusven & Trihey (1978, in Cushman 1985) discovered that only those areas of the river bed consistently submerged for at least 28 days would support a productive benthic community. Midges however were found to recolonize readily the rewetted areas when flow and river stage increased.

Dworshak Dam on the North Fork Clearwater River in Idaho was built for HEP generation and flood control. The aim was to maximize electrical output at times of greatest energy demand. This resulted in daily vertical fluctuations of about 2 m below the dam (Brusven 1984). Only 2.5 km from the dam the regulated reach flows into the larger, non-regulated Middle Fork.
Fewer than 5 species were typically encountered in the highly regulated North Fork. However, densities in near-shore, shallow areas were almost twice those on the Middle Fork and Main Stem of the river, the Chironomidae being by far the most abundant taxon. Orthocladiinae, a subfamily typical of hard-rock surfaces and gravels (Pinder 1986), represented 99% of the midges in the North Fork below the dam and only 34% above the dam. Armoured substrate covered with moss evolved below the dam owing to extreme flow fluctuations. Chironominae are more typical of finer sediments of sand and silt and were the most abundant subfamily in the North Fork above the dam, in the Middle Fork and in the Main Stem. The Tanypodinae and Diamesinae were either absent or minimally represented among the four reaches.

Many other instances can be found where chironomid midges were favoured and increased in abundance below reservoirs with fluctuating flows (Trotzky & Gregory 1974; Williams & Winget 1979) or in response to successive flow perturbations (Irvine 1985) or large discharge fluctuations into a canal (Gaschignard & Berly 1987).

Chironomidae are also tolerant of changes in thermal regime brought about by deep releases from hypolimnetic reservoirs (Blanz et al. 1969, Brown et al. 1967, in Brooker 1981; Hilsenhoff 1971; Lehmkuhl 1972; Zimmermann & Ward 1984).

Ward (1976b) reviewed the effects of flow on invertebrates downstream of large dams. Flow constancy below impoundments resulted generally in enhanced numbers or biomass, even when short-term fluctuations were superimposed. The composition of the benthos was often greatly altered however.
Chironomidae were usually favoured below such dams.

A more even discharge regime led to an increased standing crop of mosses and algae and these plants have been put forward as a possible reason for the large numbers of Chironomidae (Orthocladiinae) that appeared after regulation below Cow Green Reservoir on the Tees (Armitage 1976, 1979). The abundance and/or diversity of Chironomidae has been shown to be positively correlated

with the distribution of macrophytes beds (Pinder 1986).

Four groups of Chironomidae occurred at higher densities than expected in regulated sites characterized by a reduced and near constant flow. Three of these groups were mainly deposit feeders (Orthocladiinae, Diamesinae and Tanytarsinii) and were favoured by the prevailing conditions of reduced flows and silty stone surfaces. The fourth group were predators (Tanypodinae). Although a more restricted occurrence prevented quantitative analysis, a fifth group (Prodiamesinae) was present in a greater number of sites than expected (Armitage et al. 1987).

The tube-building Chironomidae (Chironominae and Tanytarsini) are commonly associated with soft, depositing substrates (Pinder 1986). Their density increased at stations affected by china-clay wastes (Nuttall & Bielby 1973) or sand deposition (Nuttall 1972).

** Chironomid larvae are widespread throughout the Lyd catchment. They represent 8.3% of the benthic invertebrate fauna in spring and 4.2% in autumn (Annexes D6.1Aii/iii).

*** The mosses and algae will probably increase downstream from Roadford dam due to less severe and frequent spates and subsequent greater bed stability. This should be favourable to chironomid midges.

The ubiquitous Chironomidae are thus expected to increase in numbers downstream of Roadford reservoir. The family Chironomidae consists of several hundreds species which exhibit a wide range of tolerance to environmental conditions. Almost any change in these conditions will probably be favourable to some of them (Hellawell 1986; Pinder 1986).

D6.1.4I **Simuliidae** (blackflies)

* Blackflies are filter-feeders and, like the hydropsychid caddis larvae, often increase in abundance below (surface-release) reservoirs owing to the supply of plankton. Zimmermann & Ward (1984) reviewed the influence of 15 deep-release and 2 surface-release reservoirs on the downstream zoobenthos. Simuliidae averaged nearly 18,000 individuals/m² below the surface-release dams whilst there were typically less than 200 individuals/m² at all other sites.
Filter-feeders occurred in relatively low numbers below Cow Green Reservoir on the Tees despite the abundant supply of zooplankton. One possible reason for the relative scarcity of Simuliidae was the very high densities of *Hydra* which would compete with them for settlement. The larvae collected at the time of sampling were small (first instars) and would be at a competitive disadvantage with established *Hydra* populations except where fast flows prevented the development of such populations (Armitage 1976, 1978).

Providing the substrate is stable, the current is the major factor in their distribution. The larvae clump together in places where conditions suit their method of feeding. They will be found typically on the upper surface of boulders, near the front, where the current is strong and laminar. Pupae are found mainly on back surfaces, where the current is more turbulent and weaker, or in crevices (Maitland & Penney 1967).

In Norway re-regulating weirs have been constructed downstream from impoundments in order to decrease the damage caused by sudden reductions in

flow. Simuliidae dominate the fauna below new weirs. Below older weirs, where there is much more growth of moss and algae, Chironomidae and mayflies are more likely to be dominant (Armitage 1984). In Finland and Sweden Wotton (1984) reported very high densities of the blackfly *Simulium noelleri* at the downstream side of sluice gates and small dams.

Low blackfly densities were found in the regulated River Elan in Wales, the major reason appearing to be the substantial accumulation of iron- and manganese-rich deposits on the bed surface (Scullion et al. 1982). Siltation of stone surfaces was shown to interfere with their attachment (Fredeen 1959, in Scullion et al. 1982). They were eliminated from streams polluted by china-clay wastes (Nuttall & Bielby 1973).

In general, more seasonal flow constancy below reservoirs, even when short-term fluctuations were superimposed, resulted in increased numbers of Simuliidae (Ward 1976b).

Pearson & Franklin (1968) found Simuliidae to be sensitive to stranding and thus would be eliminated downstream of impoundments where rapid variations in flow leave areas of the stream bed exposed within a short time. Both food- and oxygen-uptake of blackflies are inhibited at slow current velocities. They cannot tolerate still-water for long (Hynes 1970).

Simuliidae were almost totally absent below two surface-release, short-term regulated HEP dams in Sweden (Henricson & Sjöberg 1984). Below dam B zero discharge was allowed at night, on average 15 days per month. Below dam K the increased growth of periphyton (benthic algae) and filamentous algae following regulation adversely affected simuliid larvae, which need clean rock surfaces for attachment.

Simulium was favoured downstream of a hypolimnetic release and this was attributed to changes in thermal regime (Hilsenhoff 1971).

** In the Lyd catchment, Simuliidae make up 15.2% of the total abundance in spring and 5.4% in autumn (Annexes D6.1Aii/iii).

*** Silty conditions downstream of the dam are currently detrimental to Simuliidae and this will remain so until the higher maintained flows and HEP releases will have washed away the silt and sand that has now accumulated downstream of the dam.

Blackfly larvae should benefit from the higher mean flows and greater seasonal flow constancy brought about by the operation of Roadford Reservoir. However mosses and algae should benefit from those conditions too, and they will hinder the settlement of larvae. The expected greater macrophyte cover downstream of the dam would then prevent any sizeable blackfly populations becoming established, although they should increase in abundance in those suitable areas not covered by mosses or algae.

D6.1.5 SUMMARY AND CONCLUSIONS

i) As part of the Roadford Operational and Environmental Study, an environmental impact assessment of Roadford reservoir on the downstream macroinvertebrates was undertaken.
First a synthesis of the effects of regulation on the downstream aquatic environment was made. The impact of reservoirs on the downstream macroinvertebrates in general was then reviewed and the impact of Roadford reservoir was discussed. Finally a review of the effects of regulation on the more common taxa was made, and again the probable impact of Roadford reservoir on those taxa was estimated.

ii) In conjunction with the proposed HEP operation, higher daily mean flows and greater seasonal flow constancy will occur downstream of Roadford reservoir. The latter has been shown to compensate for the adverse effects of daily flow fluctuations.
A reduction in the severity and frequency of spates could be favourable to the mosses, algae and macrophytes downstream of the dam due to greater bed stability. This would in general be beneficial to the invertebrates.

iii) Roadford reservoir is provided with multilevel draw-offs which should minimize the release of poor quality water. Aerators will be in use during the summer to prevent stratification and deoxygenation of the deeper layers of the reservoir, ensuring that the reservoir is always mixed.

iv) The invertebrates will be less adversely affected by surface-water releases than deep-releases. They will probably benefit from the use of surface water, at least in terms of increased abundance/biomass. The use of the mixed reservoir water drawn from the best water quality level will also benefit the invertebrate communities.
The use of the scour draw-off should be strictly regulated as the discharge of large quantities of silt in the river will be highly detrimental to the benthic fauna. These deep releases may also include anoxic water and unacceptably high levels of metals. To minimize the impact on river fauna, releases from the scour draw-off should be made in conjunction with spate/flood conditions in adjacent river catchments.

v) Plankton from the reservoir usually settles rapidly in the receiving waters and therefore the enriching effect will not persist very far downstream of the dam. Overall the greatest impact of the operation of Roadford will be on the River Wolf immediately downstream of the embankment. The addition of water from the unregulated Rivers Thrushel and Lyd could rapidly mitigate any adverse effects of regulation.

vi) The invertebrates from the cylinder samples or those collected during the special habitats - pools, tree roots and submerged macrophytes - survey in the spring of 1989 are typical of similar rivers in the South West.

Two species however are of regional importance: a stonefly *Amphinemura standfussi* and a caddis *Athripsodes bilineatus*.

vii) Low flows (9 Ml/d) and silty conditions will characterize the early years of operation of Roadford Reservoir. This will generally be detrimental to the benthic invertebrates.

However, several taxa appear to be largely unaffected or even thrive under such conditions. The most notable example is the mayfly *Caenis rivulorum* whose density in the spring of 1989 reached 1280 individuals/m² at the most heavily silted site (W7), immediately downstream of the dam. The caddis *Polycentropus flavomaculatus* and the water-mites (Hydracarina) also showed a significant increase in abundance at site W7.
Sphaeriidae (bivalves) are another taxon characteristic of areas with a reduced flow and silty stone surfaces, although they have not increased downstream of the dam.

The mayfly *Ecdyonurus sp.* (Heptageniidae) appear unaffected by the changes. The closely related *Rhithrogena semicolorata* however decreased in abundance immediately downstream from the reservoir.

Stoneflies are in general very sensitive to introduced sediments and low flows. They have decreased in abundance and diversity downstream of the dam. *Leuctra geniculata* and *L. fusca* are however unaffected and will be the dominant stoneflies during the early years of operation of the reservoir. *L. nigra* is another species usually found in slow-flowing, silty reaches but it is rare in the Lyd catchment and has not increased downstream of the dam.

The first years of operation of Roadford Reservoir will be detrimental to taxa requiring fast flows and/or clean stone surfaces such as the caddis Hydropsychidae and the blackflies (Simuliidae).

Higher maintained flows and HEP releases in the following years of operation of the reservoir will flush out the accumulated sand and silt from riffle areas. Siltation of the substrate and its associated problems can therefore be considered temporary only.

viii) Some invertebrates are better adapted to withstand the pattern of pulsed HEP releases during the winter months and have been seen to be unaffected or to increase downstream of HEP reservoirs.
Some are able to burrow into the substrate during adverse conditions, such as the mayfly *Paraleptophlebia submarginata* and the stoneflies *Chloroperla torrentium* and *Leuctra fusca*.
Others are summer-growing species which overwinter in the egg stage or as small nymphs buried deep in the substrate, such as the mayflies *Caenis rivulorum* and *Ephemerella ignita* and the stoneflies *Leuctra fusca* and *L. geniculata*.
On the other hand, winter-growing species such as *L. hippopus* will be adversely affected.

Leuctridae (stoneflies) and Elminthidae (riffle beetles) are characteristic of irregular hydraulic conditions.

Large cased caddis (Limnephilidae) that were collected mainly from tree roots and submerged vegetation such as *Potamophylax* are expected to decrease in abundance or even be eliminated downstream of the dam. Those species that were also regular in pools such as *Halesus* and *Chaetopteryx villosa* may remain unaffected.

The pattern of HEP releases during the winter months will probably reduce the diversity of species downstream of the dam, but the overall abundance is expected to increase.
Autumn and winter spates associated with the unregulated River Wolf would under extreme conditions significantly reduce the total abundance and diversity of the invertebrates. The dam will stabilize the flow regime during the autumn and winter. It is thought that the pattern of HEP releases will probably be less detrimental to the benthic invertebrates than the natural winter spates since peak flows will not exceed 320 Ml/d and water velocity will be less than 0.7 m/sec. Under the harshest conditions the maximum change in water height will be 40 cm but for the majority of times the change will be approximately 25 cm. The flows that would be required to initiate scour of the river bed would be in the order of 11.6 cumecs.

ix) Higher daily mean flows and greater seasonal flow constancy will occur downstream of the dam when the reservoir will be fully operational. If coupled with surface water releases, this will generally be favourable to the filter-feeders such as the caddis Hydropsychidae, Polycentropodidae and Brachycentridae.

The expected increased standing crop of benthic mosses, algae and macrophytes downstream of the dam due to the stabilized flow regime will generally be favourable to the invertebrates. This will however be detrimental to the filter-feeding Simuliidae (blackflies) and to the mayflies Heptageniidae. Conditions will be favourable in those suitable areas not colonized by macrophytes.

Tolerant and ubiquitous taxa such as the chironomid midges are expected to increase in density.

The increased abundance will be at the expense of a reduction in species diversity if habitat diversity is lessened through flow regulation.

x) The Wolf alone is likely to be impacted in any significant way in the ca 3 km above Kellacott Stream. In this intensively surveyed stretch from 1985-1989 (riffles at sites W7-W12) only two species, the caddis *Cyrnus trimaculatus* and *Silo nigricornis*, were found confined to this area. They were rare however and both captured on only one occasion. During the first years of operation of the reservoir (compensation flow only), *Cyrnus* is expected to increase downstream of the dam.

xi) The probable reduction in species diversity is thought to be acceptable weighed up against the expected increase in abundance and considering the fact that those changes will normally be restricted to those reaches immediately downstream from the reservoir (probably not further than the confluence with the River Thrushel or the River Lyd).
Although species diversity and abundance may change, the overall total biomass is unlikely to change significantly and the effect on the other river fauna is likely to be minimal. Dippers may be the most sensitive since they depend directly on specific aquatic macroinvertebrates for their food.

xii) The recommendations made and operating rules agreed upon should if necessary be reviewed from time to time, in light of what shall be learned from a careful chemical and biological surveillance during the filling phase and after impoundment.

D6.1.6

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D6.1.7

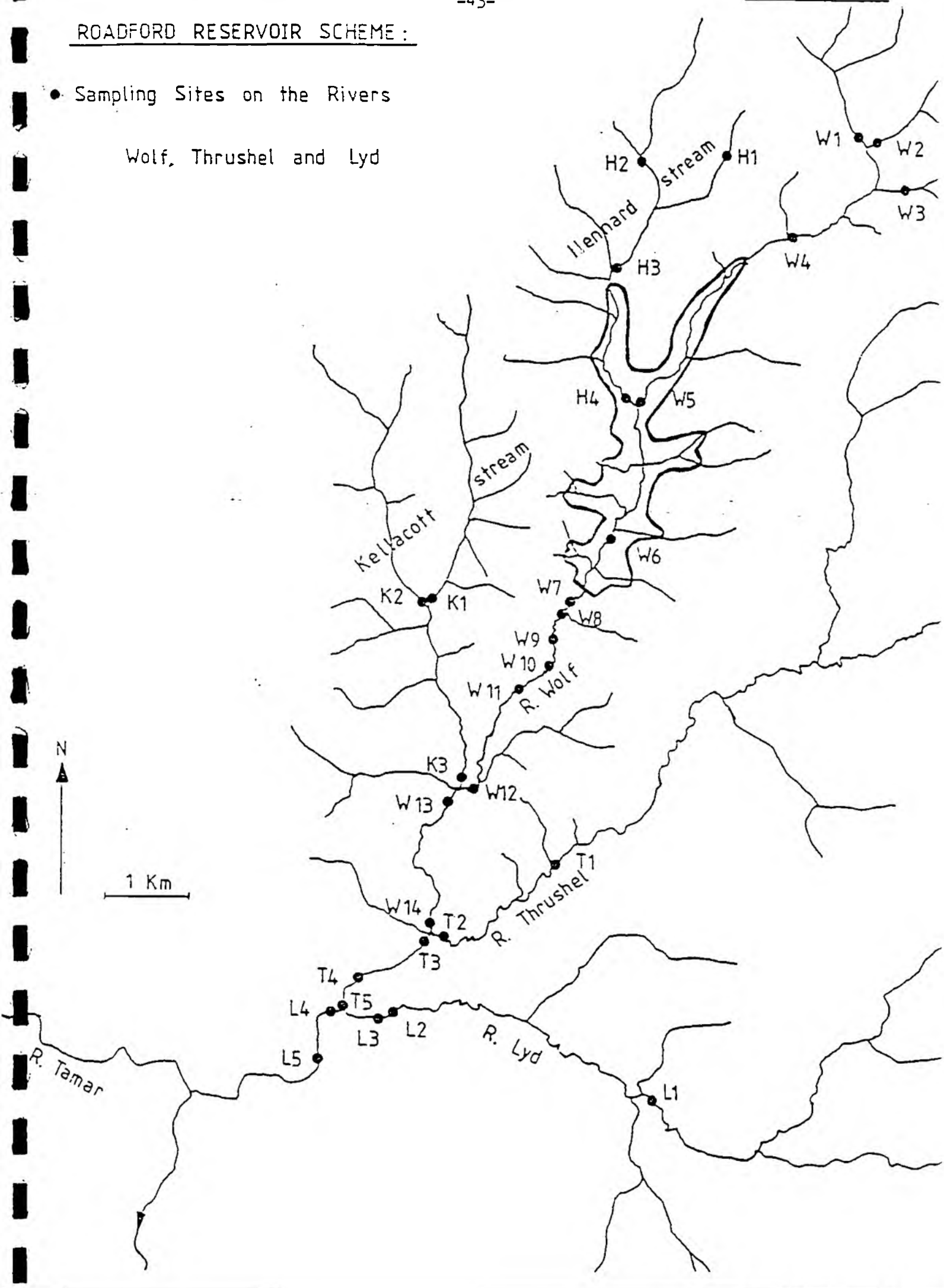
ANNEXES

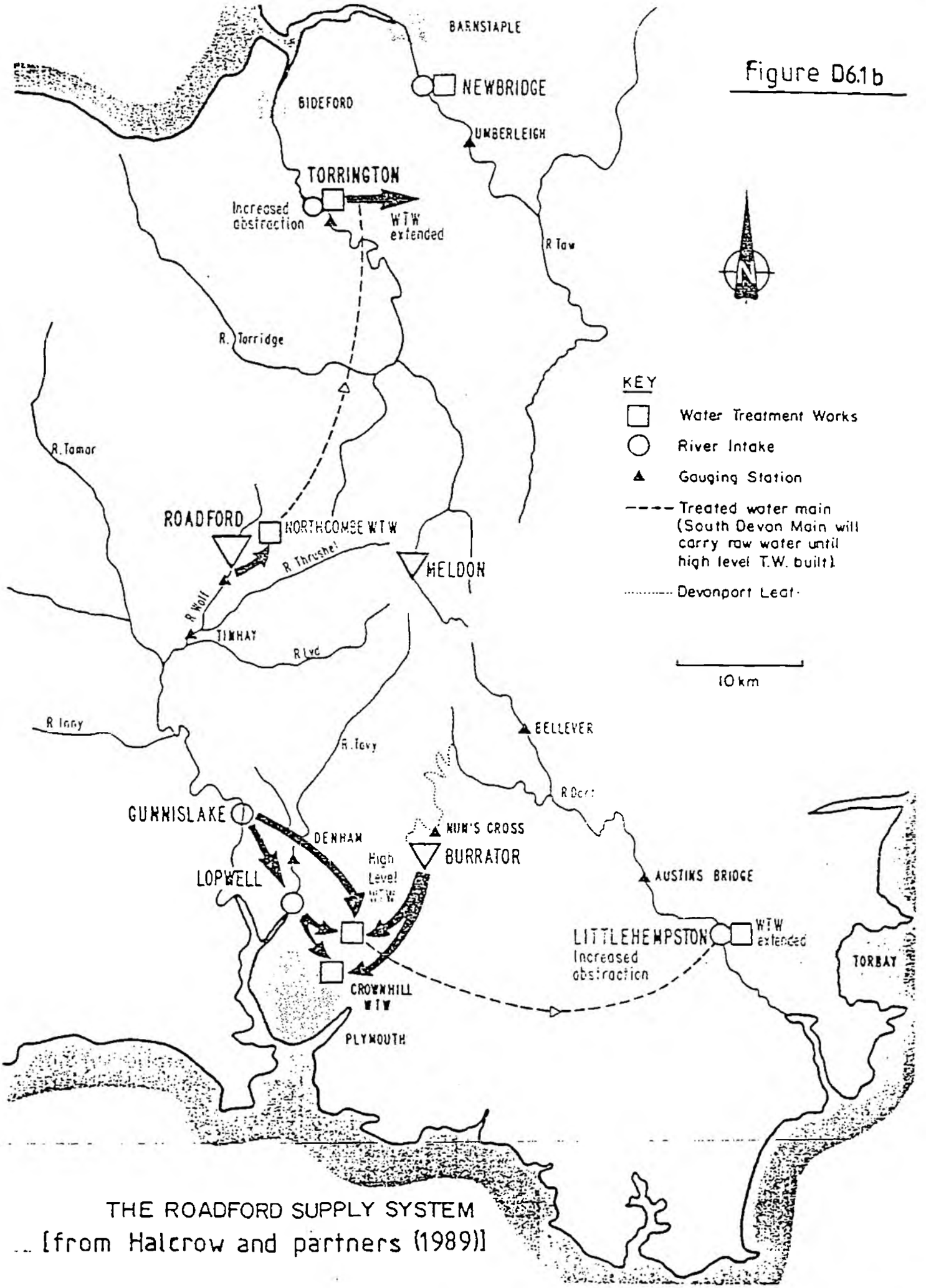
Figure D6.1a

ROADFORD RESERVOIR SCHEME :

- Sampling Sites on the Rivers

Wolf, Thrushel and Lyd





THE ROADFORD SUPPLY SYSTEM
... [from Halcrow and partners (1989)]

WEEKLY FLOW PATTERN OF RELEASES FOR HYDRO-ELECTRIC POWER PRODUCTION
"AN ENVIRONMENTAL APPROACH".

Figure D6.1c

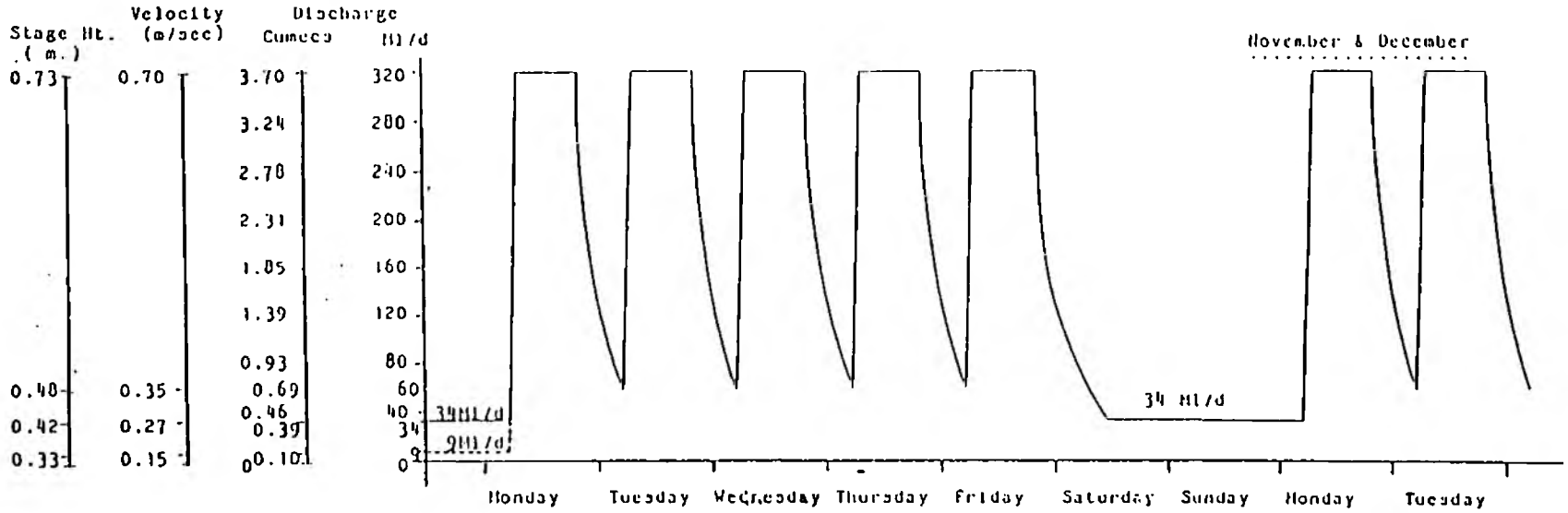
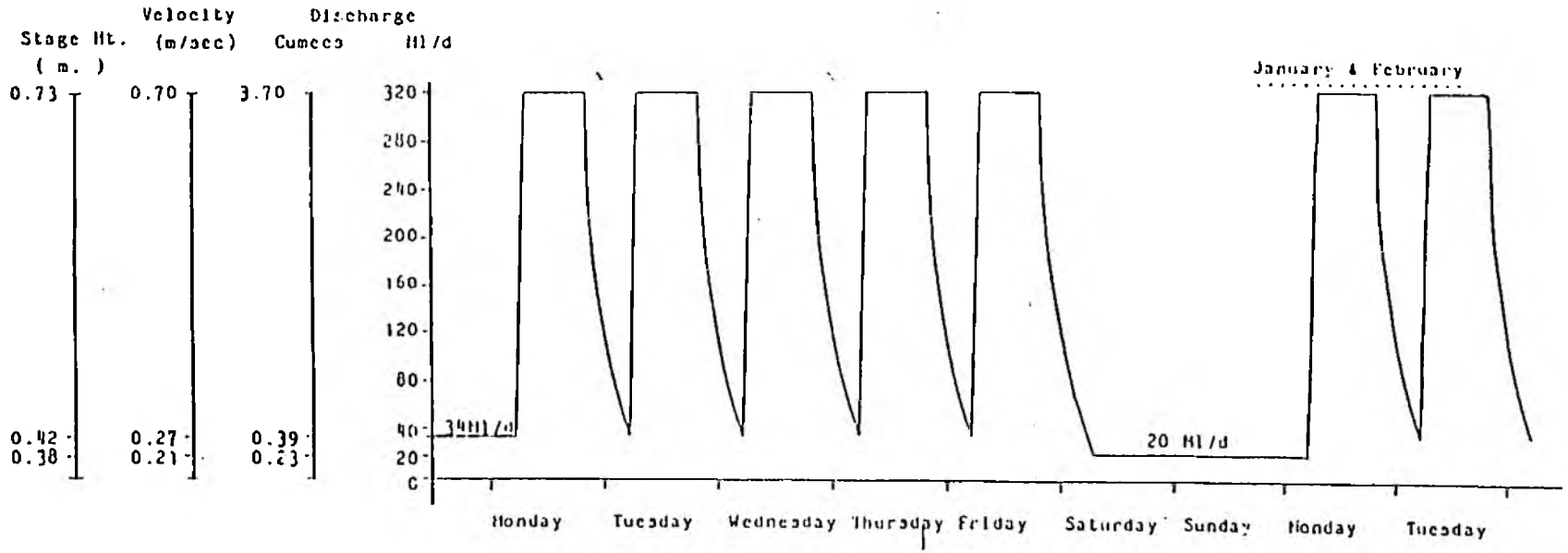


Figure D6.1d



Channel transects and riverdepths measured at four locations on the River Wolf prior to impoundment of Roadford Reservoir

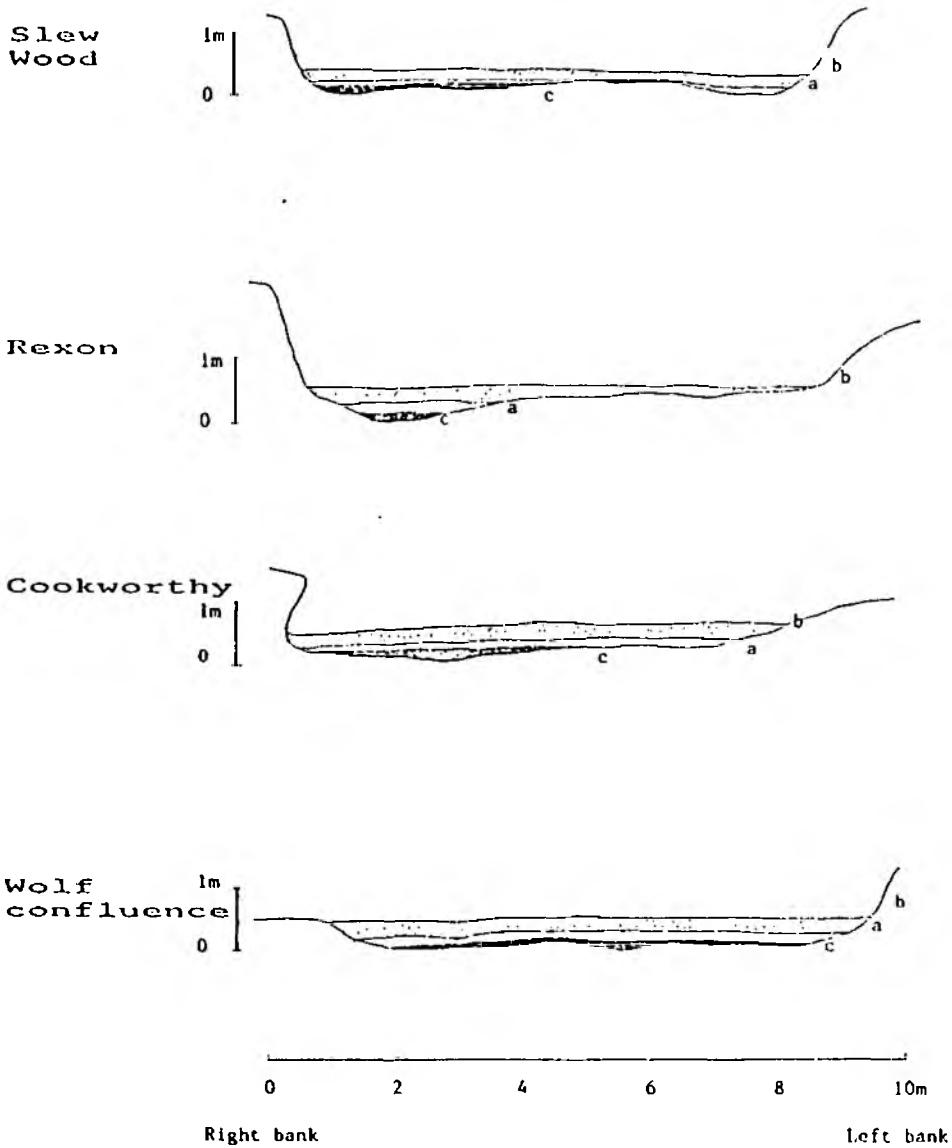
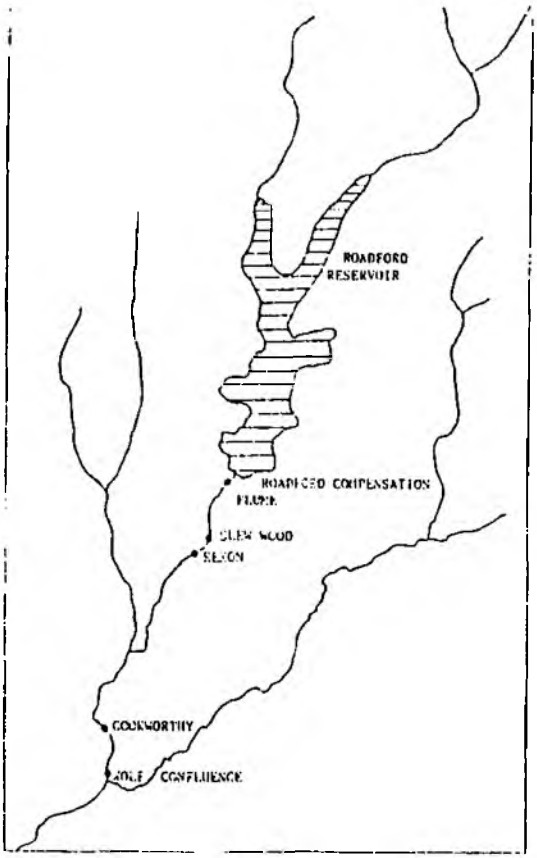


Figure D6.1e



Natural river flow (DMF) recorded on the R. Wolf at Roadford Compensation Flume.

DATE	LEVEL	DMF	
		CUMECS	Ml/d
20.9.88	b	0.127	10.97
13.10.88	a	1.247	107.74
8.8.89	c	0.009	0.78

ANNEX D6.1i: LOCATION OF SAMPLING SITES: RIVERS WOLF, THRUSHEL AND LYD

SITES			N.G.R.	
RIVER WOLF				
W1		Eworthy	SX 454954	
W2		Northcombe	SX 455954	
W3		Brockscombe	SX 459948	
W4	(4)	Germansweek	SX 445943	
W5	(7)	Hennard	SX 427924	
W6	(8)	Combepark	SX 424906	
W7		D/S Dam 1	SX 419898	
W8		D/S Dam 2	SX 418897	
W9		D/S Dam 3	SX 417895	*
W10		D/S Dam 4	SX 417892	
W11	(9)	Broadwoodwidger	SX 414889	*
W12		Rexon	SX 407876	*
W13		Cookworthy	SX 405876	
W14	(16)	Milford	SX 403864	*
H1	(1)	Boldventure	SX 438955	
H2	(2)	Witherdon	SX 428952	
H3		Seccombe	SX 424938	
H4	(6)	Grinacombe	SX 427923	
K1	(10)	Buddle	SX 403899	
K2	(11)	Upcott	SX 401900	
K3		Neathwood	SX 406877	
RIVER THRUSHEL				
T1	(14)	Hayne	SX 419869	*
T2	(15)	Barbaryball	SX 404859	
T3		D/S confluence	SX 402859	
T4	(17)	Tinhay	SX 394854	*
T5	(20)	Lifton STW	SX 393851	
RIVER LYD				
L1		Sydenham bridge	SX 428839	*
L2	(18)	U/S dairy	SX 400851	
L3	(19)	D/S dairy	SX 398850	
L4	(21)	Lifton Park	SX 392850	
L5	(22)	Lifton Gauge	SX 389844	*

Site codes:
- W: River Wolf
  - H: Hennard Stream
  - K: Kellacott Stream
- T: River Thrushel
- L: River Lyd

The numbers were attributed following a downstream sequence.
(Old site numbers in parentheses)

* Sites investigated during the special habitats survey (spring 1989) (pools, tree roots and submerged macrophytes)

RIVER WOLF, THRUSHEL AND LYD: CHEMICAL DETERMINAND VALUES (MEAN, RANGE AND STANDARD DEVIATION) FROM APRIL 1986 TO OCTOBER 1987

SITE	pH	Ca mg/l	Mg mg/l	Na mg/l	Nitrate mg/l N	Ortho-phosphate mg/l P	Conductivity (20°C) us/cm	Suspended solids (105°C) mg/l	BOD ATU mg/l O	Dissolved Oxygen % satn
RIVER WOLF										
4. Germansweek	6.9	7.8	3.2	10.0	2.2	0.02	125	26	1.5	91
	6.4-7.3	6.2-9.4	1.6-4.6	6.0-12.0	1.1-3.9	0.01-0.10	86-140	1-351	0.3-5.2	85-98
	0.3	0.8	0.6	1.2	0.7	0.02	11	77	1.1	3
6. Grinaccombe	7.0	8.4	3.3	11.0	1.5	0.03	129	31	2.7	90
	6.4-7.3	6.2-12.2	1.8-5.0	9.0-13.2	0.9-2.2	0.01-0.11	97-180	2-317	0.3-22.0	78-97
	0.3	1.1	0.8	1.1	0.4	0.03	16	70	4.7	4
8. Coabepark	7.2							10		
	6.5-8.4							2-77		
	0.3							15		
24. Dam site	7.1							22		89
	6.0-8.4							1-574		72-105
	0.4							60		6
9. Broadwoodwidger	7.1	9.7	3.8	11.1	1.7	0.03	138	22	1.5	90
	5.8-8.4	8.0-14.6	2.1-7.4	8.1-15.1	0.6-2.7	0.01-0.07	104-202	0-417	0.3-3.2	66-115
	0.3	1.3	1.1	1.4	0.6	0.01	18	53	0.7	6
16. Milford	7.3	11.5	4.2	11.4	1.7	0.03	150	26	1.8	92
	5.9-8.3	8.7-14.2	2.2-8.0	8.3-13.6	0.8-2.7	0.01-0.10	107-186	1-798	0.4-4.6	58-107
	0.3	1.5	1.0	1.3	0.6	0.02	18	76	0.9	8
RIVER THRUSHEL										
12. Kennels	7.3	15.6	4.6	11.0	1.8	0.05	171	34	2.0	91
	6.5-7.6	7.3-20.0	1.8-8.8	6.2-13.9	0.7-2.9	0.01-0.15	86-220	1-475	0.6-3.8	83-96
	0.3	2.7	1.2	1.6	0.6	0.03	29	94	0.8	4
15. Barbarybell	7.3							27		
	6.2-8.3							1-1088		
	0.3							91		
17. Tinhay	7.4	15.3	4.6	11.3	1.9	0.04	170	26	1.8	93
	6.3-8.5	10.0-19.1	2.4-8.3	8.3-14.2	0.8-2.8	0.01-0.09	120-215	0-722	0.2-3.6	85-104
	0.4	2.3	1.1	1.4	0.6	0.02	25	73	0.8	4
RIVER LYD										
22. Lifton Gauge	7.4	15.8	4.0	10.0	2.0	0.08	158	17	1.8	96
	6.3-8.5	9.2-18.6	2.3-5.2	7.0-12.0	1.2-3.1	0.03-0.19	106-183	0-439	0.3-3.3	90-104
	0.4	2.0	0.7	1.0	0.6	0.04	17	44	0.8	4

ANNUAL SUMMARY OF RIVER FLOW FOR 1980 (a "typical" year) at Combepark Farm on the R. Wolf

STATION SX48E007
DESCRIPTION COMBEPARK FARM RIVER WOLF
NGR SX-4189-8981
CATCHMENT AREA 31.1 SQ KM
START 0900.01.01.1980 FIRST RATING CURVE START 1200.12.07.1979
END 0859.01.01.1981 LAST RATING CURVE START 0900.02.09.1980

MEASURED DMF CUMECS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.840	1.788	0.606	4.060-H	0.180	0.033-E	0.614	0.144	0.126	0.582	0.620	0.671
2	0.682	1.678	0.583	1.420	0.185-H	0.031-E	0.451	0.131	0.106	0.482	0.533	0.902
3	2.021	7.442-H	0.519	1.089	0.128	0.031-E	0.384	0.152	0.105-L	0.411	0.473	0.582
4	1.460	5.300	0.415	1.057	0.101	0.027-E	0.342	0.159	0.191	0.361	0.420	0.535
5	1.250	1.860	0.611	1.026	0.094	0.025-E	0.268	0.137	0.321	0.345-L	0.379	0.505
6	1.060	1.729	1.401	0.941	0.090	0.023-E	0.270	0.133	0.143	2.685	0.352	0.454
7	0.818	2.591	1.372	0.834	0.085	0.022-E	0.404	0.120	0.144	4.053	0.328	0.379
8	0.701	5.595	1.006	0.747	0.081	0.023-E	0.252	0.102	0.151	3.282	0.313	0.353-L
9	0.908	2.206	0.890	0.694	0.077	0.022EL	0.194	0.092	0.393	2.067	0.276	0.362
10	0.679	1.601	0.939	0.651	0.069	0.063-E	0.176	0.090-L	0.489	3.041	0.250	0.447
11	0.625	1.208	0.796	0.322	0.062	0.054-E	0.174	0.110	0.319	1.492	0.237	0.702
12	0.580	1.016	1.726	0.273	0.061	0.032-E	0.471	0.277	0.314	1.011	0.215	0.738
13	0.509	0.932	1.177	0.311	0.059	0.057-E	1.305-H	0.248	0.254	1.315	0.207-L	0.784
14	0.554	0.833	0.944	0.252	0.053	1.725	0.652	0.514-H	0.229	1.270	3.678	1.518
15	0.575	0.914	0.747	0.220	0.046	0.477	0.449	0.498	0.228	6.275-E	5.429	1.422
16	0.516	1.023	0.665	0.196	0.041	0.917	0.360	0.286	1.245	6.477EH	1.854	1.453
17	0.413	0.868	0.640	0.184	0.039-E	0.672	0.347	0.263	0.582	1.519	5.479-H	3.629
18	0.389-L	0.854	0.559	0.175	0.038-E	0.386	0.631	0.220	0.613	1.093	1.410	1.808
19	0.623	0.832	0.495	0.161	0.044-E	0.275	0.865	0.187	0.489	1.116	0.988	3.853-H
20	2.736	0.750	0.436	0.150	0.074	0.207	0.627	0.184	2.518	0.863	0.886	2.326
21	3.937-H	0.709	0.393	0.144	0.054	0.196	0.427	0.174	7.215-H	0.795	0.948	1.392
22	2.010	0.877	0.359-L	0.142	0.042	0.331	0.370	0.152	1.679	1.896	1.843	1.453
23	1.709	0.945	0.787	0.132	0.038-E	0.453	0.333	0.143	1.105	1.323	1.544	1.423
24	1.104	0.833	0.797	0.124	0.037-E	0.518	0.265	0.128	0.784	1.500	1.114	1.263
25	0.852	0.789	0.602	0.165	0.035-E	0.410	0.241	0.115	0.632	1.299	1.089	1.161
26	0.713	0.678	0.536	0.136	0.057-E	0.325	0.214	0.102	0.570	1.159	0.980	2.018
27	0.639	0.636	0.491	0.114-L	0.058	2.364	0.190	0.097	1.088	1.268	1.536	1.188
28	0.583	0.622	0.779	0.141	0.044	2.473-H	0.163-L	0.101	0.939	2.268	1.216	0.970
29	0.575	0.619-L	0.753	0.118	0.037-E	0.930	0.201	0.310	0.619	1.253	0.864	0.870
30	0.674		1.062	0.125	0.033EL	0.812	0.172	0.360	0.536	0.937	0.723	0.733
31	2.539		6.48DEH		0.048-E		0.172	0.151		0.748		0.725
TOTAL	33.287	47.739	29.581	16.119	2.105	13.932	11.996	5.897	24.141	54.201	36.199	36.636
MEAN	1.073	1.646	0.954	0.537	0.067	0.464	0.386	0.190	0.804	1.748	1.206	1.181
MAX FLOW	11.710	16.439	20.001	10.817	0.353	9.423	2.141	1.443	16.706	21.467	16.081	7.138
TIME-DAY	0615-21	1400-03	2000-31	1545-01	0100-02	0630-28	1330-13	1915-14	1230-21	0815-16	1130-15	1245-19

ANNUAL TOTAL 311.832 CUMEC DAYS
ANNUAL DMF 0.852 CUMECS

MAX DMF 7.442 CUMECS 03-02
MIN DMF 0.022 CUMECS 09-06

MAX FLOW 21.467 CUMECS 0815-16-10

ANNEX D6.1iv

Taxa found during the special habitats survey (spring 1989) that were never captured in the Lyd sub-catchment (riffles) before.

	Pools	Tree roots	Submerged macrophytes
	*****	*****	**********
EPHEMEROPTERA			
Baetis niger		*	*
Centroptilum pennulatum	*	*	*
Procloeon bifidum	*	*	*
ODONATA			
Agrion virgo		*	*
HEMIPTERA			
Hydrometra stagnorum			*
Velia sp. (nymph)		*	*
Gerris sp. (nymph)	*	*	*
Notonecta sp. (nymph)			*
Sigara dorsalis		*	
COLEOPTERA			
Brychius elevatus	*		
Haliplus fluviatilis		*	
Haliplus lineatocollis		*	
Potamonectes depressus elegans	*	*	
Oreodytes septentrionalis	*		
Hydroporus tessellatus	*	*	*
Stictotarsus duodecimpustulatus	*	*	*
Helephorus aquaticus			*
TRICHOPTERA			
Polycentropus irroratus		*	*
Limnephilus lunatus		*	
Adicella reducta		*	
DIPTERA			
Anopheles claviger gp		*	

ANNEX D6.1v: Impact of low flows and siltation on the distribution and abundance of macroinvertebrates downstream of Roadford Reservoir - Spring 1989

U/S works ↓ | Dam ↓ | Kellacott Stream ↓

TAXA / SITES	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	T3	T4	T5	L4	L5
MOLLUSCA																
Potamopyrgus jenkinsi		2		25		1			2	2		2	4	1	6	6
Ancylus fluviatilis		4	1	3	1	17			4			1	1	1		1
OLIGOCHAETA	50	82	158	69	105	139	82	58	459	24	40	136	30	49	290	534
HYDRACARINA				19			1									
EPHEMEROPTERA																
Baetis rhodani	51	21	26	3	28	30	41	49	74	46	91	54	61	57	8	32
Rhithrogena semicolorata	133	84	88		74	7	21	6	76	23	71	100	96	41	78	139
Ecdyonurus sp.	2		1	9	2	2	2	2	1		1			2	2	1
Ephemerella ignita			5	40		5	3		9		5	1		1	2	1
Caenis rivulorum	14	3	1	192	8	5	2	2	9	1	8	6	7	18	14	1
PLECOPTERA																
Brachyptera risi	13	1	5		7		4		1	1	1	1	1	1		
Amphinemura sulcicollis	7	3			5					1	2	1	2		1	
Leuctra geniculata				9	5				13	21	13	40	45	9	24	1
Leuctra hippopus	3	6	1													
Leuctra fusca	3				1				8	8	4	4	11	1	2	1
Isoperla grammatica	2	2	4	1	2			1		3		4	8	2		2
Chloroperla torrentium	28	15			1					3	2	4	7	2	4	3
COLEOPTERA																
Limnius volckmari	4	20	37	39	17	75	21	20	55		15	68	19	7	7	13
Elmis aenea	1	3	15	9		5	1	1	3	2	2	4			3	
TRICHOPTERA																
Rhyacophila dorsalis	3	1	1		1		2	1			2	2	5	1	2	3
Agapetus sp.	14	2	8	2		1	2		4	2	2	6	2	3	8	9
Polycentropus flavomaculatus				9												
Hydropsyche siltalai	1		3		3				1		1	9	33	1	17	26
Lepidostoma hirtum				1								3	3		6	2
Sericostoma personatum	1	9	7	33	3	1	2	6				2	8	3	4	4
DIPTERA																
Chironomidae	50	15	26	148	26	43	9	50	57	20	19	37	47	17	33	51
Simuliidae	11	44	455		14	5	2		25	10	220	360	1838	110	34	68

ANNEX D6.1Ai

ROADFORD RELEASES TO THE RIVER WOLF:

a) Compensation release - A compensation release of 9 Ml/d will be made from Roadford Reservoir at all times.

b) Regulation releases - Regulation releases from Roadford are required to support the licensed abstractions from the River Tamar at Gunnislake. The increase in discharge to the maximum release for abstraction of 171.8 Ml/d (148 Ml/d + 10% allowance for transmission losses and 9 Ml/d compensation) will follow the natural hydrograph. The reduction in discharge will follow the descending arm of the natural hydrograph.
Under all normal circumstances the release of water from the reservoir should not exceed 320 Ml/d, with a rate of change of 0.9 cumecs in any half hour.
Discharges exceeding 320 Ml/d may be made should they be required to comply with the Reservoir Act 1975, for fisheries water bank purposes and for scour purposes.
The maximum rate of discharge for reservoir safety provision is 11.58 cumecs.

c) Hydroelectric Power Generation releases - The compensation release from Roadford, plus any releases made for water supply purposes will pass through the HEP turbines if the storage capacity is above the lower hydrogeneration control curve. Specific releases for hydrogeneration will only be made if the storage capacity in Roadford is above the upper hydrogeneration control curve.
Specific releases for hydrogeneration will be made during the winter months in accordance with an environmental approach for the operational procedure (Sambrook 1989). The pattern of regulation releases will not be manipulated so as to maximize the income from generation of electricity to the detriment of the fishery and the aquatic environment. Control curves will be used to prevent excessive drawdown of the reservoir.

HEP - Environmental proposals:

These proposals outline an alternative operational strategy based on an ecological and environmental viewpoint.
The interaction between discharge, substrate composition and sediment movement can have an important influence on the biota of the stream. The River Wolf is a salmonid river and supports populations of Atlantic Salmon and the migratory and resident component of the indigenous trout. Any combination of the direct and indirect effects of discharge can influence the spawning site choice of the adult fish, survival of the intragravel stages, emergence of the salmonid fry and the growth, survival and behaviour of the older stages.
The long-term objective of the operation of an environmentally sensitive flow regime is to maintain and improve the natural production of the wild salmonids in the receiving waters. In order to fulfil this objective in any year, specific discharges must be available throughout the year to allow completion of the natural life cycle of salmon and trout.
The discharge and velocity values should be regarded as "guidelines" against which the effects of regulation flows can be investigated and the precise pattern of releases agreed.

a) November and December (Annex D6.1c): Operation of the plant will commence 1 November each year and run during the high tariff period of 07:30 - 20:00 hours, Monday to Friday.
Increase in discharge from the reservoir to the maximum release of 320 Ml/d shall occur over a period of not less than 2 hours.
Maximum rate of rise of the discharge proposed is 0.83 cumecs in any half hour period. Hydrogeneration releases will involve a steady progressive build-up to the peak and will not be stepped.
Decrease in discharge from the maximum release will follow the descending arm of a natural hydrograph. This will result in a minimum discharge in the weekday period of 60 Ml/d. During the weekend, when generation is not economical, a minimum flow of 34 Ml/d is required.

b) January and February (Annex D6.1d): Operation of the plant will commence 1 January each year and run during the high tariff period of 07:30 - 20:00 hours, Monday to Friday.
Increase in discharge from the reservoir to the maximum release of 320 Ml/d shall occur over a period of not less than 2 hours.
Maximum rate of rise of the discharge proposed is 0.87 cumecs in any half hour period. Hydrogeneration releases will involve a steady progressive build-up to the peak and will not be stepped.
Decrease in discharge from the maximum release will follow the descending arm of a natural hydrograph. The minimum discharge in the weekday period shall be 34 Ml/d. During the weekend a minimum flow of 20 Ml/d is required.

c) March: A minimum discharge of 20 Ml/d is required.

d) April and May: A minimum discharge of 34 Ml/d is required.
The peak demand period for water supply purposes has been predicted as May to September.
Regulation releases for supply purposes will be made and superimposed on the minimum flow of 34 Ml/d to a maximum of 171.6 Ml/d (148 Ml/d + 10% allowance for transmission losses and 9 Ml/d compensation release). Patterns of release will follow the rules agreed with the representatives of the Tamar and Tributaries Fisheries Association (TTFA). The build-up to the maximum flow should be such as to avoid danger to anglers.

e) June to October: The agreement with TTFA must be adhered to during the period of any regulation releases for supply purposes. Following the descending arm of a natural hydrograph will result in a minimum flow of 34 Ml/d. This minimum is required when releases occur on consecutive days. When consecutive daily releases are not being made (block release of several days or weeks) then the compensation flow of 9 Ml/d is acceptable as the minimum flow.

Note: Even if sufficient water is not available for continuous HEP generation then the higher maintained flow will apply in order to meet the environmental requirements.

If no specific releases for hydrogeneration are being made then the minimum releases will be made:

November:	60 Ml/d
December:	34 Ml/d
January and February:	20 Ml/d
March:	20 Ml/d
April and May:	34 Ml/d
June to October:	Consecutive days: 34 Ml/d

Other days: 9 Ml/d

Compensation flow and regulation releases from Roadford Reservoir in the early years of operation.

The following proposals must be seen as guidelines only which should be reviewed and modified in the light of experience:

a) In the 13 months following impoundment (September 1989 - September 1990) the storage capacity in the reservoir is unlikely to be sufficient to enable releases equivalent to the higher maintained flows, let alone releases for HEP operation. Only the compensation flow of 9 Ml/d will be released.

b) In the second year (October 1990 - September 1991) the precise pattern of higher maintained flows will be considered. A meeting will be held in early October 1990 between representatives of the NRA, South West Water plc and TTFA to agree to a detailed programme of regulation releases. The actual volume of water in the reservoir and the predicted volume will be key factors in deciding the pattern of releases. If hydrogeneration, in addition to the higher maintained flows, should be considered possible then the diurnal fluctuations may be used commencing on 16 December 1990.

c) In the third year (October 1991 - September 1992) the pattern of regulation releases will again be considered. These will include a range of higher maintained flows and may include a variation on the full hydrogeneration releases proposed. Diurnal fluctuations associated with hydrogeneration releases may begin on 1 November 1991, by agreement.

d) In the fourth year (October 1992 - September 1993), under average conditions, there should be sufficient volume of water in the reservoir to allow the first complete annual pattern of higher maintained flows and hydrogeneration releases. Diurnal fluctuations could commence on 1 November 1993.

The proposed pattern of releases for hydrogeneration and higher maintained flows for the proceeding 12 months will be reviewed on an annual basis. A meeting will be convened with the representatives of the TTFA in early October every year.

In the event of a failure to agree there will be a process of arbitration.

ANNEX D6.1Aii

ABUNDANCE OF MACROINVERTEBRATES AT THOSE SAMPLING SITES AFFECTED BY ROADFORD RESERVOIR: 1985 TO 1989, SPRING

The total abundance and relative abundance (last 2 columns) are for all sites and years combined.

Component members of species groups:

Baetis scambus gp:	B. scambus and B. fuscatus
Rhithrogena semicolorata gp:	R. semicolorata and R. germanica (= haarupi)
Caenis luctuosa gp:	C. luctuosa (= moesta) and C. macrura
Nemoura cambrica gp:	N. cambrica and N. erratica
Potamophylax latipennis gp:	P. latipennis and P. cingulatus
Pilaria discicollis gp:	as defined in Brindle (1967)
Chelifera gp:	)
Hemerodromia gp:	) Follows Brindle (1964)
Wiedemannia gp:	)

TAXA	SITE W1 85	86	87	88	89	SITE W5 85	86	87	89	SITE W6 85	86	87	88	89
TRICLADIDA														
Polycelis felina									1					
Phagocata vitta														
NEMATODA						1					1	3		
MOLLUSCA														
Potamopyrgus jenkinsi	13	1		1		1	4		2	2			1	
Lymnaea peregra														
Planorbis crista														
Ancylus fluviatilis	19					29	1		4	8			1	1
Zonitoides nitidus		1												
Sphaerium sp.						1		1						
Pisidium sp.	3	1	2				1							
OLIGOCHAETA	142	69	301	28	50	98	133	78	82	113	271	166	98	158
HIRUDINEA														
Glossiphonia complanata													1	
Helobdella stagnalis														
Erpobdella octoculata										5	3	3	18	3
Trocheta subviridis		1	2					1			1			4
HYDRACARINA														
CRUSTACEA														
Asellus meridianus														
Gammarus pulex		2				2				6	4	10	7	
EPHEMEROPTERA														
Baetis scambus gp													4	
Baetis rhodani	23	71	19	46	51	15	35	7	21	8	54	2	13	26
Baetis muticus	3	2		2	7	2	1		1		4		10	3
Centroptilum luteolum														
Rhithrogena semicolorata gp	18	26	106	36	133	50	53	98	84	67	58	98	65	88
Heptagenia sulphurea														
Ecdyonurus sp.	4	1	1	4	2	1		4		4	2		18	1
Paraleptophlebia submarginata								1						
Habrophlebia fusca		1								1			8	
Ephemerella ignita	9			17		8				9			69	5
Ephemera danica														
Caenis luctuosa gp														
Caenis rivulorum	28			6	14	3			3	6	1		16	1
PLECOPTERA														
Brachyptera risi		2	8		13	1	8	23	1	1		11		5
Amphinemura standfussi														
Amphinemura sulcicollis	6	3	2	2	7	4	3	1	3	2	3			
Nemoura cambrica gp			1											
Leuctra sp.				1	3				2				3	
Leuctra geniculata	4			23							1		31	
Leuctra inermis	1					3	1			2				2

D/M SITE(24)	SITE W7	SITE W8		SITE W9	SITE W10	SITE W11					SITE W12
87	89	88	89	89	89	85	86	87	88	89	89
*** *** ***	*** ***	***	***	*** ***	*** ***	***	***	***	***	***	*** ***
			1		1		5				
	25			1		6	2	2	2		2
	3		1	17		17	1		1		4
						2				1	
189	69	26	105	139	82	433	105	70	17	58	459
1	1					1	2	1			
							1			3	
4		1	1	7	3	5					
		1		2			2	8	1	1	
	19	1			1						
										1	
3	19	3	2			4	13	2	8	1	1
	4		1						6		
6	3	6	28	30	41	18	50	44	31	49	74
	12		13	5	3	2	3	11	2	3	2
	1										
85		4	74	7	21	15	40	79	1	6	76
								1			3
	9	3	2	2	2	15	4	6	2	2	1
	1		3						2		
	40	27		5	3	45			23		9
	2					1					
	192	1	8	5	2	20			4	2	9
6			7		4		2	1			1
			1				1				
			5			2	3				
							1				
			1						1	1	
	9	2	5					2	3		13
			1								

PAGE 1

TAXA	SITE W13 89	SITE W14 85	86	87	88	89	SITE T3 89	SITE T4 85	86	87	88	89
TRICLADIDA												
Polycelis felina												
Phagocata vitta												
NEMATODA			1									1
MOLLUSCA												
Potamopyrgus jenkinsi	2	81			1		2	33	6		10	4
Lymnaea peregra												
Planorbis crista					2							
Ancylus fluviatilis		5					1					1
Zonitoides nitidus	1											
Sphaerium sp.		1										
Pisidium sp.							1	1				
OLIGOCHAETA	24	215	79	95	101	40	136	575	150	121	43	30
HIRUDINEA												
Glossiphonia complanata		1	1	1			2	1				2
Helobdella stagnalis					1	1	5			1		
Erpobdella octoculata		5	1			1		5	3		1	1
Trocheta subviridis	1		1	1	4	1	1					1
HYDRACARINA												
CRUSTACEA												
Asellus meridianus				2	2	1						
Gammarus pulex	3	2	6	2	4			2	3		1	
EPHEMEROPTERA												
Baetis scambus gp					7						5	
Baetis rhodani	46	34	45	7	11	91	54	73	84	28	7	61
Baetis muticus	4	7	1		1	8	11	13	3	9	4	5
Centroptilum luteolum												
Rhithrogena semicolorata gp	23	59	31	28	5	71	100	19	58	113	19	96
Heptagenia sulphurea												
Ecdyonurus sp.		31		2	6	1		18	1		9	
Paraleptophlebia submarginata												1
Habrophlebia fusca	6	47			21		5				3	1
Ephemerella ignita		221			97	5	1	62			57	
Ephemera danica												
Caenis luctuosa gp											2	
Caenis rivulorum	1	117	3		34	8	6	21	4		5	7
PLECOPTERA												
Brachyptera risi	1		1	1		1	1	1	1			1
Amphinemura standfussi												
Amphinemura sulcicollis	1		1		1	2	1		1			2
Nemoura cambrica gp												
Leuctra sp.					6	1					2	4
Leuctra geniculata	21	13	1		8	13	40	4	9	11	12	45
Leuctra inermis		4				1				1		1

SPRING 1985-89

SITE T5					SITE L4					SITE L5					TO	REL.
85	86	87	88	89	85	86	87	88	89	85	86	87	88	89	TALS	ABUND. (%)
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	****	*********
					2										3	
								1							1	
	1					3					4				22	0.1
11	4		13	1	8	2		1	6	14		15	50	6	335	1.2
			1												1	
															2	
7	1		3	1	4		1	1		7			12	1	152	0.6
									1		1				4	
															3	
2														1	15	0.1
263	150	43	60	49	231	218	113	105	290	110	94	70	139	534	7617	28.1
3	1	1			1						3			1	25	0.1
	3														15	0.1
43	25	3	1	2	2					9	1	1	2		159	0.6
	1						1								36	0.1
															21	0.1
															6	
3	3	4			2	3		2	3	1		4	1		136	0.5
			2								1		2		32	0.1
50	60	64	29	57	19	15	27	2	8	35	20	112	34	32	1876	6.9
23	5	6	3	2	10	3	2		1	6	3	4	2	7	234	0.9
															1	
16	23	33	19	41	10	72	75	48	78	44	58	81	58	139	2805	10.3
			2			1			1						8	
44	3	1	6	2	33	7			2	44		8	2	1	311	1.1
															2	
31	2		1						3						136	0.5
39		1	30	1	3	3		18	2	19	4		59	1	892	3.3
					2										5	
															2	
40	6		15	18		4			14	15	1		1	1	642	2.4
				1											103	0.4
															2	
		1					2		1	1		1			61	0.2
															2	
			4					19	5				5	1	59	0.2
2	4	4	4	9	22	21	1	5	24	12	10	5	5	1	399	1.5
									1						18	0.1

PAGE 2

TAXA	SITE W1 85	86	87	88	89	SITE W5 85	86	87	89	SITE W6 85	86	87	88	89
Leuctra hippopus			4		3			1	6					1
Leuctra nigra			1					1						
Leuctra fusca					3						2		1	
Isoperla grammatica	12		3	10	2	17	2	2	2	12	7	7	14	4
Perla bipunctata														
Chloroperla torrentium	36	4	2	9	28	4	5		15		7	2	7	
Chloroperla tripunctata														
COLEOPTERA														
Oreodytes sanmarkii														
Gyrinus sp.	1					2				1				
Orectochilus villosus	1		1		1	2	2			1				
Hydrophilidae larva								1						
Hydraena gracilis		1			1				1		2		1	1
Helophorus brevipalpis														
Helophorus grandis				1										
Elmis aenea	9				1	12	2	1	3	6	3	2	7	15
Esolus parallelepipedus														
Limnius volckmari	8	4		2	4	10	5		20	12	7	6	43	37
Oulimnius sp.							1							
Oulimnius tuberculatus		1												
MEGALOPTERA														
Sialis lutaria														
TRICHOPTERA														
Rhyacophila pupa									1					1
Rhyacophila dorsalis	1	1		8	3	2	4		1		2	2	2	1
Rhyacophila munda														
Glossosomatidae pupa													6	
Glossosoma sp.								1			3		1	
Agapetus sp.	1	1	2	30	14	3	1		2	23	2	3	28	8
Plectrocnemia conspersa					1	1	1							
Polycentropus flavomaculatus	9			1									3	
Cyrnus trimaculatus														
Tinodes dives	1									3				
Lype reducta		1												
Psychomyia pusilla														
Hydropsychidae pupa														
Hydropsyche pellucidula							2				1			1
Hydropsyche siltalai	13	4	1		1	6	6			17	2	2	2	3
Limnephilidae														
Limnephilidae pupa														
Drusus annulatus	4	2	1				1							
Potamophylax latipennis gp														
Potamophylax latipennis					1		1							
Potamophylax cingulatus		1												
Halesus sp.					1								1	
Halesus radiatus														
Chaetopteryx villosa		1				1								
Odontocerum albicorne						1								
Athripsodes sp.													2	

SPRING 1985-89

DYM SITE(24)	SITE W7	SITE W8		SITE W9	SITE W10	SITE W11					SITE W12
87	89	88	89	89	89	85	86	87	88	89	89
*** *** ***	*** ***	***	***	*** ***	*** ***	***	***	***	***	***	*** ***
				1			1				
			1					1			8
4	1	1	2			25	2	6		1	
10		1	1			35	4	12			
	1										
							1				
			1				2	1			
								1			
	9			5	1	16	2			1	3
	6	1		3			1			1	1
5	39	13	17	75	21	50	4	11	9	20	55
	2										
	3								1		
						1					
		1	1		2		1		6	1	
		1			1						
			1								
2	2	1		1	2	76	8	33	2		4
1							1				
	9								1		
	1										
						4					
1	2						3	1		1	
2			3			8	3	7			1
						2	1				
							1				
						2					
	2			1							

PAGE 3

TAXA	SITE W13 89	SITE W14 85	86	87	88	89	SITE T3 89	SITE T4 85	86	87	88	89
Leuctra hippopus								1				
Leuctra nigra				1								1
Leuctra fusca	8				22	4	4		2	1	13	11
Isoperla grammatica	3	2	2				4	6	1	6	2	8
Perla bipunctata								1				1
Chloroperla torrentium	3	26	3	3	3	2	4	3	3	12		7
Chloroperla tripunctata												
COLEOPTERA												
Oreodytes sanmarkii											1	
Gyrinus sp.		1						1				
Orectochilus villosus		1	1				3	1	1			
Hydrophilidae larva												
Hydraena gracilis									1			
Helophorus brevipalpis												
Helophorus grandis												
Elmis aenea	2	3			1	2	4	2				
Esolus parallelepipedus						1					1	
Limnius volckmari		47	2	5	17	15	68	103	4	6	20	19
Oulimnius sp.							1					
Oulimnius tuberculatus					1							
MEGALOPTERA												
Sialis lutaria												
TRICHOPTERA												
Rhyacophila pupa							2				2	
Rhyacophila dorsalis		5	3	1	6	2	2	11	5	3	5	5
Rhyacophila munda		1										
Glossosomatidae pupa							4				2	1
Glossosoma sp.						1			1	2		5
Agapetus sp.	2	3	1	2	23	2	6	7	2	7	17	2
Plectrocnemia conspersa	1	4						1				
Polycentropus flavomaculatus					1						2	
Cyrnus trimaculatus												
Tinodes dives												
Lype reducta												
Psychomyia pusilla			1									
Hydropsychidae pupa					1							
Hydropsyche pellucidula				1				1				
Hydropsyche siltalai		13	8	3	5	1	9	32	7	36	24	33
Limnephilidae												
Limnephilidae pupa												
Drusus annulatus												
Potamophylax latipennis gp				2								
Potamophylax latipennis												
Potamophylax cingulatus												
Halesus sp.												
Halesus radiatus		1										
Chaetopteryx villosa												
Odontocerum albicorne												
Athripsodes sp.			1				1				5	7

SITE T5					SITE L4					SITE L5					TO	REL.
85	86	87	88	89	85	86	87	88	89	85	86	87	88	89	TALS	ABND. (%)
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	****	*********
							1								17	0.1
					1					3					10	
			1	1		3		12	2		6		9	1	116	0.4
7	5	1	1	2	2	1	2			4		4	2	2	203	0.7
					1			1	1		2			4	11	
6		5		2	5	6	5	4	4	2	4	2	1	3	300	1.1
							1	1	1						3	
															2	
															6	
					4	1					1				22	0.1
															1	
				1				1	1				1		16	0.1
															1	
															1	
7	2	4	1		1				3	3			5		138	0.5
			1					2	2			1	2		23	0.1
74	23	10	21	7	22	7	5	15	7	20	1	7	14	13	1029	3.8
															4	
	1														7	
															1	
						1			1		2			1	11	
3	1		7	1	6		3	4	2	6	1	5	3	3	132	0.5
															1	
			2					3					10	1	31	0.1
3	4	6	1			3			4	4	4	5	1	11	61	0.2
9	2	5	24	3	32	30	4	15	8	30	16	16	7	9	533	2.0
1					1					1					14	0.1
															26	0.1
															1	
1					8					9					26	0.1
															1	
															1	
													1		2	
	1	1				1	1		1				1	2	22	0.1
69	16	20	10	1	88	29	43	15	17	40	28	79	39	26	772	2.8
1					2										3	
												2			2	
						1							1		13	
															2	
															3	
															1	
															2	
												1			2	
															4	
					1					1					3	
	8	1	3	4		9			1		1	2	3	3	54	0.2

TAXA	SITE W1 85	86	87	88	89	SITE W5 85	86	87	89	SITE W6 85	86	87	88	89
Athripsodes cinereus														
Athripsodes albifrons														
Athripsodes bilineatus	7					1								
Triaenodus bicolor	1													
Triaenodes conspersus														
Goeridae pupa														
Silo pallipes	3				16	1		3	2			3	9	1
Lepidostoma hirtum														
Brachycentrus subnubilus														
Sericostoma personatum		1	2	2	1	1	2		9	21		4	12	7
DIPTERA														
Limonia sp.											4			
Pedicia rivosa	1		4											
Dicranota sp.		3	9	14	3		1						6	
Eloeophila sp.		1												
Pilaria discicollis gp				2										
Gonomyia sp.														
Ceratopogonidae			1						3	1	3	1	1	4
Chironomidae	6	3	2	29	50	9	16	3	15	7	15	1	13	26
Simuliidae	1		4	23	11	3	6	11	44		16	3	18	455
Empididae pupa			1	1					1				1	
Chelifera gp					2								1	1
Hemerodromia gp		1			1									3
Wiedemannia gp			1											
Atherix ibis								1		3		5	3	5
Atherix marginata														

SHUNG 1985-89

DYM STTE(24)	STTE W7	STTE W8		STTE W9	STTE W10	STTE W11					STTE W12
87	89	88	89	89	89	85	86	87	88	89	89
*** *** ***	*** ***	***	***	*** ***	*** ***	***	***	***	***	***	*** ***
						43					
3	1										
	1										
	33	1	3	1	2	4	11	7	5	6	
						2	1				
1											
	9		1	3	1	5	2				7
2	148	30	26	43	9	26	9	8	336	50	57
4		6	14	5	2	1	5	11	61		25
	2	4							3		
	15				1		1				
	7		1				1				1
	3		1					1			1

TAXA	SITE W13 89	SITE W14 85	86	87	88	89	SITE T3 89	SITE T4 85	86	87	88	89
Athripsodes cinerous									1			
Athripsodes albifrons					1						4	
Athripsodes bilineatus		2										
Triaenodes bicolor		14										
Triaenodes conspersus												
Goeridae pupa												
Silo pallipes												
Lepidostoma hirtum		2	3				3				1	3
Brachycentrus subnubilus					13						4	
Sericostoma personatum		2	3	4	1		2		3	1	1	8
DIPTERA												
Limnia sp.												
Podicia rivosa												
Dicranota sp.		1		2	11					1		1
Eloeophila sp.												
Pilaria discicollis gp												
Gonomyia sp.					1							
Ceratopogonidae	1	10	3		1	2	2	56	1	1	1	3
Chironomidae	20	88	51	1	124	19	37	237	37	72	39	47
Simuliidae	10	101	17	2	113	220	360	74	33	232	7	1838
Empididae pupa					14						7	2
Cholifera gp							1					4
Hemerodromia gp		1			1		3	3	1			2
Wiedemannia gp									1	2		
Atherix ibis				1						1	1	
Atherix marginata												

SITE T5					SITE L4					SITE L5					TO	REL.
85	86	87	88	89	85	86	87	88	89	85	86	87	88	89	TALS	ABUND.(%)
															1	
			6					1					7		19	0.1
10					13				1	11					88	0.3
															15	0.1
					13					2					15	0.1
													1		1	
						2	2	2	2			6		2	58	0.2
1	1	2	1		4	15	5		6		2	1	1	2	54	0.2
			9					3					12		41	0.2
3	2	2	3	3		6	4	2	4		6	26	9	4	234	0.9
															4	
															5	
			4		1	3	1	3	1			5	4		77	0.3
															2	
												1			3	
															1	
5	4	2	1	2	2			2		2			2	2	147	0.5
71	45	13	29	17	45	39	19	21	33	14	20	27	107	51	2262	8.3
41	7	5	53	110	3	2	4		34	20	5	7	37	68	4132	15.2
		2	4			3	1					4	2	1	53	0.2
				2			4		1			6		1	40	0.1
	1				1	1			1				1	1	32	0.1
		2					1								7	
		4	2			1									33	0.1
									1		1				2	

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ANNEX D6.1Aiii

ABUNDANCE OF MACROINVERTEBRATES AT THOSE SAMPLING SITES AFFECTED BY ROADFORD RESERVOIR: 1985 TO 1988, AUTUMN

The total abundance and relative abundance (last 2 columns) are for all sites and years combined.

Component members of species groups:

Baetis scambus gp:	B. scambus and B. fuscatus
Rhithrogena semicolorata gp:	R. semicolorata and R. germanica (= haarupi)
Nemoura cambrica gp:	N. cambrica and N. erratica
Potamophylax latipennis gp:	P. latipennis and P. cingulatus
Tipula montium gp:	T. montium, T. couckei and T. lateralis
Pilaria discicollis gp:	as defined in Brindle (1967)
Chelifera gp:	)
Hemerodromia gp:	) Follows Brindle (1964)
Wiedemannia gp:	)

TAXA	SITE W1 85	86	87	88	SITE W5 85	86	87	88	SITE W6 85	86	87	88
TRICLADIDA												
Planariidae												1
Polycelis felina												
NEMATODA										3		
MOLLUSCA												
Potamopyrgus jenkinsi	1		2		116	25	3	2	3		5	
Lymnaea peregra												
Planorbis albus												
Ancylus fluviatilis	1		1	1	58		9		3			3
Zonitoides nitidus				1				1				
Sphaerium sp.			1									
Pisidium sp.	1	3	2			3				1	1	
OLIGOCHAETA	9	86	67	143	302	54	19	37	229	112	12	27
HIRUDINEA												
Hemiclepsis marginata												
Glossiphonia complanata												1
Helobdella stagnalis							1					
Erpobdella octoculata					1				2	10		1
Trocheta subviridis						1				2		1
HYDRACARINA												
CRUSTACEA												
Asellus meridianus												
Gammarus pulex					6	1		1	37	41	3	37
EPHEMEROPTERA												
Baetis scambus gp												
Baetis vernus										1		
Baetis rhodani	11	7	4	13	15	10	12	66	17	10	2	19
Baetis muticus	4	1							8	3		
Centroptilum luteolum												
Rhithrogena semicolorata gp	6	6	2	8	26	1	2	34		5		7
Heptagenia sulphurea												
Ecdyonurus sp.	5	3	7	13	17	2	4	15	3	2	2	34
Paraleptophlebia submarginata			1	2					1			
Ephemerella ignita		1				1						
Ephemera danica												
Caenis rivulorum												
PLECOPTERA												
Protonemura praecox												
Protonemura meyeri												
Amphinemura sulcicollis												
Nemurella picteti												
Nemoura avicularis	1		5	2					5			
Nemoura cambrica gp			1									
Leuctra sp.												

AUTUMN 1985-88

DAM SITE(24)	SITE W7	SITE W8	SITE W9	SITE W10	SITE W11				SITE W12
87	88	88	88	88	85	86	87	88	88
*** *** ***	*** ***	*** ***	*** ***	*** ***	***	***	***	***	*** ***
	1		1		10		3		1
	1								
					1				
1		2	11	11	1		12	2	69
							1		
					1		3	1	
	47	36	45	40	40	51	65	10	157
			1				1		
			1			1	3		2
1	2		3	4	3				5
			1	1		2	1	1	
					2				
						1			
1	16	1	2	6	12	3	2		2
	1	9	10	13	7	42		48	17
						3			
						1			
		10	3		16	1			10
1	26	13	3	8	21	5	13	5	4
	2				3				
							4		
		2							
						1			
					3		1		

TAXA	SITE W13 88	SITE W14 85	SITE W14 86	SITE W14 87	SITE W14 88	SITE T3 88	SITE T4 85	SITE T4 86	SITE T4 87	SITE T4 88
TRICLADIDA										
Planariidae										
Polycelis felina										
NEMATODA					2	1				
MOLLUSCA										
Potamopyrgus jenkinsi		10		3		1	84	1	2	
Lymnaea peregra						1	1		1	
Planorbis albus										
Ancylus fluviatilis				11	3	2	4		1	
Zonitoides nitidus										
Sphaerium sp.										
Pisidium sp.			1		1	1	3			
OLIGOCHAETA	2	46	208	52	95	77	170	78	32	47
HIRUDINEA										
Hemiclepsis marginata										
Glossiphonia complanata		1			4	1	1	3		1
Haldobdella stagnalis			1			2			3	5
Erpobdella octoculata	1	2					14	1		8
Trocheta subviridis					1				2	
HYDRACARINA										
CRUSTACEA										
Asellus meridianus					11					
Gammarus pulex	1	9	5	11	3	1	9	5	1	
EPHEMEROPTERA										
Baetis scambus gp			8		1					
Baetis vernus										
Baetis rhodani	8	14	48	1	11	19	21	36		9
Baetis muticus			2					1		
Centroptilum luteolum										
Rhithrogena semicolorata gp	2	5	1	4	4	10	63	6		9
Heptagenia sulphurea										1
Ecdyonurus sp.	1	3	7	1		1	3	3	1	
Paraleptophlebia submarginata					1			1		
Ephemerella ignita			8					3		
Ephemera danica					1					
Caenis rivulorum						1	1			
PLECOPTERA										
Protonemura praecox										1
Protonemura meyeri										
Amphinemura sulcicollis	1									
Nemurella picteti										
Nemoura avicularis							1			
Nemoura cambrica gp										
Leuctra sp.										1

AUTUMN 1985-88

SITE T5				SITE L4				SITE L5				TO	REL.
85	86	87	88	85	86	87	88	85	86	87	88	TALS	NEND.(%)
***	***	***	***	***	***	***	***	***	***	***	***	****	*********
												1	
				1								1	
		1					3				2	12	0.1
104	2	2	4	21	1	3	1	14		19	4	449	4.0
						1						5	
												1	
6		3	1			2	14	1			3	236	2.1
						1						3	
		1				2						5	
4												26	0.2
375	89	115	126	273	71	120	96	90	267	14	156	4187	37.0
	1											1	
16		2		5			1	9			1	48	0.4
	1						1					21	0.2
21	2	6	3	18	2		3	5	2		3	123	1.1
					1							14	0.1
												2	
												12	0.1
10	2	2	1	19	2		3	8	8	20	9	300	2.6
	1								1			11	0.1
									1			2	
20	30	2	13	5	34	1	7	4	28	3	16	663	5.9
6	2			5	1				3	1		40	0.4
												1	
14	4	12	16	52	4	6	48	70	14	1	62	544	4.8
											1	2	
10	4	3	10	14	1		6	2	4	1	10	291	2.6
5	1										1	18	0.2
	1				1				2		1	18	0.2
2				1				1			1	10	0.1
3							1					6	0.1
				2								3	
							1			30		33	0.3
												1	
												1	
		1	1									20	0.2
												1	
												1	

PAGE: 8

TAXA	SITE W1 85	86	87	88	SITE W5 85	86	87	88	SITE W6 85	86	87	88
Leuctra geniculata	2											
Leuctra inermis	2								1			
Leuctra hippopus			1	6		3						
Leuctra nigra				1	2							
Leuctra fusca		29	9	31		15	2	1		9	1	10
Perlodes microcephala					1			1		1		
Isoperla grammatica					2							
Dinocras cephalotes												
Perla bipunctata												
Chloroperla torrentium	3											
COLEOPTERA												
Dytiscidae												
Agabus sp.	1											
Gyrinus sp.					3							
Orectochilus villosus				1			1			1		
Hydraena gracilis										2		1
Helophorus brevipalpis												
Helodes sp.				1								
Elmis aenea		2	1	2	5	4	6	2	1	1	1	7
Esolus parallelopipedis										1	1	
Limnius volckmari		1	4	2	5	10	24	21	1	43	12	45
Oulimnius sp.							1					
Oulimnius tuberculatus												
MEGALOPTERA												
Sialis lutaria												
TRICHOPTERA												
Rhyacophila pupa												
Rhyacophila dorsalis		3	2	2		3		2		5		2
Rhyacophila munda												
Glossosomatidae pupa												
Glossosoma sp.	1							1				
Agapetus sp.	4				2		2					
Plectrocnemia conspersa					1							
Polycentropus flavomaculatus		2		1		1		1				
Tinodes dives									1			
Lype reducta							1					
Hydropsyche pellucidula					2							3
Hydropsyche contubernalis												
Hydropsyche siltalai			1	5	1	1	4	2		1	1	10
Hydropsyche instabilis												
Limnephilidae			1									
Limnephilidae pupa				2								
Limnephilus sp.												
Anabolia nervosa	1											
Potamophylax latipennis												
Potamophylax cingulatus												
Allogamus auricollis	1											
Chaetopteryx villosa	1		1									
Beraea maurus		1										

DM SITE(24)	SITE W7	SITE W8	SITE W9	SITE W10	SITE W11				SITE W12
87	88	88	88	88	85	86	87	88	88
*** *** ***	*** ***	*** ***	*** ***	*** ***	*** ***	*** ***	*** ***	*** ***	*** ***
						33	1		
	1				3	1			
					1				
	1						1		
				1					
1									
			1	2	3		1	3	3
	1			2			1		1
1	4	11	59	58	2	2	5	4	28
	1			2					
		1		1	1	4		1	2
			1	1		2	1		2
1					5				1
	2						1		
					1				
						9			1
				2	2	4		1	
						2			

TAXA	STIE W13 88	STIE W14 85	86	87	88	STIE T3 88	STIE T4 85	86	87	88
Leuctra geniculata		1					1			
Leuctra inermis										
Leuctra hippopus			1							
Leuctra nigra										
Leuctra fusca			33	2		1		17		
Perlodes microcephala								1		
Isoperla grammatica										
Dinocras cephalotes										
Perla bipunctata										
Chloroperla torrentium										
COLEOPTERA										
Dytiscidae										
Agabus sp.										
Gyrinus sp.		2					1			
Oreotochilus villosus				2	2					1
Hydraena gracilis										1
Halophorus brevipalpis										
Helodes sp.										
Elmis aenea	1	4	1	4	1	3	4		1	2
Esolus parallelepipedus			1	2	2	2			2	1
Limnius volckmari		14	15	17	31	35	100	13	20	13
Oulimnius sp.					1					
Oulimnius tuberculatus										
MEGALOPTERA										
Sialis lutaria				1						
TRICHOPTERA										
Rhyacophila pupa			1							
Rhyacophila dorsalis		2		1	1	2	1	1	1	
Rhyacophila munda										
Glossosomatidae pupa					1					
Glossosoma sp.	1		1		3	3		2		1
Agapetus sp.		2		1	1	1	11			1
Plectrocnemia conspersa										
Polycentropus flavomaculatus				2	3		1			
Tinodes dives		1								
Type reducta										
Hydropsyche pellucidula			6	6			9			
Hydropsyche contubernalis										
Hydropsyche siltalai		22		7	1	2	9		2	2
Hydropsyche instabilis										
Limnephilidae										
Limnephilidae pupa					1					
Limnephilus sp.										
Anabolia nervosa										
Potamophylax latipennis										
Potamophylax cingulatus										
Allogamus auricollis										
Chaetopteryx villosa										
Beraea maura										

AUTUMN 1985-88

SITE T5				SITE L4				SITE L5				TO	REL.
85	86	87	88	85	86	87	88	85	86	87	88	TALS	ABUND.(%)
***	***	***	***	***	***	***	***	***	***	***	***	****	*********
												4	
												3	
					1				1		1	14	0.1
												3	
	32				34				51		1	315	2.8
				1	1				1	1	2	10	0.1
				2						1		5	
							2					2	
				3	1							4	
							1		1			10	0.1
												1	
												1	
								3				9	0.1
	1						1			2	1	15	0.1
							1				2	8	0.1
												1	
												1	
2		7		3	1		21	2		29	3	134	1.2
	3	3	6		2	2	8		2		8	51	0.5
60	12	40	24	30	3	5	51	40	13	1	39	918	8.1
	1											6	0.1
							2			4		6	0.1
												1	
		1										2	
2				4	1		3	5	5	7	2	67	0.6
								1				1	
												1	
1	8	2	5		6		11		3		23	79	0.7
10			1	50	1		9	40		1	6	150	1.4
		1									1	3	
9	1			1				1				26	0.2
				2				2				7	0.1
												1	
3	2	2	1	12	3		10	1		9	6	85	0.8
					2							2	
7		5	9	86			124	21	3	208	32	575	5.1
				10								10	0.1
											1	4	
												3	
3												3	
												1	
											1	1	
								12				12	0.1
												1	
				1								3	
												1	

TAXA	SITE W4 85	86	87	88	SITE W5 85	86	87	88	SITE W6 85	86	87	88
Odontocerum albicorne					1							
Athripsodes sp.												
Athripsodes cinereus												
Athripsodes bilineatus					9							
Triaenodes bicolor												
Triaenodes conspersus												
Goera pilosa												
Silo pallipes			1	6	5	1	3	3				1
Silo nigricornis												
Lepidostoma hirtum												
Brachycentrus subnubilus												
Sericostoma personatum			9	4	4			3		1	3	
DIPTERA												
Dolichopeza albipes												
Tipula sp.									2			
Tipula (Savtschenkia) rufina												
Tipula (Yamatotipula) montium gp												
Limonia sp.									1			
Antocha vitripennis												
Pedicia rivosa				1								
Trichyphona sp.												
Dicranota sp.	1	18	8	11	9	7	2	3		3	4	
Eloeophila sp.			1	1		1		1		1	2	
Pilaria discicollis gp				1								
Pericoma sp.												
Dixa puberula	1											
Thaumalea sp.					1							
Ceratopogonidae				1	9	1			1			2
Chironomidae	19	15	5	10	41	1	1	6	7		1	5
Simuliidae	17	29	1	17	9	1		20	19	7	1	33
Empididae pupa										1		
Chelifera gp								1				
Hemerodromia gp					1							
Wiedemannia gp												
Dolichopodidae								1				
Atherix ibis						1				8		6
Atherix marginata												
Tabanidae												
Limnophora sp.												

DYM STIE(24)	SITE W7	SITE W8	SITE W9	SITE W10	SITE W11				SITE W12
87	88	88	88	88	85	86	87	88	88
*** *** ***	*** ***	*** ***	*** ***	*** ***	***	***	***	***	*** ***
							1		
					4				
1							4		
			2	10			19	3	8
							1		
					3				
	2			1					
					1				
					2				
			2		4		3		1
1	5	5	5		10	11	6	2	3
		2		1	4	60			
	1	1	2	1					1
					1				

TAXA	STTE W13 88	STTE W14 85	86	87	88	STTE T3 88	STTE T4 85	86	87	88	STTE T5 85	86	87	88
Odontocerum albicorne														
Athripsodes sp.					1									
Athripsodes cinereus													1	
Athripsodes bilineatus											7			
Triaenodes bicolor											2			
Triaenodes conspersus		2												
Coera pilosa		2		1										
Silo pallipes		1			1					2				
Silo nigricornis														
Lepidostoma hirtum						1					2			
Brachycentrus subnubilus														1
Sericostoma personatum		4			4	3			1		3		1	
DIPTERA														
Dolichopeza albipes														
Tipula sp.											1			
Tipula (Savtschenkia) rufina														
Tipula (Yamatotipula) montium gp														
Limonia sp.							2							
Antocha vitripennis														
Podicia rivosa											1			
Trichyphona sp.												1		
Dicranota sp.			16	3	3	3	2	4	1			2		2
Eloeophila sp.			1		4							2		1
Pilaria discicollis gp														
Pericoma sp.														
Dixa puberula														
Thaumalea sp.														
Ceratopogonidae		1		2	1	1	4		3	1	10		2	
Chironomidae	1	22	13	9	5	7	6	3	2	4	15	6	3	2
Simuliidae	2	65	93			2	3	26		2	17	10		1
Empididae pupa								1				1		
Chelifera gp														
Hemerodromia gp													1	
Wiedemannia gp					1								1	
Dolichopodidae														
Atherix ibis			2		3	1	1				3	3	4	1
Atherix marginata									1					1
Tabanidae														1
Limnophora sp.		1												

SITE L4				SITE L5				TO	REL.
85	86	87	88	85	86	87	88	TALS	ABUND.(%)
***	***	***	***	***	***	***	***	****	*********
								1	
			1			1		4	
								1	
2				4				26	0.2
								2	
1								3	
								3	
		3	4	1		1	2	36	0.3
								4	
				2		11	8	24	0.2
						1		2	
8	1		9	13	5	1	11	130	1.1
						2		2	
1								4	
						7		7	0.1
							1	2	
2				3				11	0.1
			1			1		2	
								2	
								1	
6		1	7	1	2			122	1.1
			2				1	18	0.2
								1	
						1	1	3	
								3	
								1	
2								51	0.5
21	11		40	15	19	16	99	478	4.2
50	1		7	93	20		3	616	5.4
								3	
								1	
2								4	
			3					5	
								1	
2			8	1	1	6		57	0.5
	1	2			1			6	0.1
								1	
								2	

ANNEX D6.1Aiv: ABUNDANCE OF MACROINVERTEBRATES AT SELECTED SITES ON THE RIVERS WOLF, THRUSHEL AND LYD: 1985 TO 1989, SPRING

85-89: cylinder samples

89P,89R,89G: kick samples for the special habitats survey in pools (P), tree roots (R) and grass (G) (submerged macrophytes)

Categories of abundance:

r:	1-3	individuals (rare)
o:	4-10	individuals (occasional)
c:	11-50	individuals (common)
a:	51-100	individuals (abundant)
va:	>100	individuals (very abundant)

The total and relative abundance (last 2 columns) are for the cylinder samples, all sites and years combined.

Component members of species groups:

Baetis scambus gp:	B. scambus and B. fuscatus
Rhithrogena semicolorata gp:	R. semicolorata and R. germanica (= haarupi)
Caenis luctuosa gp:	C. luctuosa (= moesta) and C. macrura
Nemoura cambrica gp:	N. cambrica and N. erratica
Potamophylax latipennis gp:	P. latipennis and P. cingulatus
Tipula montium gp:	T. montium, T. couckei and T. lateralis
Pilaria discicollis gp:	as defined in Brindle (1967)
Anopheles claviger gp:	A. claviger and A. algeriensis
Chelifera gp:	)
Hemerodromia gp:	) Follows Brindle (1964)
Wiedemannia gp:	)

TAXA	89	STTE W0 89P	89R	89G	STTE W11 85	86	87	88	89	89P	89R	89G	89
NEMATODA						5							
MOLLUSCA													
Potamopyrgus jenkinsi	1	r.	c.	o.	6	2	2	2			c.		2
Lymnaea palustris													
Lymnaea peregra			r.							o.	o.	c.	
Planorbis crista													
Ancylus fluviatilis	17				17	1		1					4
Zonitoides nitidis													
Sphaerium sp.											r.		
Pisidium sp.					2				1				
OLIGOCHAETA	139				433	105	70	17	58				459
HIRUDINEA													
Glossiphonia complanata					1	2	1						
Helobdella stagnalis						1			3				
Erpobdella octoculata	7				5								
Trocheta subviridis	2					2	8	1	1				
HYDRACARINA											r.		
CRUSTACEA													
Asellus meridianus									1				
Gammarus pulex		o.	o.	r.	4	13	2	8	1	o.	r.		1
EPHEMEROPTERA													
Baetis scambus gp								6			o.	c.	
Baetis vernus													
Baetis rhodani	30				18	50	44	31	49		o.	c.	74
Baetis muticus	5				2	3	11	2	3				2
Baetis niger			r.	r.							c.	c.	
Centroptilum luteolum												r.	
Centroptilum pennulatum		o.	r.							o.	r.		
Procloeon bifidum		r.								r.	r.	r.	
Rhithrogena semicolorata gp	7				15	40	79	1	6				76
Heptagenia sulphurea							1						3
Ecdyonurus sp.	2				15	4	6	2	2				1
Paraleptophlebia submarginata		r.	r.										
Habrophlebia fusca		o.	c.	r.				2		o.	o.		
Ephemerella ignita	5	c.	c.	c.	45			23		o.	c.	a.	9
Ephemera danica					1								
Caenis luctuosa gp													
Caenis rivulorum	5				20			4	2				9
PLECOPTERA													
Brachyptera risi						2	1						1
Protonemura meyeri													
Amphinemura standfussi						1							
Amphinemura sulcicollis					2	3							
Nemoura cambrica gp						1							
Leuctra sp.								1	1				

STTE W12			STTE W14								STTE T1							
89P	89R	89G	85	86	87	88	89	89P	89R	89G	85	86	87	89	89P	89R	89G
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
				1								4					
o.	c.		81			1		c.	c.	o.		3	3	28	c.	va.	c.
																r.	
r.	r.								r.	r.							r.
						2											
			5											1			
																	r.
			1														
														1			
			215	79	95	101	40				47	94	93	188			
			1	1	1								1				
						1	1						1				
			5	1			1				4						
				1	1	4	1						1				
r.								r.							r.		
					2	2	1										
c.	r.	r.	2	6	2	4		o.	o.	r.		1	4		c.	r.	
		r.				7											
		r.															
	r.	r.	34	45	7	11	91		r.	o.	27	33	36	42		o.	r.
			7	1		1	8				4	1	12	11			
		o.							r.	o.						r.	r.
	r.																
o.	r.							r.	r.	r.					r.	o.	c.
r.		r.														r.	
			59	31	28	5	71				4	26	119	120			
r.		r.	31		2	6	1	r.	r.	r.	2	4			r.	r.	o.
	r.										2	2	1				r.
o.	r.	o.	47			21		o.	c.	o.		5	1	1	c.	c.	c.
o.	o.	c.	221			97	5	c.	a.	c.					c.	c.	c.
												1		1			
r.									r.			1					
			117	3		34	8					2	1	10	r.		
				1	1		1				3		1	1			
				1		1	2					1	2	8			
						6	1										

TAXA	STTE T4 85	86	87	88	89	89P	89R	89G	STTE 11 89	89P	89R	89G
NEMATODA					1				2			
MOLLUSCA												
Potamopyrgus jenkinsi	33	6		10	4	o.	r.	o.	1	r.	r.	
Lymnaea palustris												
Lymnaea peregra							r.					
Planorbis crista												
Ancylus fluviatilis					1							
Zonitoides nitidis												
Sphaerium sp.												
Pisidium sp.	1					r.						
OLIGOCHAETA	575	150	121	43	30				410			
HIRUDINEA												
Glossiphonia complanata	1				2					r.		
Helobdella stagnalis			1									
Erpobdella octoculata	5	3		1	1		r.					
Trochota subviridis					1							
HYDRACARINA						o.				r.		r.
CRUSTACEA												
Asellus meridianus												
Gammarus pulex	2	3		1		c.	c.	c.	1		o.	r.
EPHEMEROPTERA												
Baetis scambus gp				5								
Baetis vernus												
Baetis rhodani	73	84	28	7	61				11		r.	c.
Baetis muticus	13	3	9	4	5			r.				
Baetis niger												
Centroptilum luteolum												
Centroptilum pennulatum							c.	r.		r.		
Procloeon bifidum						r.	r.					
Rhithrogena semicolorata gp	19	58	113	19	96				109			
Heptagenia sulphurea												
Ecdyonurus sp.	18	1		9				r.		r.		
Paraleptophlebia submarginata					1	r.	r.	r.				
Habrophlebia fusca				3	1	c.	o.	o.		o.		
Ephemerella ignita	62			57		o.	c.	c.	1	c.	c.	va.
Ephemera danica												
Caenis luctuosa gp				2			r.					
Caenis rivulorum	21	4		5	7				3	c.	r.	
PLECOPTERA												
Brachyptera risi	1	1			1							
Protonemura meyeri											r.	
Amphinemura standfussi												
Amphinemura sulcicollis		1			2					r.		
Nemoura cambrica gp												
Leuctra sp.				2	4				1			

SITE LS								TO	REL.
85	86	87	88	89	89P	89R	89G	TNLS	ABUND.(%)
	4							17	0.1
14		15	50	6	a.	va.	c.	270	1.6
								-	
								-	
								2	
7			12	1				67	0.4
	1							1	
								1	
				1	r.	r.		6	
110	94	70	139	534				4509	26.2
	3			1				15	0.1
								8	
9	1	1	2					46	0.3
								23	0.1
						r.		-	
								6	
1		4	1		o.	r.	r.	61	0.4
	1		2					21	0.1
								-	
35	20	112	34	32		r.	c.	1119	6.5
6	3	4	2	7				129	0.7
								-	
								-	
					r.	o.		-	
								-	
44	58	81	58	139				1481	8.6
								4	
44		8	2	1		r.		161	0.9
						r.		6	
					r.	o.		81	0.5
19	4		59	1	a.	a.	c.	608	3.5
						r.		3	
								3	
15	1		1	1				273	1.6
								15	0.1
								-	
								1	
1		1						25	0.1
								1	
			5	1				22	0.1

TAXA	89	SITE WD 89P	89R	89G	SITE WD1 85	86	87	88	89	89P	89R	89G	89
Leuctra geniculata							2	3		o.			13
Leuctra inermis										r.			
Leuctra hippopus													
Leuctra nigra	1					1							
Leuctra fusca			r.				1			r.			8
Isoperla grammatica					25	2	6		1				
Perla bipunctata													
Chloroperla torrentium					35	4	12						
Chloroperla tripunctata													
ODONATA													
Agrion virgo			r.									r.	
HEMIPTERA													
Hydrometra stagnorum												r.	
Velia sp.				o.							r.	c.	
Gerris sp.										r.	r.	c.	
Notonecta sp.													
Sigara dorsalis													
COLEOPTERA													
Brychius elevatus													
Haliplus fluviatilis													
Haliplus lineatocollis													
Potamonectes sp.		o.	r.							o.			
Potamonectes depressus elegans										r.			
Oreodytes sp.										r.			
Oreodytes sanmarkii													
Oreodytes septentrionalis													
Hydroporus sp.													
Hydroporus tessellatus											r.		
Agabus bipustulatus		r.											
Platambus maculatus											r.	r.	
Stictotarsus duodecimpustulatus			r.								o.		
Gyrinus sp.			r.									r.	
Gyrinus urinator												r.	
Orectochilus villosus						1							
Hydraena gracilis						2	1				r.		
Helophorus aquaticus													
Helophorus brevipalpis			r.	c.			1				o.	c.	
Helophorus grandis													
Elmis aenea	5	r.		r.	16	2			1				3
Esolus parallelepipedus	3					1			1				1
Limnius volckmari	75	r.			50	4	11	9	20				55
Oulimnius sp.													
Oulimnius tuberculatus								1					
MEGALOPTERA													
Sialis lutaria					1								

STTE W12			STTE W14									STTE T1						
89P	89R	89G	85	86	87	88	89	89P	89R	89G	85	86	87	89	89P	89R	89G
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
c.			13	1		8	13	c.				11	16	5	c.	r.	r.
			4				1							1			
					1									1			
r.						22	4	r.				4	6	7			
			2	2							1	5	18	13			
			26	3	3	3	2				2	5	4	14			
									o.							r.	r.
		r.															
		c.								c.							o.
		c.															o.
															r.		
c.								r.							o.		
																	r.
r.																	
r.																	
		r.													r.		
	r.	o.							r.							r.	r.
	r.								r.	r.							
	r.	r.	1						r.		1						
		r.	1	1							1	3		3			
														3			
																	r.
		c.							o.	c.					o.	o.	c.
		o.															
r.	r.		3			1	2	r.	r.					3	r.	o.	
							1		r.					4			
r.			47	2	5	17	15	r.			2		10	42	r.		
r.								r.									
						1											

TAXA	SITE T4 85	86	87	88	89	89P	89R	89S	SITE E3 89	89P	89R	89S
Leuctra geniculata	4	9	11	12	45	o.		o.	2	c.		
Leuctra inermis			1		1				2			
Leuctra hippopus	1											
Leuctra nigra					1							
Leuctra fusca		2	1	13	11				7	c.		r.
Isoperla grammatica	6	1	6	2	8				1			r.
Perla bipunctata	1				1							
Chloroperla torrentium	3	3	12		7				5			
Chloroperla tripunctata									1			
ODONATA												
Agrion virgo							r.					
HEMIPTERA												
Hydrometra stagnorum												
Velia sp.												o.
Gerris sp.												
Notonecta sp.								r.				
Sigara dorsalis							r.					
COLEOPTERA												
Brychius elevatus												
Haliplus fluviatilis							r.					
Haliplus lineatocollis							r.					
Potamonectes sp.						c.		r.		o.		
Potamonectes depressus elegans												
Oreodytes sp.												
Oreodytes sanmarkii				1						r.		
Oreodytes septentrionalis												
Hydroporus sp.												
Hydroporus tessellatus							r.				r.	
Agabus bipustulatus												
Platambus maculatus							r.	o.			o.	r.
Stictotarsus duodecimpustulatus						r.	r.					
Gyrinus sp.	1						o.					
Gyrinus urinator												
Orectochilus villosus	1	1						r.			r.	
Hydraena gracilis		1										
Halophorus aquaticus												
Helophorus brevipalpis							o.	c.				a.
Helophorus grandis												
Elmis aenea	2							o.		c.	o.	r.
Esolus parallelepipedus				1					1			
Limnius volckmari	103	4	6	20	19				8			
Oulimnius sp.												
Oulimnius tuberculatus												
MEGALOPTERA												
Sialis lutaria												

STTE 15								TO	R&L.
85	86	87	88	89	89P	89R	89G	TALS	NITED.(%)
***	***	***	***	***	***	***	***	****	*********
12	10	5	5	1	o.			201	1.2
								10	0.1
								1	
3								8	
	6		9	1	r.		r.	102	0.6
4		4	2	2				111	0.6
	2			4				8	
2	4	2	1	3				155	0.9
								1	
						r.		-	
								-	
								-	
								-	
								-	
								-	
								-	
								-	
								-	
					o.			-	
						r.		-	
								-	
					r.	r.		1	
								-	
								-	
								-	
								-	
						o.	r.	-	
								-	
								3	
								-	
	1					r.		13	0.1
			1					8	
								-	
					o.	o.	r.	1	
								-	
3			5			r.		46	0.3
		1	2					16	0.1
20	1	7	14	13				579	3.4
								-	
								2	
								1	

TAXA	89	STTE W0 89P	89R	89G	STTE W11 85	86	87	88	89	89P	89R	89G
TRICHOPTERA												
Rhyacophila pupa												
Rhyacophila dorsalis						1		6	1			
Rhyacophila minch												
Glossosomatidae pupa												r.
Glossosoma sp.												
Agapetus sp.	1				76	8	33	2				
Plectrocnemia conspersa						1						
Polycentropus flavomaculatus			r.					1			r.	
Polycentropus irroratus												
Cymus trimaculatus												
Tinodes waeneri												
Tinodes dives					4							
Lype reducta			o.									
Psychomyia pusilla												
Hydropsychidae pupa												
Hydropsyche pellucidula						3	1		1			
Hydropsyche siltalai					8	3	7					
Limnephilidae pupa												
Limnephilus sp.												
Limnephilus lunatus												
Drusus annulatus					2	1						
Potamophylax latipennis gp												
Potamophylax latipennis						1						
Halesus sp.		r.										
Halesus radiatus												
Chaetopteryx villosa		r.			2							
Odontocerum albicorne												
Leptoceridae pupa												
Athripsodes sp.	1											
Athripsodes cinereus												
Athripsodes albifrons												
Athripsodes bilineatus					43							
Triaenodes bicolor												
Triaenodes conspersus												
Adicella reducta												
Goeridae pupa												
Silo pallipes												
Lepidostoma hirtum												
Brachycentrus subnubilus										r.	r.	
Sericostoma personatum	1				4	11	7	5	6			

	STTE W12			STTE W14								STTE T1						
89	89P	89R	89G	85	86	87	88	89	89P	89R	89G	85	86	87	89	89P	89R	89G
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
				5	3	1	6	2			r.	3	2	2	1			
				1														
																		r.
								1						1	2			
4				3	1	2	23	2					10	10	41			
				4											1			
	r.						1						1		2	r.	r.	
										r.								
									r.									
										o.								
					1					r.								
							1											
						1							1		1			
1				13	8	3	5	1				3	2	6	3			
												5						
												1	1					
						2												
										r.								
									r.	r.								
	r.	r.		1						r.			1				r.	
		r.											1			o.	r.	
		r.																
					1						r.		4	2	5			
							1											
				2					r.	r.						r.	r.	
				14														
				2	3					r.	r.		1			o.	c.	o.
	o.	r.					13		c.	o.	o.							
	o.			2	3	4	1			r.		3	5	5	11	r.		

TAXA	SITE T4 85	86	87	88	89	89P	89R	89G	SITE L1 89	89P	89R	89G
TRICHOPTERA												
Rhyacophila pupa				2					1			
Rhyacophila dorsalis	11	5	3	5	5			r.	1	r.	o.	r.
Rhyacophila munda												
Glossosomatidae pupa				2	1				1			
Glossosoma sp.		1	2		5				10	r.		r.
Agapetus sp.	7	2	7	17	2				1			
Plectrocnemia conspersa	1											
Polycentropus flavomaculatus				2				r.		r.	r.	
Polycentropus irroratus							o.	r.				
Cyrnus trimaculatus												
Tinodes waeneri												
Tinodes dives												
Lype reducta												
Psychomyia pusilla												
Hydropsychidae pupa												
Hydropsyche pellucidula	1								1			
Hydropsyche siltalai	32	7	36	24	33				1		o.	
Limnephilidae pupa												
Limnephilus sp.												
Limnephilus lunatus							r.					
Drusus annulatus												
Potamophylax latipennis gp								r.				
Potamophylax latipennis												
Halesus sp.								o.		r.		r.
Halesus radiatus							r.					
Chaetopteryx villosa												
Odontocerum albicorne												
Leptoceridae pupa												
Athripsodes sp.				5	7							
Athripsodes cinereus		1										
Athripsodes albifrons				4								
Athripsodes bilineatus						r.		r.				
Triaenodes bicolor												
Triaenodes conspersus												
Adicella reducta											r.	
Goeridae pupa												
Silo pallipes									4			
Lepidostoma hirtum				1	3		c.	c.	1	c.	o.	c.
Brachycentrus subnubilus				4			c.	c.		c.	c.	c.
Sericostoma personatum		3	1	1	8	r.	r.	r.	1	o.	r.	r.

SITE L5								TO	REL.
85	86	87	88	89	89P	89R	89G	TNLS	ABUND. (%)
***	***	***	***	***	***	***	***	****	*********
	2			1				6	
6	1	5	3	3				81	0.5
								1	
			10	1				15	0.1
4	4	5	1	11				47	0.3
30	16	16	7	9				330	1.9
1								8	
								7	
								-	
								-	
								-	
9								13	0.1
								-	
								1	
			1					2	
			1	2				13	0.1
40	28	79	39	26	r.			408	2.4
		2						2	
								5	
								-	
			1					6	
								2	
								1	
						r.	r.	-	
		1			r.	c.		3	
					o.	o.		3	
1								1	
								-	
	1	2	3	3				34	0.2
								1	
			7					12	0.1
11								56	0.3
								14	0.1
2								2	
								-	
			1					1	
		6		2				12	0.1
	2	1	1	2	c.	a.	r.	17	0.1
			12		o.	r.	r.	29	0.2
	6	26	9	4	r.	r.		127	0.7

TAXA	89	STTE W0 89P	89R	89G	STTE W1 85	86	87	88	89	89P	89R	89G
DIPTERA												
Tipula sp.												
Tipula (Yamatotipula) montana gp												
Tipula (Savtschenkia) rufina												
Dicranota sp.					2	1						
Eloeophila sp.												
Pilaria discicollis gp												
Gonomyia sp.												
Periocoma sp.											r.	
Dixa puberula												r.
Anopheles claviger gp												
Ceratopogonidae	3				5	2						
Chironomidae	43	o.	c.	o.	26	9	8	336	50	r.	o.	c.
Simuliidae	5			r.	1	5	11	61				r.
Empididae pupa								3				
Chelifera gp						1						
Hemerodromia gp						1						
Wiedemannia gp												
Atherix ibis							1					
Atherix marginata												
Limnophora sp.												r.

SITE W12				SITE W14								SITE T1						
89	89P	89R	89G	85	86	87	88	89	89P	89R	89G	85	86	87	89	89P	89R	89G
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
												1						
													1					r.
				1		2	11						2	1				
													1		1			
							1											
											r.							
7				10	3		1	2					1	1	8			
57	o.	o.	r.	88	51	1	124	19	o.	o.	o.	124	62	34	107	c.	o.	c.
25		r.		101	17	2	113	220			r.	19	25	152	350			
	r.						14						1		1			
													1	1	8			
1				1			1								2			
													1		1			
1						1			r.					1				

TAXA	SITE T4 85	86	87	88	89	89P	89R	89G	SITE L1 89	89P	89R	89G
DIPTERA												
Tipula sp.												
Tipula (Yamatotipula) montium gp								r.				
Tipula (Savtschenkia) rufina											r.	
Dicranota sp.			1		1							
Elooophila sp.												
Pilaria discicollis gp												
Gonomyia sp.												
Pericoma sp.												
Dixa puberula								r.				o.
Anopheles claviger gp							r.					
Ceratopogonidae	56	1	1	1	3				1			
Chironomidae	237	37	72	39	47	o.	c.	c.	24	c.	c.	c.
Simuliidae	74	33	232	7	1838				238		r.	o.
Empididae pupa				7	2							
Chelifera gp					4							
Hemerodromia gp	3	1			2				1			
Wiedemannia gp		1	2									
Atherix ibis			1	1								
Atherix marginata											r.	
Limnophora sp.												

SITE L5								TO	REL.
85	86	87	88	89	89P	89R	89G	TNLS	ABUND. (%)
***	***	***	***	***	***	***	***	****	*********
								1	
								1	
								-	
		5	4					31	0.2
								2	
		1						1	
								1	
								-	
								-	
								-	
2			2	2				112	0.7
14	20	27	107	51	a.	r.		1814	10.5
20	5	7	37	68			r.	3666	21.3
		4	2	1				35	0.2
		6		1				22	0.1
			1	1				15	0.1
								5	
						r.		6	
	1							1	
								-	

Annex E

RECREATION

HALCROW

ANNEX E - RECREATION

CONTENTS

E1 INTRODUCTION

E1.1 Roadford

Roadford Lake is located 3 miles to the north of the A30, approximately 12 miles northeast of Launceston and 14 miles west of Okehampton. A new junction, planned for 1992, will give access to the improved A30, 1½ miles south of the dam. Access from the north is effected by narrow country lanes.

Roadford is the second largest area of inland water (298 ha) in South West Water's region, surpassed only by Colliford Lake on Bodmin Moor (364 ha).

At the Public Inquiry in 1980, the Inspector's report indicated that initially, provision would be made for only a few recreations compatible with the rural character of the countryside, such as fishing, walking and passive enjoyment of the lake's special character. At the southern end of the lake there would be some non-statutory footpaths and around Germansweek at the norther end; the continuity of a number of existing rights of way would be maintained by the formation of some new linking public rights of way (Figure E1).

While noting the potential of the reservoir for recreational development, it was decided to provide at an early stage only limited car parking together with toilet facilities. Further recreational facilities would be considered as and when necessary in the light of proven demand within the constraints imposed by finance, the surrounding road system, the adjoining farm activity and with due regard to the views of the local community.

The Roadford Water and Land Use Consultative Group (RWLUG) was formed following that Inquiry "to advise South West Water Authority as to the nature and scale of the use to which the land and the water at Roadford Reservoir will be put for recreational facilities, taking into account the views of all those with a legitimate interest in the regime of the reservoir and its surroundings".

This Group includes representatives of Parish, District and County Councils, governing bodies of sport, conservation and special interest groups and meets regularly. It has recognised that many visitors will be attracted to Roadford regardless of the earlier stated intentions of low key provision of facilities. With this in mind, South West Water employed PIEDA Consultancy to provide a development framework for recreation and leisure at Roadford. In drawing up this document, PIEDA addressed the policies of land and consulted with County and District Councils, the South Western Council for Sport and Recreation and the Westcountry Tourist Board. It is intended that any development would be of the highest quality and would not compromise the atmosphere and environment that are the essence of the site. The development framework has been discussed with the two District planning authorities and the RWLUG.

E1.2 Burrator

Burrator Reservoir lies within the Dartmoor National Park, near Yelverton approximately 11 miles northeast of Plymouth. It is easily accessible from the B3212 and is encircled by a single track road.

South West Water's landholding extends to 2,225 ha, with 61 ha of water at top water level. 1,659 ha of moorland are licensed to the Dartmoor National Park Authority (DNP) under a ten year Management Agreement to study herbage, secure public access to open land, manage Ancient Monuments (over 90 recorded) and intervene in the agricultural use of the land. The remaining 505 ha of land immediately surrounding the water is managed directly, mainly as forestry by South West Water.

Limited facilities for informal and active recreation are provided at Burrator. There is no designated public area but there are seven waymarked forest paths and there is general access over 2,145 ha of land. Six small car parks accommodate 40 cars with 200 additional spaces in informal parking areas. There is a public toilet block below the dam. Ice creams and snacks are available from mobile vending units at the dam and at Norsworthy Bridge. Horse riding takes place on the open moorland and various tracks including public bridlepaths. Birdwatchers have access to 5.3 km of shoreline. Access to the extreme eastern edge of the reservoir is not permitted. Approximately 14 ha of water and a similar area of land are designated as a Special Protection Zone to protect bird life.

Turning to active recreation, 5.3 km of shore is currently available for bank anglers fishing for brown and rainbow trout in the "Budget" (low key) fishery. A local scout group has a licence for scouting activities with use of 0.6 ha of land. Diving, canoeing and climbing licences are issued occasionally on an ad hoc basis and there are one or two orienteering events held annually. The local Parish Council is sensitive to active recreation on the water. A joint Working Party SWW/DNP reported on recreational use of Burrator and associated lands in 1980 and concluded that there were some aspects of sailing and rowing that were unacceptable. DNP would be willing to see trials of such quiet watersport activities. Wind conditions render the site unsuitable for advanced sailing although it could be used as a training facility when drawn down.

A local family retains and exercises sporting rights on land on the eastern side of the reservoir.

South West Water has been carrying out a study of the recreation and amenity facilities at its sites throughout the region. Burrator has been highlighted as one where facilities for informal and active recreation should be improved although as in the case of Roadford, no firm proposals are available for study. The site is designated Landscape Type VII (Major Conifer Plantation) and is subject to DNP's policies.

E1.3 Meldon

Meldon Reservoir also lies within the Dartmoor National Park within the landscape classification 'High Moorland'. It is 4 miles south west of Okehampton and 27 miles west of Exeter. It is accessible from a junction off the A30.

South west Water's landholding is small 75 acres of land and water, with 54 acres of water at top water level. The former Devon Trust for Nature Conservation (now Devon Wildlife Trust) has a 21 year lease that expires in 1994, to manage 14.32 acres of land as a Nature Reserve. There is no public access to the Reserve.

A public car park (60- 70 cars) and toilets adjoin the reservoir, provided by Dartmoor National Park Authority.

There is some use for picnicking and the public has access to approximately 1.4 miles or 2,500 yards of bank in approximately 16 acres of land. There is a viewing point by the Dam (foot access only).

Organised active recreation takes place on 40 acres of water. Club watersports activity is mainly sailing and boardsailing. Military training is confined to canoe exercises. Training in sailing, boardsailing and canoeing is organised by a local hotel which markets specialist activity holidays. The only infrastructure to support watersports is a primitive slipway, close to the Dam.

Fishing for wild brown trout and rainbow trout stocked as fry is available free of charge for holders of a current NRA rod licence.

South West Water's view of Meldon is that, given its High Moorland status, its steep sides, the high rainfall and exposed position, it should remain an area for low key activity.

The site is under the day to day management of South West Water's Roadford Ranger.

E2 EXISTING RECREATIONAL USE

E2.1 Roadford

There are five small car parks and the main 120 space Dam car park. This houses a public toilet block in an adjacent meadow and there is a shop and tea room, and childrens' play and picnic areas. It is too early for a pattern of usage to emerge but early indications are that 500 to 1,000 visitors are attracted each Sunday to view the reservoir. Most walk across the dam before returning to their cars. Conservative estimates based on visitor surveys at other sites are that 250,000 public access visits are likely to occur annually. These will probably take place between 10 am and 6 pm. Sunday afternoons and bank holidays will be the busiest times. July and August will probably attract peak visitor numbers.

There are two existing statutory bridlepaths adjacent to the northern reaches of the reservoir. Initial indications are that these are little used. Proposals from within the RWLUG for permissive bridleways at the southern end of the reservoir are under consideration.

In addition to the re-routed statutory bridlepaths there are two statutory footpaths at the Southweek Arm. Permissive waymarked paths start at either side of the dam. One is surfaced, suitable for the disabled.

E2.2 Burrator

The use by the general public of lay-bys and forest walks is very high. The formal car parks are often full but the parking capacity of 240 is rarely reached except on bank holidays. The estimated annual visits were as high as 868,000 per annum in 1975 based on 20% visits occurring in July and August and the Dartmoor National Park parking survey of 2,800 persons per day during the period. This is more than twice the number of annual visits received currently at any other South West Water recreation site. The site is busy all year round, especially on Sunday afternoons, even when wet. Visitors mostly arrive between 10 am and 6 pm. Afternoons and early summer evenings are the most popular. In summer 50% of visits are from holidaymakers; 90% of visits are from local residents for the remainder of the year. An average of 12 coaches visit each week. There is no general public access to the shoreline but the water can be seen from the surrounding road.

The seven forest walks which radiate from, and return to, the perimeter road are used all year round. DNP runs guided walks from Norsworthy Bridge for part of the year. Possibly 130,000 people go for a walk of greater than 2 miles.

It is estimated that in 1987, 3,000 visits were made for birdwatching. September to March is the most popular time and visitors generally arrive before mid-day.

The trout fishery is zoned for fly fishing and spinning. Day and season permits are available and between 2,000 and 4,500 annual visits are made. The season last from 15 March to 30 September, from sunrise to midnight. March, July and August are the busiest months, accounting for 15% of total visits. Local anglers tend to fish for 2 to 3 hours in the late evening whilst holiday anglers fish for 5 to 6 hours during the day.

Between 20 and 30 visits for diving are made and 50 to 100 canoeing visits annually. These activities are most likely to take place between April and September. There are no established patterns of usage.

E2.3 Meldon

The car park is used as a starting off point for walking across Dartmoor. Surveys in 1987 indicated probably a maximum annually of 16,300 general visits of which 3,000 walked over 2 miles. In the summer there can be up

to 100 cars, especially on Sundays. 75% of annual visits probably occur in July and August. There has been a noticeable increase in visits since the reservoir was signposted from the new A30 trunk road junction in 1990.

There is limited educational use of the Nature Reserve which could be expanded.

The Meldon Sailing Club's membership has dwindled to less than a dozen. Their licence permits a maximum of 30 craft on the water; the usage in the past has been confined to weekends in the summer months. Army canoeing takes place mainly between June and September - a maximum of 10 canoes at any one time on no more than three days a week. There are probably 500 canoe launchings annually. The use by hotel guests undertaking watersports training totals around 1,200 annual visits, mainly for boardsailing.

Visitors who fish for trout account for perhaps 100 annual visits. They are mainly in the 30-50 age group. There is a noticeable absence of pensioners, probably because of the difficult terrain and most activity taking place in the evening.

E3 PROPOSED FUTURE RECREATIONAL USE

E3.1 Roadford

Permissive footpaths around the water's edge will not be established until the reservoir is full. Access in the northern and eastern reaches is currently confined to staff only, since the Resident Engineer perceives a real danger to the public from saturated ground where the reservoir has yet to take shape. See Figure E1.

A natural brown trout bank fishery is planned, with autumn stocking of fingerlings when water conditions are appropriate. Provided this stocking takes place by the Autumn of 1991, the fishery will open in the spring of 1993. The season will operate from mid-March to mid-October from one hour before sunrise to one hour after sunset. Bank fishing will be zoned to avoid conflict with sensitive conservation areas and angling effort is likely to be concentrated in the middle reaches.

As outlined in 1.1 above, detailed consultations and discussions within the RWLUG and with planning authorities are required before any activities or facilities additional to those specified at the Public Inquiry can be developed. For the purposes of this report, activities and facilities that have been acceptable at other comparable South West Water recreation sites have been highlighted and the impact that drawdown is likely to have upon them is shown in Table E1.

E3.2 Burrator

The Dartmoor National Park Authority has identified the reservoir and its surrounding area as one that is heavily used and where management to maintain the attractiveness and enhance enjoyment of it should receive high priority. The consultation draft for the second review of the National Park Plan identifies the need for early preparation and implementation of a recreation management plan.

In South West Water's recent review of its recreation provision, Burrator has been highlighted as a site where improvements for active and informal recreation are a priority. Any major improvements would need to be part of a coherent strategy for the site, as part of a regional plan. In advance of detailed discussions and consultations with the local planning authority (DNP) and other interested bodies, it is not possible to link specific additional activities or facilities with Burrator. Table E2 highlights activities that have been acceptable at other comparable recreation sites and indicates the likely effects of drawdown upon them.

E3.3 Meldon

There are no plans to develop new facilities or encourage additional activities. The site has been identified as one requiring improved interpretation and re-signing. The slipway poses an ongoing maintenance

problem and improvements could be made to facilities provided for watersports participants.

E3.4 General

South West Water Plc provides a diverse range of leisure and recreation activities throughout its region. It is committed to improving the quality and range of that provision where this does not bring about undue conflict or compromise its conservation duties. Within this framework, it is already clear that certain water based activities are not acceptable eg power-boating and jet skiing. These have not been considered in Table E1 and E2.

E4 DRAWDOWN

E4.1 Roadford

Two example years have been used for the purposes of this study, 1987 is used as an 'unremarkable year' and 1989 as a 'dry year'.
References in the following paragraphs to 'unremarkable' and 'dry' years relate therefore to years similar to the illustrative example years, 1987 and 1989.

In an unremarkable year, water level would decline gradually from July, giving no more than 3m of drawdown by the end of September, when levels would begin to rise, with full recovery by early November. This degree of drawdown at maximum would result in a water area of 260 ha and lengths of slope of exposed shoreline up to 50m extending to 200m in creeks.

In a dry year top water level would be maintained until early June. The level would drop by 4m over the following 2 months then by early September a further decline to 9.1m of drawdown would leave a reduced water area in the region of 173 ha, maintained until the middle of October. Lengths of slope of shoreline exposed in the Dam area would be around 85m with up to 290m in the Westweek Arm and up to 430m in the Southweek Arm. By the end of October, the water level would improve by 1m, returning to drawdown of around 5m at the end of December.

See Figures E2 and E3.

E4.2 Burrator

E4.2.1 Existing Situation

At present in a typical year, reservoir levels fluctuate throughout the year from full capacity to not more than 1.9m of drawdown (80% full) giving a minimum water area of 53 ha. Only between mid August and mid October is the level likely to drop below that level with a peak of 3.4m drawdown (58% full) at the end of September, and a water area of 47 ha.

In a one in 10 year summer drought, the reservoir is likely to be drawn down steadily to around 3.2m by July. From July to mid October this level of drawdown is maintained, with a peak of 4.0m (45 ha water area) at the end of July. The reservoir level recovers rapidly to return to top water level in early November.

The drawdown experienced in 1989 is illustrated in Figure E4.

E4.2.2 Halcrow Case

In an unremarkable year, water levels would fluctuate more frequently than at present from mid January to mid May but drawdown would not often exceed 1m, reducing the water area to 59 ha (92% full). In May, drawdown would fall to 2.5m improving to under 1m throughout June, after which

levels would be likely to plummet. Drawdown of 6.6m (32 ha water area) could be experienced in August, recovering to 5m in early September before dropping to 6.6m until early October. The reservoir would rapidly return to capacity by mid October, with small fluctuations in level to the year end (the maximum drawdown of 1.5m in early December), providing average rainfall occurred in the month.

In a dry year drawdown of 1.9m could be experienced in early January, then an improvement to fluctuations not exceeding 1.2m. A sharp decrease from the middle of May to in the order of 4.2m of drawdown in early summer, with a further drop in level to 5m drawdown in late July and a drawdown peak of around 9.6m in early September. Water level would make a sharp recovery in the month and the reservoir would remain full to the year end, apart from a 'blip' to 2.5m drawdown in early December, followed by a rapid recovery.

E4.3 Meldon

Four cases have been examined in relation to Meldon:

1976 - 'very dry year'
1986 - 'wet year'
1987 - 'unremarkable'
1989 - 'dry year'

throughout the following paragraphs, references will be made in those terms.

Hydrograph 9 in Volume 6 of this report illustrates the storage level in Meldon Reservoir in each of these 4 years under the HOC rules.

E4.3.1 Very Dry Year

The historical position shows drawdown levels fluctuating to no more than 4m from January to June. Thereafter, the water level would plummet, reaching 10m of drawdown in early July and a peak of 18m in mid September, with a rapid recovery to TWL by the end of that month.

The Halcrow case would, in fact, result in improved levels from January to May, with the reservoir virtually full. Thereafter the historic pattern would be followed until the mid September peak where levels might drop to 23m of drawdown and recovery to full capacity might take an additional week.

E4.3.2 Wet Year

In a typical wet year, Meldon is shown to be full for most of the year, with no more than 3m of drawdown occurring for one week in March and one week in late October.

The Halcrow case would mimic the historic pattern apart from a drawdown over three weeks in July reaching no more than 4m and a similar occurrence in late September/early October.

E4.3.3 Unremarkable Year

In a year such as 1987, Meldon has historically experienced sporadic drawdown not exceeding 3m between January and early August and from mid October to December. The reservoir is generally full in February and April. Levels drop in August but never exceed 4m of drawdown.

The Halcrow case would be likely to result in the reservoir being full from October to May. Fluctuations in levels from May to the end of July would be less than those experienced historically, but in August and September levels could drop sharply to give 7m - 8m of drawdown before a rapid recovery.

E4.3.4 Dry Year

The reservoir fluctuates between full capacity and 4m of drawdown from January to mid June in a dry year. Rapid drawdown to a maximum of 17m in early September is followed by an equally rapid recovery to 7.4m within two weeks and sustained for a further three weeks before a quick return to full capacity. By the middle of November the reservoir level will tend to fluctuate, reaching no more than 4m drawdown.

The Halcrow case would result in full capacity from January to mid May. Thereafter, the drawdown pattern would be likely to mimic historical patterns until mid October, when the reservoir is likely to remain full.

E5 IMPACT OF INCREASED DRAWDOWN ON RECREATION USES

E5.1 Roadford

It is not possible at this stage to accurately predict the effect of drawdown on the enjoyment of informal visitors. Early observations indicate that repeat visits to view the changing water levels in the new reservoir are being made.

It is probable that a shoreline environment similar to that at Wimbleball Lake will emerge, with very little vegetation on exposed banks. Observations at Wimbleball during the drought year of 1989 indicated no decrease in visitor numbers. Surprisingly, the majority of visitors were content to remain in the picnic field even though the lake had disappeared from view.

A users survey (1985/86) of reservoir-based recreation clubs, undertaken by Sunderland Polytechnic, indicated that 20% of those respondents who were casual users considered that drawdown did reduce their enjoyment. However, several respondents commented that drawdown actually increased their enjoyment owing to seeing the reservoir in a variety of states.

The reservoir is certain to be visually unattractive in dry years when large expanses of mud are exposed as a consequence of drawdown. The use of an appropriate herbaceous colonist to reduce the visual impact of these expanses should be explored. Depending on the period over which the drawdown occurs and the length of the time that mud remains exposed, there is also a potential danger to walkers straying from nominated footpaths. Children in particular are tempted to walk across such mudflats and whilst at small reservoirs the problem is relatively easy to contain, there could be serious management problems on a water the size of Roadford with the large numbers of casual visitors envisaged. Imaginative zoning and education of visitors will need to be employed.

In dry years, there will be some temptation to horse riders to leave bridleways in order to ride closer to the water's edge or to take their horse for a drink. This potential problem will need to be managed by a process of education and zoning as described above.

During a dry year, there would be fluctuating levels during the crucial time of March - end of May (the period when it can normally be expected that birds will raise one brood successfully) and any adverse effect on breeding would impair the enjoyment of birdwatchers. From observations of reed breeding species at other reservoirs, it would appear that species breeding in reed stems are unlikely to be affected and the introduction of Phragmites (reed) in areas such as the Westweek Arm might provide additional valuable habitat. The impact on wildlife is fully addressed in Annex D.

The bank fishery will undoubtedly be affected by drawdown as access to the shore becomes increasingly difficult. In initial years, stocking will be on an annual basis in late Autumn and it is unlikely that drawdown will hamper that operation. Inconvenience to anglers, particularly handicapped anglers

is likely to be the main consequence of either operating regime in dry years and use of the fishery can be expected to decline as the water becomes less attractive.

E5.2 Burrator

Burrator's attraction appears to prevail throughout very dry years and, in fact, increased visits were noticed during 1989. The shoreline is colonised with Littorella uniflora which produces a green sward thus reducing the visual impact of drawdown. Since there is at present no general public access to the shoreline, the water is observed from a distance which softens the impact of drawdown. Oscillating drawdown at Burrator has become accepted as part of the annual cycle. Should a round reservoir walk be introduced, levels no lower than those experienced in 1989 would be desirable for aesthetic and safety reasons.

Probably the greatest impact of the proposed operating rules would be on the aquatic and bird life; although these are not special, it would have a knock-on effect for visitors with natural history interests. This is addressed in Annex D.

Burrator is not a first class fishery and data are not readily available on effects on catches during previous drought years. Estimated rod days over a ten year period appear to indicate lessening of effort in the 1984 drought year as shown below.

Table 1

Year	Estimated Rod Days
1980	3,238
1981	4,028
1982	3,168
1983	2,532
1984	2,070
1985	1,296
1986	3,117
1987	4,550
1988	3,305
1989	3,174

The Ranger's observations are that, with a degree of drawdown anglers enjoy the freedom to fish areas not normally available. there was only a small decline in fishing effort in the drought year of 1989, when lowest storage was 1,546Ml reducing the surface area to 35 ha (37% full).

Monthly stockings are effected from fish transportation lorries via the slipway. It was possible to carry out this operation during the 1989 drought year, although any lower level would be likely to cause difficulties.
Diving is not likely to be affected by drawdown. Canoeing groups launch in the Sheepstor dam area and are able to launch in a dry year.

The case for future operation of Burrator presents drawdown scenarios not previously experienced. In an unremarkable year, drawdown levels would be accelerated and prolonged. At such a relatively small water body with unequalled popularity as a public amenity, there is a case for imposing a maximum drawdown level during a typical year, when water resources are secure. A minimum net storage of 2,000Ml (47% net capacity) would ensure a maximum drawdown of less than 4.5m and guarantee a water area of greater than 45 ha. Lowest recorded levels prior to 1989 were 2,123Ml (1984) and 1,946Ml (1976).

In a dry year the levels would be maintained in the region of 4.5m drawdown from May to July, with lower levels between July and end September. Again, if it were feasible, a maximum drawdown level would help to lessen the visual impact and permit water based recreation to continue. A minimum net storage of 1,500Ml (35% net capacity) would ensure a maximum drawdown of around 6m, guaranteeing a surface area of greater than 35 ha.

E5.3 Meldon

The impacts on the low key activities at Meldon are set out in Table E3.

TABLE E1
IMPACT OF DRAWDOWN ON ROADFORD RECREATION AND AMENITY

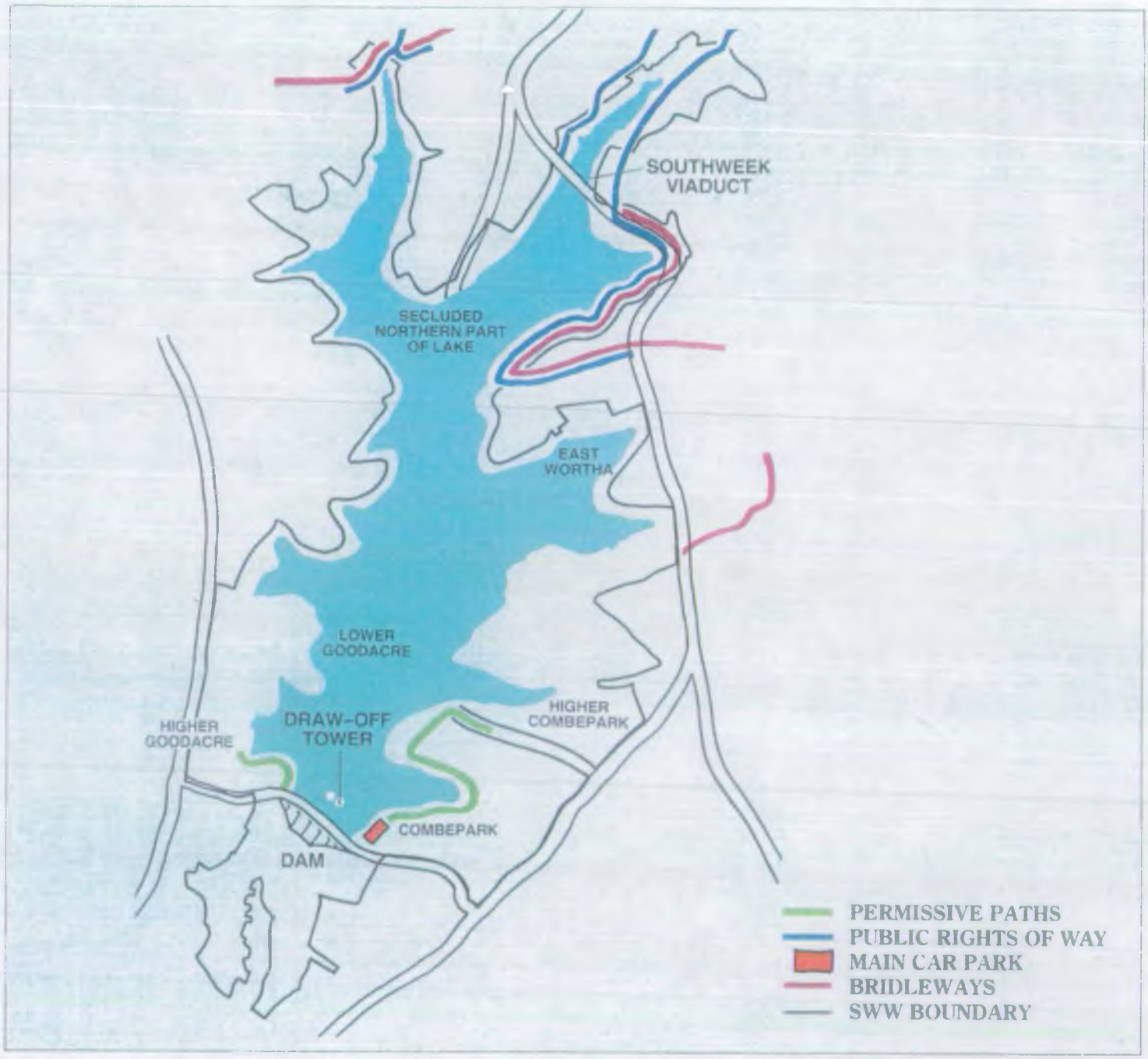
Year Type	Activity/Facility	Effects of Drawdown	Remedy
Unremarkable	Accommodation	Some visual impact if directly by water's edge July to end of October	Site accommodation with view of water body, not shoreline
	Cycle Track	Temptation to cylce by water's edge	Good signing/ interpretation
	Boardsailing Canoeing Rowing Sailing	Water would be up to 50m further away during busy season July - end September. Water body reduced to 260 ha. Wider bodies of exposed mud in creeks	Site slipway in location least affected. Consider floating pontoon with steps. Restrict areas for beginners
	Visitor Centre	May provoke questions. No impact on enjoyment	Interpret and explain purpose of operation cycle
Dry	Accommodation	Visual impact if directly by water's edge, increasing with drawdown, June to January	Site Accommodation with view of water body, not shoreline
	Cycle Track	Temptation to cycle by water's edge - June - January	Good signing/ interpretation
	Boardsailing Canoeing Rowing Sailing	Water would be 10m-60m away June - mid July and up to 400m away July to September. Water body reduced to 173 ha. Wider bodies of exposed mud in creeks. Large areas of exposed mud, dangerous if boats beached	Site slipway in location least affected. Consider floating pontoon with steps. Restricted areas for beginners. Redefine areas of water allocated to different groups as conditions change
	Visitor Centre	May provoke questions. No impact on enjoyment	Interpret and explain purpose of operation cycle
	Cycle Track	Temptation to cycle by water's edge - June - January	Good signing/ interpretation

TABLE E2
IMPACT OF DRAWDOWN ON BURRATOR RECREATION AND AMENITY

Year Type	Activity/Facility	Effects of Drawdown	Remedy
Unremarkable	Accommodation	Negligible until end June. Visual impact July increasing through to end September	Careful siting of buildings to ensure maximum views of water body. North west or south west
	Boardsailing Rowing Sailing	Reduced water body August and September: difficult to launch and recover	Restrict to training Redefine areas of water allocated to groups as conditions change
	Visitor Centre	Questions likely. No impact on enjoyment	Interpret and explain operational cycle
Dry	Accommodation	Negligible until May. Visual impact May to end July increasing dramatically August and September	Careful siting of buildings to ensure maximum views of water body. North west or south west
	Boardsailing Rowing Sailing	Reduced water body May to end September. August and September sometimes unsafe or impossible to launch and recover	Restrict to training Redefine areas of water allocated to groups as conditions change. halt activities when safety reasons dictate
	Visitor Centre	Questions likely. No impact on enjoyment	Interpret and explain operational cycle

TABLE E3
IMPACT OF DRAWDOWN ON MELDON RECREATION AND AMENITY

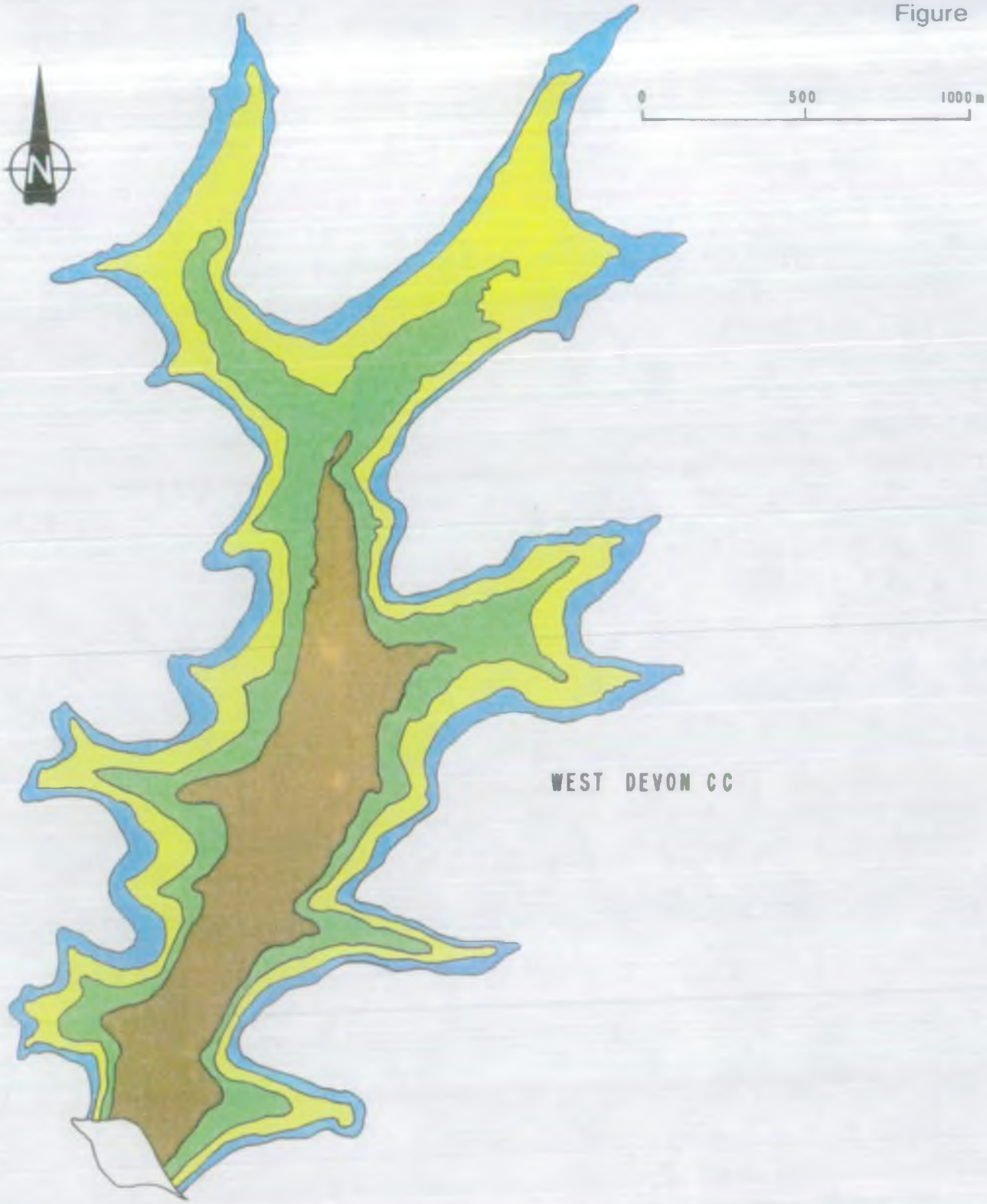
Year Type	Activity/Facility	Effects of Drawdown	Remedy
Very Dry	Watersports	July-September. Steep sides and stony base would make for extreme difficulties	Stop inexperienced users. Stop all activities at peak
	Walking) Fishing)	People tempted to get close to dangerous banks at extreme drawdown	Monitor and increase patrols if necessary. Interpret operational cycle
	Nature Reserve	Island dries out, creating interest for non-typical species	Possible bund. Is a remedy necessary?
Wet	Watersports	Negligible	
	Walking) Fishing)	Negligible	
Unremarkable	Watersports	Negligible	
	Walking) Fishing)	Negligible	
	Nature Reserve	Negligible	
Dry	Watersports	July to September. Some difficulties caused by steep sides	Stop inexperienced users
	Walking) Fishing)	People tempted to get close to dangerous banks	Monitor and patrol. Interpret opeational cycle
	Nature Reserve	Some drying out not as severe as very dry year	



By Courtesy of SWW Public Relations

Proposed Recreation at Roadford

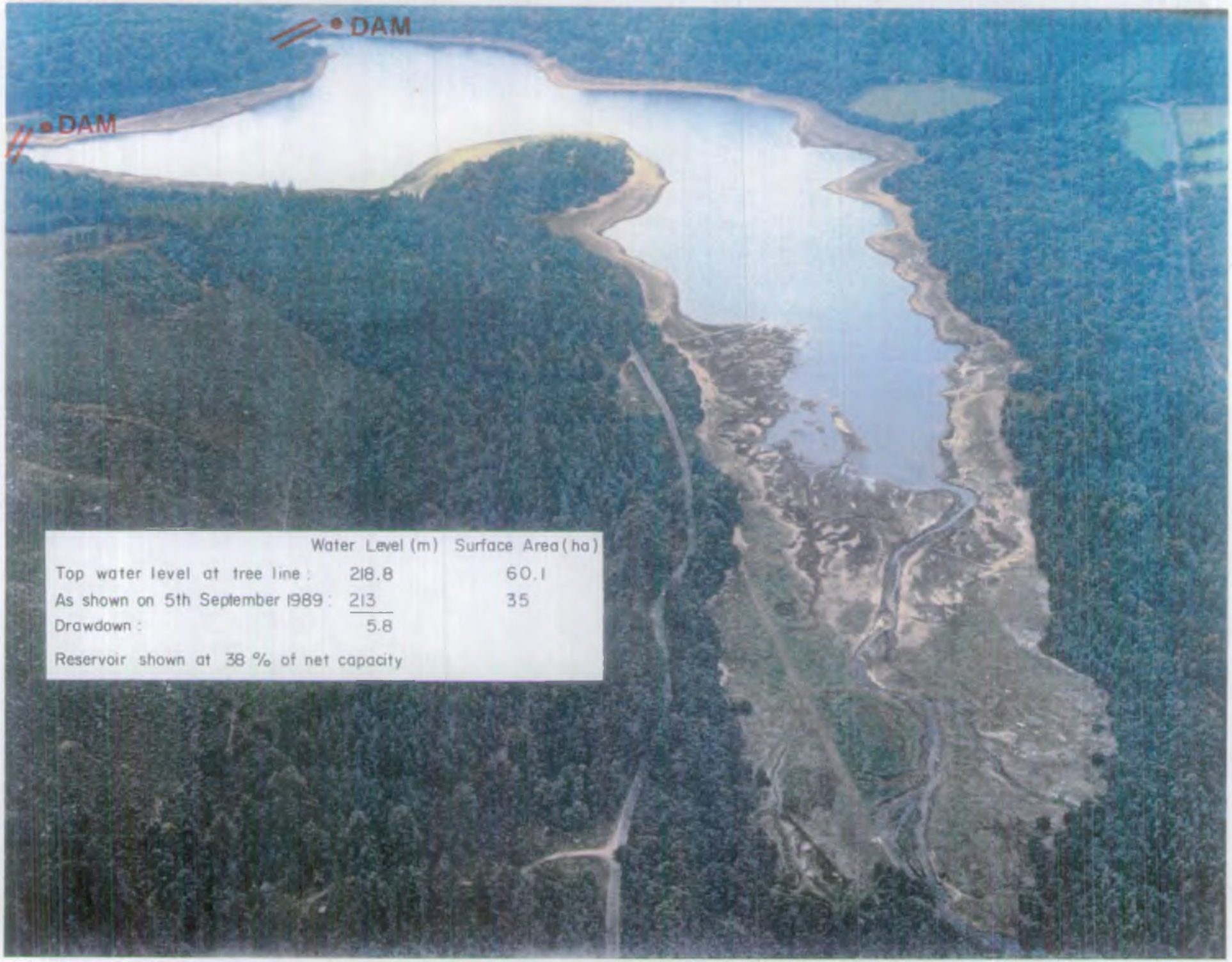
Figure E2



BAND	STAGE	AREA
TOP	122 - 127 m	232 - 305 ha
UPPER MIDDLE	114 - 122 m	129 - 232 ha
LOWER MIDDLE	107 - 114 m	68 - 129 ha
LOW	92 - 107 m	2 - 68 ha

PLAN OF ROADFORD RESERVOIR SHOWING POSITION OF SHORELINE AT DIFFERENT STAGES

AERIAL VIEW OF PARTIALLY FILLED RESERVOIR
reservoir at 7% of net capacity (Roadford)



Burrator Reservoir Draw Down
September 1989

Figure E4