THE BIOLOGY AND MANAGEMENT OF THE RIVER DEE

INSTITUTE of TERRESTRIAL ECOLOGY
NATURAL ENVIRONMENT RESEARCH COUNCIL

Natural Environment Research Council

INSTITUTE OF TERRESTRIAL ECOLOGY

The biology and management of the River Dee

Edited by
DAVID JENKINS
Banchory Research Station
Hill of Brathens, Glassel
BANCHORY
Kincardineshire

Printed in Great Britain by
The Lavenham Press Ltd, Lavenham, Suffolk

Published in 1985 by
Institute of Terrestrial Ecology
Administrative Headquarters
Monks Wood Experimental Station
Abbots Ripton
HUNTINGDON PE17 2LS

BRITISH LIBRARY CATALOGUING-IN-PUBLICATION DATA
The biology and management of the River Dee.—(ITE symposium, ISSN 0263-8614; no. 14)
1. Stream ecology—Scotland—Dee River 2. Dee, River (Grampian)
I. Jenkins, D. (David), 1926– II. Institute of Terrestrial Ecology
III. Series
574.5'26323'094124 QH141
ISBN 0 904282 88 0

COVER ILLUSTRATION
River Dee west from Invercauld, with the high corries and plateau of 1196 m (3924 ft) Beinn a'Bhuird in the background marking the watershed boundary (Photograph N Picozzi)
The centre pages illustrate part of Grampian Region showing the water shed of the River Dee.

Acknowledgements
All the papers were typed by Mrs L M Burnett and Mrs E J P Allen, ITE Banchory. Considerable help during the symposium was received from Dr N G Bayfield, Mr J W H Conroy and Mr A D Littlejohn. Mrs L M Burnett and Mrs J Jenkins helped with the organization of the symposium. Mrs J King checked all the references and Mrs P A Ward helped with the final editing and proof reading. The photographs were selected by Mr N Picozzi. The symposium was planned by a steering committee composed of Dr D Jenkins (ITE), Dr P S Maitland (ITE), Mr W M Shearer (DAFS) and Mr J A Forster (NCC).

The *Institute of Terrestrial Ecology (ITE)* was established in 1973, from the former Nature Conservancy's research stations and staff, joined later by the Institute of Tree Biology and the Culture Centre of Algae and Protozoa. ITE contributes to, and draws upon, the collective knowledge of the 13 sister institutes which make up the *Natural Environment Research Council*, spanning all the environmental sciences.

The Institute studies the factors determining the structure, composition and processes of land and freshwater systems, and of individual plant and animal species. It is developing a sounder scientific basis for predicting and modelling environmental trends arising from natural or man-made change. The results of this research are available to those responsible for the protection, management and wise use of our natural resources.

One quarter of ITE's work is research commissioned by customers, such as the Department of Environment, the European Economic Community, the Nature Conservancy Council and the Overseas Development Administration. The remainder is fundamental research supported by NERC.

ITE's expertise is widely used by international organizations in overseas projects and programmes of research.

Dr D Jenkins
Institute of Terrestrial Ecology
Banchory Research Station
Hill of Brathens, Glassel
BANCHORY
Kincardineshire
AB3 4BY
033 02 (Banchory) 3434

Contents

Preface

The aims of this symposium were to describe different interests in the River Dee, to assess existing knowledge, to identify gaps in knowledge and to determine whether there are conflicts between the different interests and, if so, ways of reconciling them.

Many people are interested in the River Dee. It is widely known as one of the more beautiful parts of eastern Scotland attracting many tourists each year. The strong associations of the valley with Royalty have given it the name 'Royal Deeside'. Recently, many new people have come to make their homes in Deeside, not only because of its accessibility to Aberdeen, but because it is a lovely place in which to live. Scenic beauty adds therefore to the local economy, with the river as the focus of the main valley.

The river is also important as a source of drinking water, as it is very largely free of pollution; it supplies the city of Aberdeen, as well as villages in the valley. At least until recently, the Dee has been one of the most important salmon rivers in northern Scotland and, through salmon fishing, it makes an essential contribution to the local economy. It has been carefully managed as a salmon fishery for over 100 years, and recent decreases in numbers of fish caught by rod and line, together with the threats of increased abstraction of water from the river, are a cause of concern to people interested in the fishery.

However, tourism and the salmon fishery are not the only important contributors to the local economy. Agriculture, forestry, and other sport are also important interests affecting the river. Farmers graze their stock adjacent to the river and are responsible for the farming practices which determine the chemistry of the water running off their land. Under the influence of price differences and subsidy, agriculture is changing, with fewer cattle, more grain, new crops, and ever earlier ploughing after the harvest. In the mid-reaches, a great extent is forested by both private estates and the Forestry Commission, and the upper valley is one of the most densely wooded parts of Britain.

The river is of value to geographers, at least partly because the course and the banks have been little disturbed. The purity of its water typifies highland streams running over granite, and, to the ecologist, the Dee is an excellent example of a nutrient-poor river with little ecological change from source to mouth. These features make the river and its associated tributaries and lochs of considerable interest to natural scientists, and several wildlife species found on and by the waterways are important to conservationists. This scientific interest is not merely academic, but is shared by a large and ever-growing number of amateur naturalists who not only watch birds, but also study the flowers, butterflies, moths and the interesting wild mammals of the area.

The expansion in the human population at the Aberdeen end of the valley and increased wealth have given rise to new water-based recreational activities, including water ski-ing, canoeing, wind-surfing and, most recently, skin-diving. These activities, together with walking and picnicking, and camping where this is permitted by the landowners, put pressure on the banks of the river. All these interests and activities testify to the importance of the river system; and the symposium reflected a need to discuss whether future management of the area needs greater liaison and co-ordination to ensure that conflict is avoided and developments agreed, and that the river as a whole is wisely managed.

David Jenkins
Hill of Brathens
July 1985

The physical background of the River Dee

JUDITH K MAIZELS
Department of Geography, University of Aberdeen

1 Introduction

This paper examines the physical background to the Dee and its catchment from 4 approaches: (i) the major geomorphic characteristics of the catchment, including its solid geology and topography, the development of the drainage network, its glacial history and associated glacial and fluvioglacial deposits; (ii) the nature of the bank and bed materials, and the longitudinal profile of the river; (iii) the development of meanders, bars and islands in the river; (iv) some evidence for channel changes since the mid-19th century, relating these to concepts of dynamic equilibrium. The discussion suggests further lines of research necessary for understanding more fully the relationships between fluvial processes and associated landforms of the Dee.

2 Catchment geomorphology

2.1 Solid geology and topography

The Dee catchment covers an area of about 2100 km^2, dominated by Precambrian metamorphic and igneous rocks (Figure 1). These rocks comprise the older Moine schists and granulites in the west, and the younger south-west/north-east striking Dalradian schists and gneisses, together with outcrops of limestones, black schists, quartzites, quartz schists and quartz-porphyry dykes in the centre and east of the catchment (Bremner 1912, 1922; Fraser 1963; Johnstone 1966). The oldest igneous rocks are associated with the period of Caledonian mountain uplift and overfolding, which occurred during Lower Palaeozoic times. Older basic intrusions were subsequently metamorphosed to produce hornblende schist and epidiorites, now forming such mountain areas as Morven (871 m above Ordnance Datum (OD)), while the acidic 'newer' granitic rocks now form the most extensive bedrock type in the catchment, representing some 52% of the area. These granites also form the highest massifs in the catchment, including Lochnagar (1154 m above OD) and Mt Keen (938 m) in the south, Hill of Fare (471 m) in the north-east, and the Cairngorm plateau to the north, with a number of summits rising above 1000 m along the Dee watershed. The Dee rises on the Braeriach plateau at about 1220 m, while the maximum elevation of the catchment is reached on Ben Macdui, at 1309 m.

These upland massifs are deeply dissected by the Dee and its tributaries, forming both deep narrow valleys and broad enclosed rock basins or 'howes' (eg Howe of Cromar). The basin areas create 'open' reaches on the Dee (eg Bremner 1912) and are believed to result from a combination of deep chemical weathering of the granites (eg Smith 1981) and selective deep glacial erosion (Bremner 1931).

2.2 Development of the drainage network

During the Mesozoic era, the Grampians are believed to have been mantled by a series of sedimentary cover rocks (Bremner 1942), and to have been uplifted several times during the Tertiary period. Each period of uplift generated a new 'cycle of erosion' such that the Grampians were subjected to extensive sub-aerial weathering to produce a succession of peneplaned erosion surfaces, with residual granite mountain ridges, or summits forming the monadnock level of the Cairngorm plateau (Johnstone 1966; Sissons 1967).

The uplifted Cairngorm surface may have exhibited an overall west-east slope (but see Sissons 1967, p24), so that the 'proto-Dee' drainage system that developed on that surface drained towards the east, and gradually became superimposed on to the underlying crystalline base; the resulting dendritic river system (Brown 1985, Figure 1) was largely discordant with the underlying geology (Bremner 1912; Smith 1981) (Figure 1).

This model of drainage development is, however, complicated by the existence of a number of apparent anomalies. Bremner (1912), for example, claimed that evidence of misfit streams and dry valleys, anomalous valley size, valley orientation, stream length and sub-catchment size in several tributary basins was indicative of river capture (eg the upper *Gairn* may have been lost to the *Feshie* catchment and the upper *Tarf* to the *Tilt*). In addition, geological controls on drainage are clearly important in the many reaches where streams are locally adjusting to softer rock types, structural weaknesses, strike directions and fault lines. The Dee itself appears to follow a west-to-east orientated tectonic depression between the main granitic intrusions (eg Bremner 1912, 1922; Johnstone 1966).

2.3 Glacial history and associated deposits

The whole of the Dee catchment was mantled during the last glaciation, the Late Devensian, by the Scottish ice sheet, which flowed generally from west to east, and reached a maximum thickness of over 1000 m (Clapperton & Sugden 1977; Lowe & Walker 1977). The ice sheet probably retreated and wasted away during the period between 16 000 and 13 500 years BP (Vasari 1977). A later, relatively short-lived period of glacier advance, the Loch Lomond Advance, occurred in the Dee catchment between *c* 10 650 and 10 145 years BP (Vasari 1977), but was confined to the corries of the Cairngorms and southern Grampians (eg Sugden & Clapperton 1975).

The de-glaciation of the Late Devensian Scottish ice sheet was associated with the formation of an

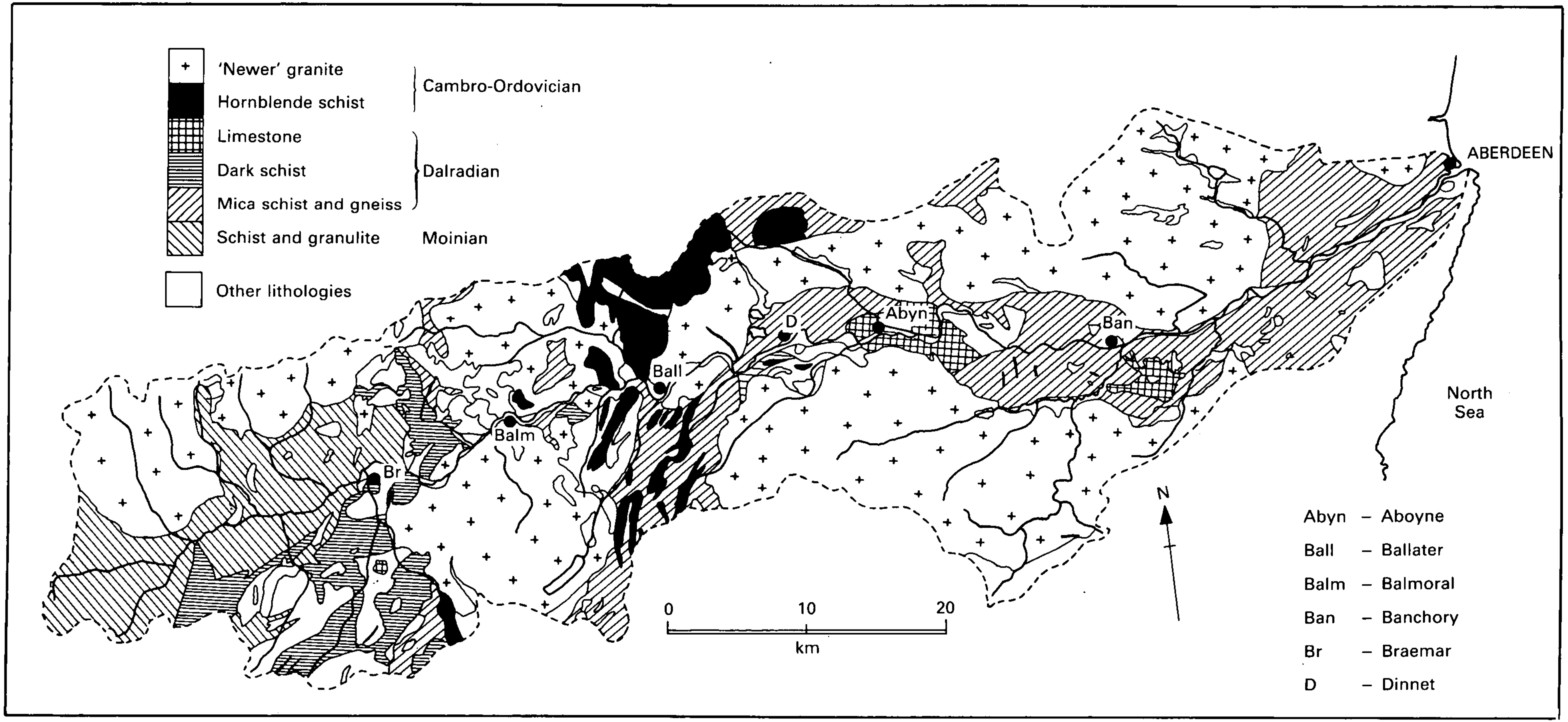


Figure 1. Generalized solid geology of the Dee catchment. Based on Geological Survey of Scotland, 1:253440, Sheet 9 (1913) & Sheet 12 (1910); and Johnstone (1966)

extensive and varied series of glacial and fluvioglacial landforms and sediments in the Dee catchment (eg Bremner 1912, 1931; Clapperton & Sugden 1972; Sugden & Clapperton 1975; Smith 1981). Many valleys were widened and over-deepened by glacial erosion, and valley-side slopes were scarred by meltwater channels and mantled with till and hummocky moraines, lateral and terminal moraines, kame terraces, kames and eskers.

The deep rock basins (and gorges?) (eg at Braemar, Ballater, Dinnet, and some upper glens) have been infilled with coarse outwash sands and gravels deposited by meltwaters from the decaying ice masses. Kettle hole lakes, such as Lochs Davan and Kinord, formed around large, isolated, wasting ice masses.

The sand and gravel outwash deposits have since been dissected into a series of terraces. Up to 4 or 5 such terraces or terrace fragments have been identified in the wider parts of the Dee valley (eg between Cambus O'May and Aboyne). These terraces exhibit distinctive braided palaeochannel patterns representing the glacial Dee meltwater streams (Bremner 1931) (Figures 2i, ii) which extended across the formerly broad valley floor. The terrace sediments comprise stratified sands and gravels (Institute of Geological Sciences (IGS) 1977), as well as coarse cobble and boulder beds representing deposition in streams with a much higher discharge and tractive velocity than in the present-day Dee.

The terrace sequence probably dates from the final stages of de-glaciation, with downcutting associated with a major change in the hydrological regime of the Dee as ice disappeared from the catchment. This downcutting may well have culminated, between 9700 and 8000 years BP (cf Forth Valley; Sissons 1967), in the formation of the buried channel that appears to underlie the lower Dee, where an IGS borehole extended to 15 m below the present river level (at Bridge of Dee; IGS 1977). Since that time, the Dee has infilled this channel and appears to have been only slowly modifying its narrow floodplain from a state of long-term dynamic equilibrium (see later, section 5), despite land use and settlement changes in the catchment over the past 5000 years (Edwards 1975).

3 Bank and bed materials, and the longitudinal profile, of the Dee

3.1 Bank materials

The Dee and its tributaries have access to a wide range of source materials and flow through a variety of substrates and bank materials, reflecting the numerous different bedrock types and extensive glacial, fluvioglacial, periglacial and slope deposits in the catchment.

3.1.1 Bedrock

Bedrock forms the channel boundary where more resistant rock types, especially quartz-porphyry dykes and certain granites, are present, acting to constrict the channel and often creating rapids or waterfalls bounded by near-vertical walls. Where erosion has caused block collapse into the stream, the bedrock banks act as a major contributor of large bouldery material to the stream bed.

3.1.2 Till

In many parts of the Dee valley, bedrock is mantled by till (glacial drift), ranging from only a few metres thick (eg Bremner 1925) to tens of metres thick. The till banks form relatively soft, readily saturated banks, which provide a wide range of sediment sizes and rock types to the river sediment load.

3.1.3 Slope deposits

In the upland valleys, streams flow through banks which comprise alluvial fan, solifluction, landslip and scree deposits, of a variety of ages, and which contribute heterogeneous, poorly sorted, coarse, angular, non-cohesive materials to the water.

3.1.4 Fluvioglacial outwash deposits

The most extensive river bank material, particularly in the middle and lower reaches of the Dee and its tributaries, is represented by the late Devensian sand and gravel deposits forming the terrace sequence. These deposits are readily erodible, non-cohesive, coarse, poorly sorted deposits, providing an abundant supply of heterogeneous material to the rivers (IGS 1977). Bank collapse is through grain-by-grain removal, and, while the smaller sizes may be moved during moderate and high river flows, the larger cobbles and boulders may rarely be moved and accumulate at the foot of the bank.

3.1.5 'Recent' alluvium

'Recent' alluvium represents bar and overbank deposits that have accumulated to form the present river floodplain. These sediments generally comprise up to 30 cm of fine-grained sands and silts (IGS 1977), but often include lenses or sheets of pebbles and cobbles derived from flood events which deposited overbank gravel bars and sheets. The alluvium is found only on the present floodplain and lowest terrace, and is absent on the higher fluvioglacial terraces. The alluvium forms a relatively thin superficial cover, and appears to be accumulating only slowly. It forms low, unstable banks that are readily undercut and slough into the river.

3.1.6 Artificial embankments

Artificial embankments have been constructed at a number of reaches on the Dee as a means of flood protection, bank stabilization and channelization (Willetts 1985). These embankments include revetments, comprising boulders held in wire baskets, concrete piles and fences, and stone and earth levees.

3.1.7 Vegetation

The majority of the river banks, especially in the middle and lower reaches of the Dee, are vegetated, thereby

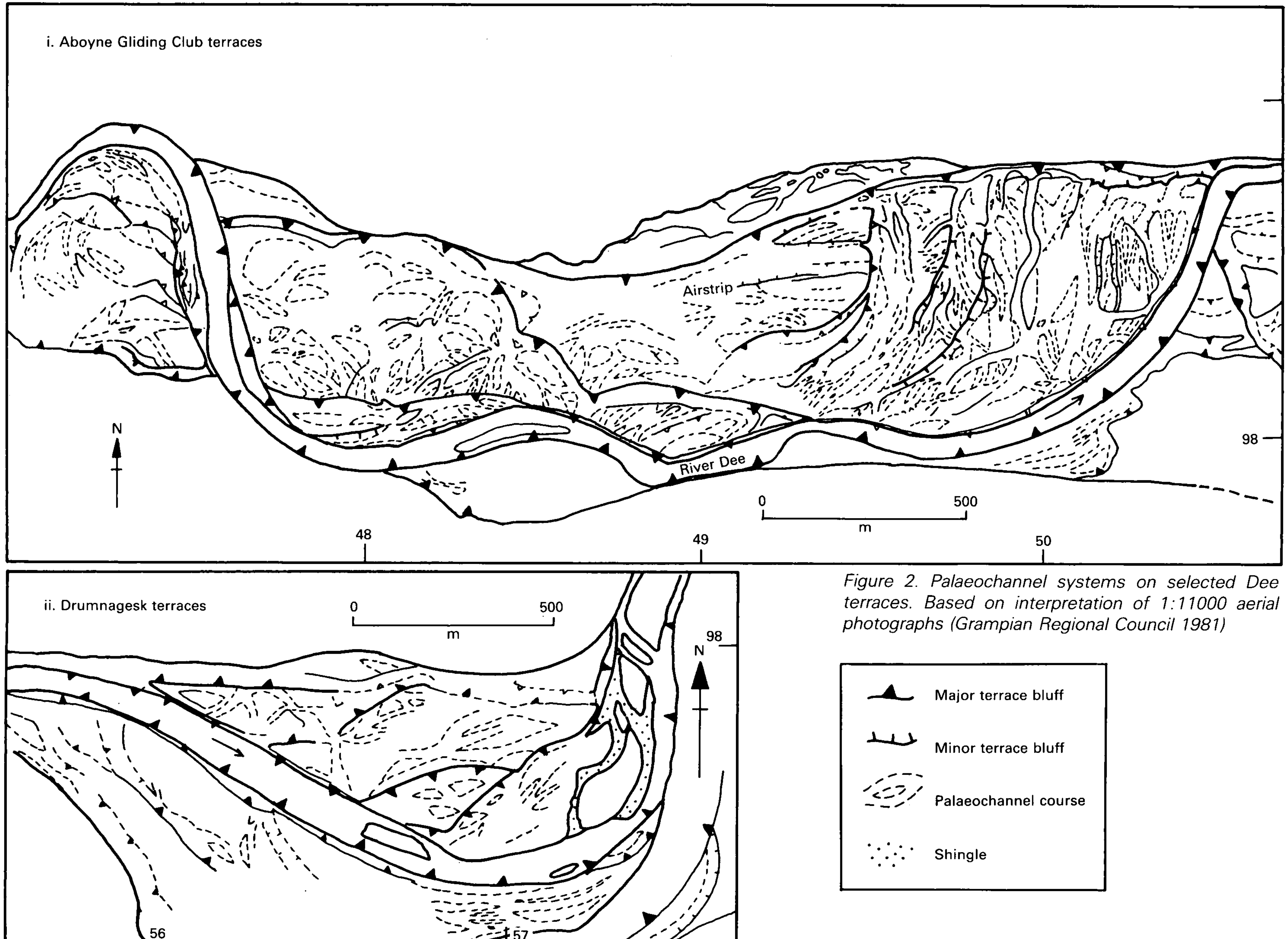


Figure 2. Palaeochannel systems on selected Dee terraces. Based on interpretation of 1:11000 aerial photographs (Grampian Regional Council 1981)

acting to increase resistance to bank erosion and overall bank stability. Other gravel-bank rivers in the UK with tree-lined channels tend to be about 30% narrower than streams with grassy banks (Charlton *et al.* 1978), as a result of increased bank resistance.

3.1.8 Discussion

Many banks along the Dee exhibit a composite vertical and downstream stratigraphy, with different sections of the bank containing different materials, each exhibiting a different texture, permeability, cohesion, tensile strength, saturation limit, and susceptibility to both sub-aerial and fluvial erosion (eg Thorne & Lewin 1979; Simons & Li 1982). Bank materials often differ on opposite banks, and vary rapidly downstream (eg Charlton 1982). The extent of the different bank materials in the Dee river system would prove a worthwhile project for future investigation. Spatial patterns of bank erosion are highly variable, and exercise a major control on river channel geometry, and on rates of sediment supply, transport and deposition in the river.

3.2 Bed sediments

The Dee is characterized by its pebbly bed sediments and may be classified as a 'gravel-bed river'. Although it also includes boulder bed and bedrock reaches, the Dee flows mostly over a stony shingle bed, with clasts (pebbles) derived predominantly from local inputs and reworking of till and outwash bank sediments. The size of material depends both on local sediment supplies and on the tractive force of flow. Clast sizes exhibit an overall decrease in size downstream (eg preliminary data on Figure 3), but show local peaks in size where coarse-grained banks are exposed or where local residual deposits of larger cobbles or boulders are present.

The bed sediments comprise a wide range of rock types, but are dominated by granites (eg 53% granites in the Dinnet-Potarch reach), together with a large variety of schists and gneisses (totalling 36%). Most of these clasts are rounded, suggesting a relatively long distance of transport, either in the present river or in a former meltwater river. The sediments contain little fine matrix material (sand and silt), which tends to be flushed out during high flow events and to be redeposited farther downstream as bar-top and overbank deposits on the floodplain (Willetts 1985). The coarser sediments are dominated by a strong imbricated fabric, with a stable, densely packed orientation particularly resistant to erosion, forming an 'armoured' bed. As a result, the bed sediments tend to be far more resistant to stream scour and removal than the adjacent bank sediments, and hence lateral bank retreat is a more likely response to flood erosion than is bed degradation.

3.3 Longitudinal profile

The longitudinal profile of a river represents the long-term response of fluvial processes (especially downstream changes in stream discharge), operating in a catchment of varied rock structure, with its own history of tectonic and climatic change, vegetation, soil and land use patterns. The Dee exhibits a distinctive concave-upward longitudinal profile over its stream length of about 140 km, decreasing in gradient downstream. The long profile does not follow a smooth downstream curve in gradient, but in detail comprises a series of irregular steep sections alternating with sections of anomalously low channel gradient (Bremner 1912) (Figure 3). Although the mean gradient from source to mouth is about 8.9 m km^{-1}, the upper reaches of Glen Dee are considerably oversteepened, with a drop of over 600 m in just 3.8 km, producing an average local gradient of 160 m km^{-1}. The Natural Environment Research Council (NERC) (1975) mean slope measure of 'S1085' (mean gradient between points at 10% and 85% along the channel length) is only 3.4 m km^{-1} and is more representative of gradients over most of the Dee. Nevertheless, steeper reaches occur, especially over bedrock (eg 7.3 m km^{-1} in the Cambus O'May reach; 4.1 m km^{-1} in the Crathie reach; and 4.3 m km^{-1} in the Potarch reach), while lower gradients occur where the valley floor widens out and the channel is able to meander through more erodible gravel and alluvial sediments (eg 2.2 m km^{-1} in the Braemar reach; 2.8 to 0.7 m km^{-1} in the Dinnet-Aboyne reach; and 1.2 to 0.8 m km^{-1} in the lower Dee east of Park). In most of these wider, more open sections of the valley, sediment infilling has taken place behind downstream rock bars or gorge constrictions which have acted as local 'base levels' for upstream aggradation.

The longitudinal profile of the Dee apears to have resulted from a combination of glacial and fluvioglacial erosion of the (weathered?) bedrock to form a series of steep gorge or rock-walled reaches and deep rock basins, followed by infilling of these basins with fluvioglacial and fluvial sediments. The longitudinal profile of the present river probably differs significantly from the profiles of the river during Late-glacial and early Post-glacial times. The gradients of the different terrace surfaces, however, have not yet been determined, while the depth of sand and gravel infill above the bedrock surface also remains unknown.

4 Fluvial processes: meander and bar development

4.1 Introduction

The Dee exhibits a range of channel patterns reflecting fluvial processes operating in a variety of bed and bank materials, valley floor and sediment supply conditions. The traditional classification of channel patterns is into straight, meandering and braided patterns (Leopold & Wolman 1957). This approach, however, while providing a convenient framework for channel pattern description on the Dee, is a somewhat artificial approach to the study of fluvial processes because similar processes of scour and deposition operate in each channel environment. Bars and islands, for example, are common to both straight and meander-

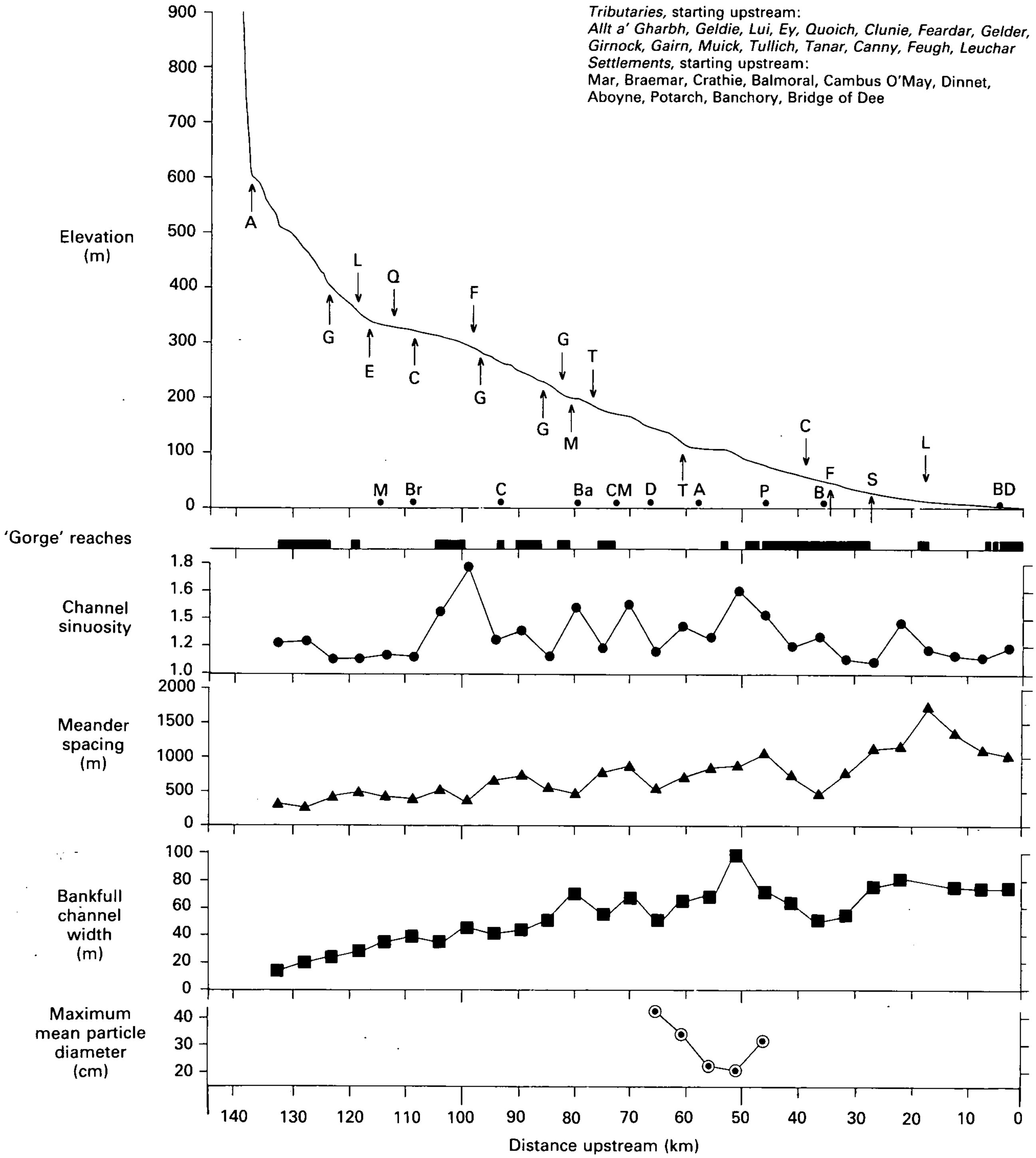


Figure 3. Longitudinal profile and downstream changes in channel characteristics of the River Dee

ing reaches. In addition, this classification of channel pattern types is normally limited to alluvial channels, ie channels that are free to alter the geometry of their channel boundaries as a means of adjusting to any changes in flow hydraulics. This condition is not always present in the Dee, particularly where bed sediment is too coarse or too well imbricated to be readily moved, or where relatively resistant banks formed by rock, till, outwash or concrete all act to preclude free bank retreat and unconfined meander development.

4.2 Characteristics of straight reaches on the Dee

The most important flow characteristic of straight gravel-bed reaches is that of flow deflection, by which, even in a straight channel, the main flow path and the location of the dominant flow cell meander alternately from one bank to the other (eg Leopold 1982). This pattern of flow, in turn, tends to result in alternating zones of bed scour to form 'pools', and in zones of sediment concentration to form 'riffles' and lateral bars.

A riffle is a zone of shallow flow over a coarse-grained bed, presenting high resistance to flow and little sediment storage. A bar is a large depositional unit (longer than the associated channel width) of sands and gravels acting as a major storage zone for bedload sediment (Church & Jones 1982). Bars and riffles develop and evolve during high flow events when bed sediment becomes mobile; at low flows, most bars and riffles remain inactive or emerge as shingle bars or islands.

A straight reach is defined as extending for a distance of 10-14 times the channel width, as within this distance one would otherwise expect a meander to have developed (see below). On the Dee, 30 such straight reaches were identified, averaging 811 ± 322 m in length, with a mean downstream spacing of 4.19 ± 3.31 km, representing about 16% of the total main stream length. These straight reaches included gravel, bedrock and artificially embanked reaches.

In 15 of the straight reaches examined in detail from aerial photographs, riffle spacing was found to average 5.5 times channel width, but with a correlation coefficient of only +0.49 (ie only 24% statistical explanation). Hence, mean riffle spacing conforms to the geometric pattern recognized on most rivers, where pool-riffle spacing is generally 5-7 times channel width. However, the large variability in spacing appears to reflect the numerous local controls on patterns of flow and sedimentation (eg sources of sediment input, the presence of coarse bed material and constrictions of the channel caused by bedrock outcrops and relatively resistant high banks of till and outwash).

Bars and riffles are also seen to be extremely variable in terms of their location within the channel and their size, shape and orientation across the channel (Figure 4). Some riffles extend for only 30 m, while others extend for over 200 m downstream; in some reaches, sequences of 'gravel tongues' extend as indistinct shallows for hundreds of metres, paralleled by long scour pools at the foot of one or both banks. Riffle forms include narrow, linear gravel accumulations close to one bank, small patches of coarse sediment attached to one bank, and broad shingle zones extending partly or wholly across the channel bed.

4.3 Characteristics of meandering reaches on the Dee

With increased discharge, stream power and sediment transport, the strength and asymmetry of individual flow cells increase sufficiently to allow banks to be more readily eroded to form a meander bend (eg Leopold 1982).

On the Dee, 221 meanders have been identified, with a mean spacing of 609 ± 400 m, ie an average wavelength of 1200 m, and with both spacing and wavelengths generally increasing downstream with increases in discharge and channel capacity (especially channel width) (Figure 3). Mean wavelength (λ) over 5 km reaches has been found to be related to both mean annual flood (Q_{ma}) (only for reaches at Polhollick, Woodend and Park) and to channel width (W), estimated from Ordnance Survey (OS) maps, such that:

$$\lambda = 93.3\,Q_{ma}^{0.52} \quad (1)$$
$$\lambda/2 = 18.9\,W^{0.91} \quad (2)$$
$$\text{and } \lambda = 37.8\,W^{0.91} \quad (3)$$

The wavelength-discharge relationship conforms closely to that established for other gravel-bed rivers (eg Dury 1977; Charlton 1982; Hey & Thorne 1984), but the wavelength-width relationship is defined by a much higher coefficient (37.8) than is normally (ie 10-14) found. Hence, it appears that wavelengths in the Dee tend to be much greater than would be expected for equivalent width (and discharge?) conditions in fine-grained, lowland floodplain channels. These large wavelengths are found on a particularly narrow floodplain, rarely exceeding 850 m, and generally averaging less than 400 m. As a result, overall channel sinuosity (defined as the ratio between channel length and meander axis length) is relatively low (Figure 3), averaging only 1.27 ± 0.18. Only 3 5 km reaches exhibit sinuosities exceeding 1.5 (ie 'meandering'), while over 60% of reaches exhibit values of less than 1.25. The predicted amplitudes (Lewin & Brindle 1977) of the Dee range between *c* 620 m and 3.2 km, thereby far exceeding the actual width of much of the active floodplain.

The distinctive meander pattern of the Dee, comprising long wavelength, low curvature meanders, interspersed with numerous straight reaches, may result from several mechanisms. First, weak meander development may result from rapid rates of bank erosion, thereby preventing full development of secondary

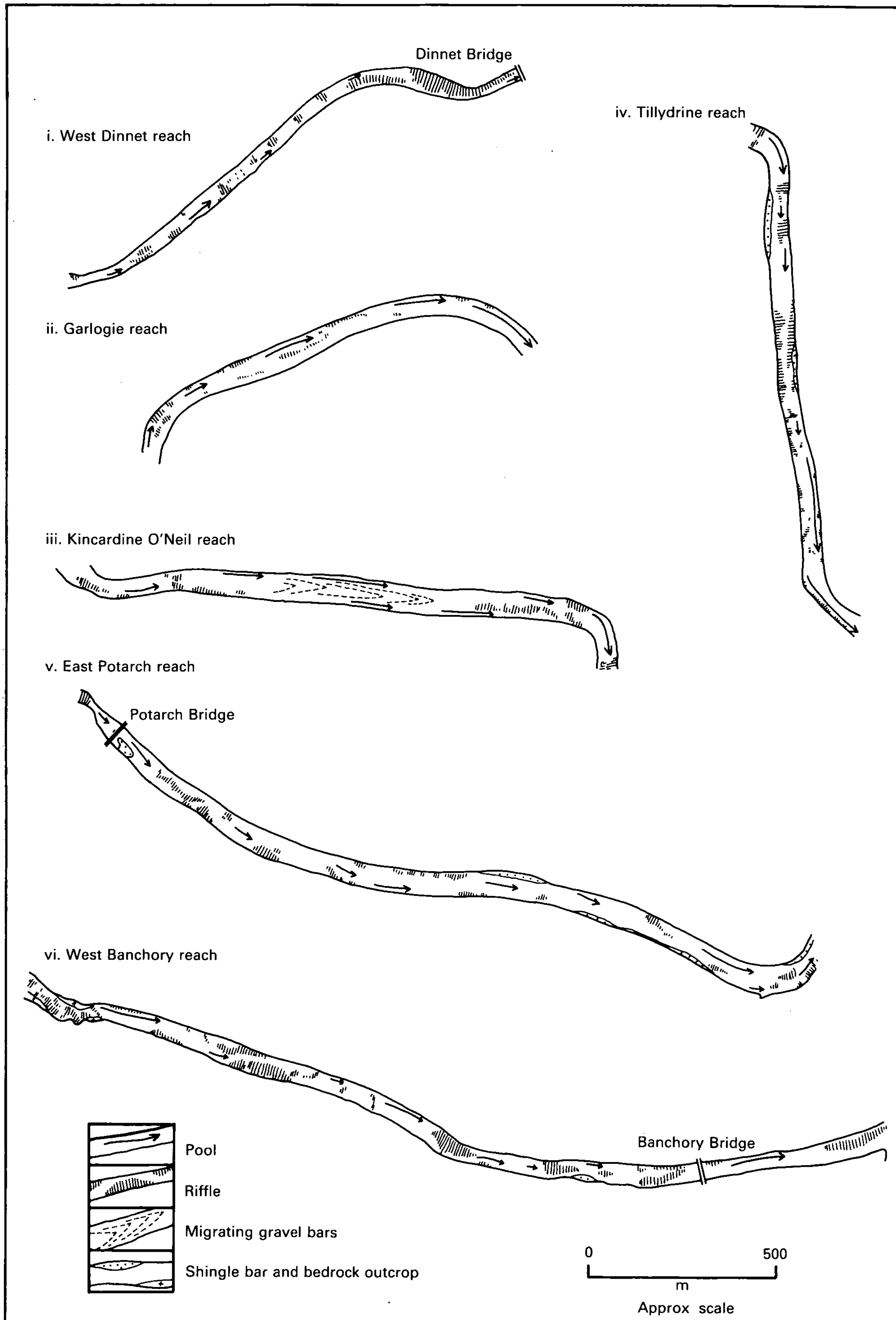


Figure 4. Pool and riffle sequences in straight reaches of the Dee. Based on interpretation of 1:11000 aerial photographs (GRC 1981)

flows and the stable development of meander forms (Newson 1981; Ferguson & Werritty 1983). Second, it is possible that the meander pattern may be partly inherited from a period of different hydrological conditions in the past (eg wetter Atlantic period; Smith 1981), since when lower river discharges may have precluded any major channel re-adjustment (Ferguson 1981), largely because channel sediments are so coarse. Third, the presence of resistant terrace bluffs, together with rock-walls and artificial embankments, have acted as a major control on meander development by reducing the floodplain width to below the theoretical meander amplitude. As a result, much of the Dee exhibits the distorted meander forms characteristic of 'second degree meander confinement' (Lewin & Brindle 1977), where meanders include box-shaped reaches with one or more right-angled bends, ensconced or entrenched meanders, and long straight reaches hugging the edge of the valley floor (Figure 5). An analysis of the distribution of free and

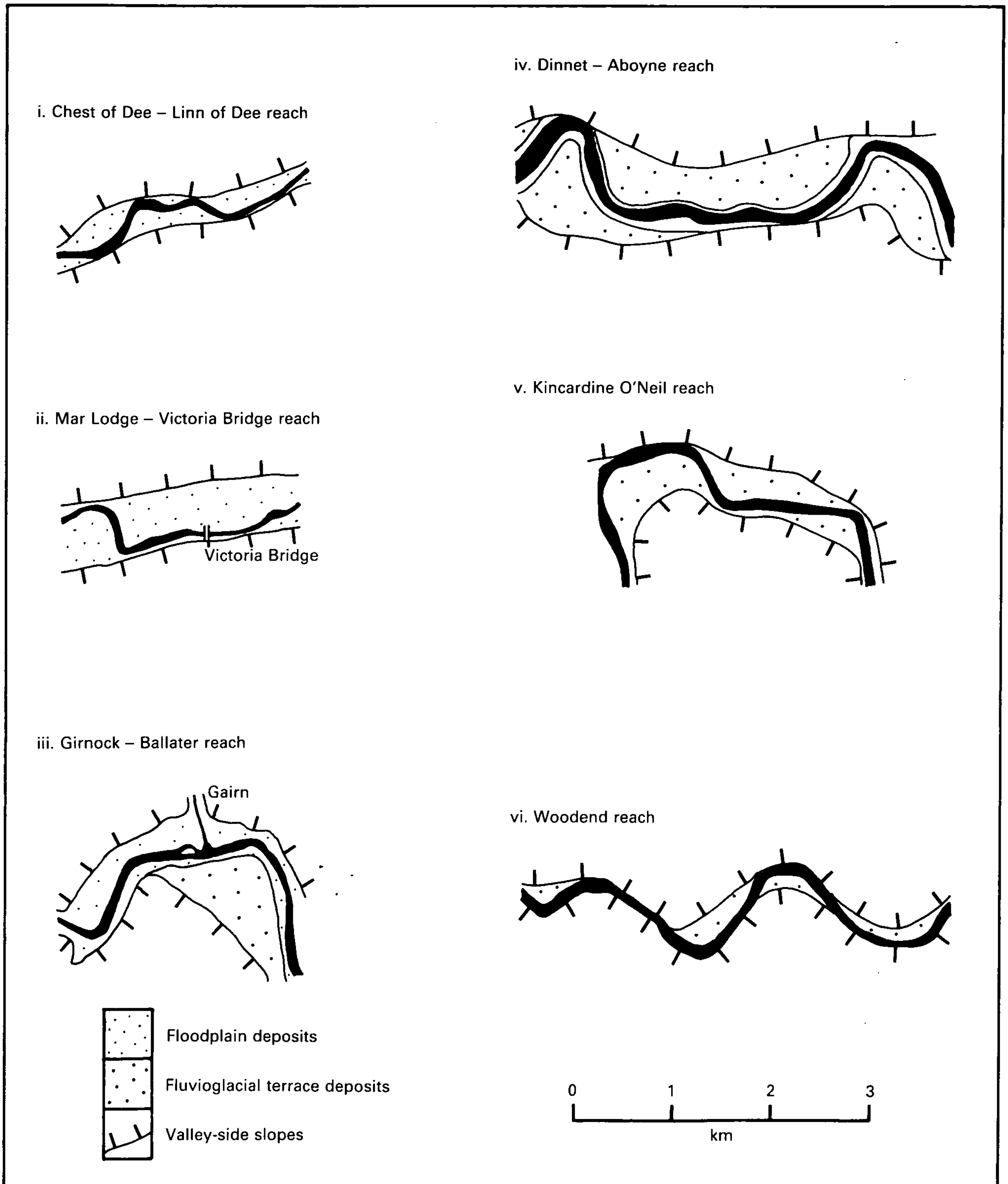


Figure 5. Examples of the confined meander forms on the Dee

confined meanders in the Dee catchment would be valuable in determining the role of these lateral constraints on meander development.

4.4 Development of bars and islands

4.4.1 Origins of bars and islands in gravel-bed rivers

Bars (active bedforms) and islands (inactive and often vegetated) can form in a number of possible ways, both depositional and erosional, and at a variety of dates during the river's history. Many bars and islands tend to be both polygenetic and of varied age at any one site and over a downstream distance. The main origins of bars and islands may be classified as primary (ie depositional) and secondary (ie erosional), although most forms are derived from a combination of these processes.

The primary origins include:

i. deposition of a lateral or point bar;
ii. deposition of a mid-channel (medial) bar, normally located near a significant local source of sediment supply (eg just downstream of a meander bend);
iii. deposition of a bar at a tributary junction where excess sediment brought down by the tributary is dumped as backwater forms behind the main stream (Church & Jones 1982).

The secondary origins result from the dissection of any primary bar form by chute (flood) channels (Church & Jones 1982). During flood events, a bar becomes partly or wholly submerged, and a flood channel is frequently scoured into the back (ie at the foot of the channel bank) of the bar or down the bar front. During successive floods, the chutes can migrate upchannel, progressively incising into the bar; the chute channel itself may eventually become the dominant channel, and, as its banks are progressively widened, it may develop its own system of associated channel bars. Often, a series of partly or fully formed chute channels develops at different elevations on the bar during different flood events.

4.4.2 Bars and islands in the River Dee

In the Dee, 38 island reaches have been identified (from OS maps) averaging 250 ± 240 m in length, and with a highly variable downstream spacing, averaging 3.28 ± 4.18 km. Preliminary examination suggests that bars and islands of all 4 origins (see above) are present (see Figure 6). Lateral and point bars are being actively formed at many sites, but the majority of bars, especially point bars, represent deposits that have been dissected and reworked at a variety of periods during the river's recent history.

Most islands in the Dee are now largely or completely inactive. The highest islands often lie at the same height as adjacent outwash terraces, suggesting that some islands at least are thousands of years old. The Dee is characterized by long stretches free of islands, separated by zones of intense and active sedimentation which form major 'megaform' bar assemblages (Church & Jones 1982), as in the Dinnet and Drumnagesk reaches. These complex systems of bars, locally varying in origin, age, rates of development and flow thresholds for development, need to be studied in more detail, in order to understand the spatial patterns of fluvial processes in the Dee.

5 Channel changes

5.1 Historical channel changes

Evidence has been presented earlier (section 2.3) of long-term changes in the hydrological regime and channel pattern of the Dee, associated with deglaciation and terrace formation at the end of the Late Devensian. Evidence of more recent channel changes since the mid-19th century is also available from OS maps (at scales of 1:25 000, 1:10 560 and 1:10 000, dating from 1864/66, 1900, 1962-69) and from aerial photographs (1:11 000, 1974, 1977, 1981; Grampian Regional Council). Most historical channel changes probably occurred during short-term, high-magnitude flow events (ie bankfull and, particularly, overbank floods), as in many other gravel-bed and upland rivers (eg Anderson & Calver 1980; Werritty & Ferguson 1980; Werritty 1984). Although some reaches may be unstable and vulnerable to change even at low flows (eg Church & Jones 1982), it appears that major change is very localized, and much of the channel may remain unchanged for many decades (Ferguson 1981).

Major floods occurred in the Dee during the historical period, and could account for significant channel changes. For the period 1864/66 to 1900, major floods occurred in 1873 and 1895, and for 1900 to 1969, in 1913, 1920, 1937 and 1951 (eg Warren 1985). Indeed, a number of historical channel changes associated with floods have been noted in the local literature. In particular, the effects of the 1829 'Muckle Spate' (McConnochie 1900; Bremner 1922; Wyness 1950), the 1920 floods (Bremner 1922) and the 1956 Cairngorm floods (Baird & Lewis 1957) have been widely reported.

Initial examination of the available evidence suggests that significant changes in channel course, pattern and wavelength have occurred at numerous sites on the Dee, in association with periods of local bank retreat, meander migration and abandonment, bar accretion, chute channel formation and island development (Figures 7 & 8). These changes have been concentrated in zones of local bank instability on the wider parts of the floodplain that present some potential for lateral channel expansion or channel initiation, and for increased sediment availability and reworking.

5.2 Estimates of rates of channel change and bank retreat

No field measurements of the rates of bank retreat are yet available for streams in the Dee catchment. However, measurements from historical map evidence provide estimates of overall net rates of bank recession over periods of between 34 and 104 years

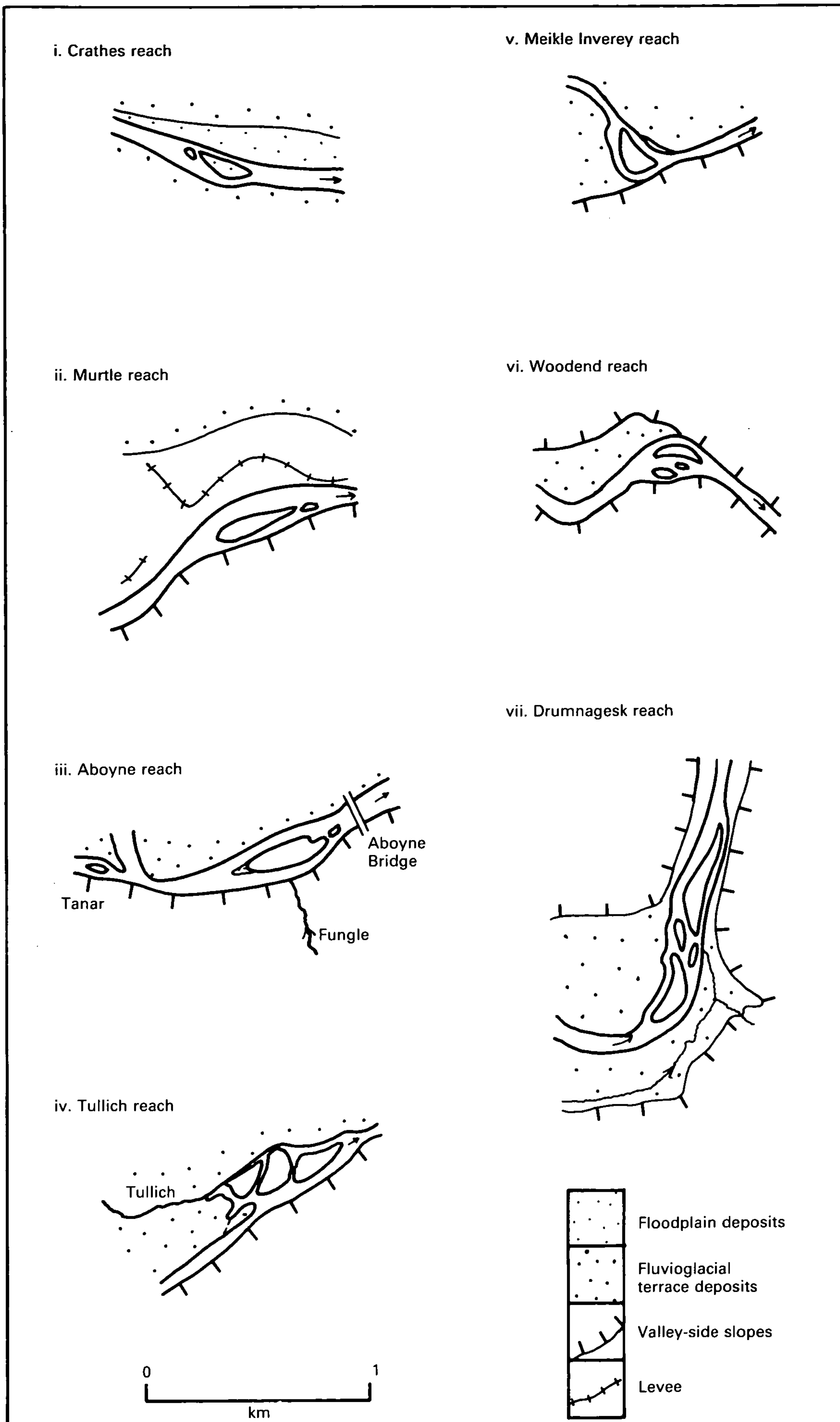


Figure 6. Examples of dissected lateral bar, point bar, tributary bar, and bar assemblage deposits in the Dee

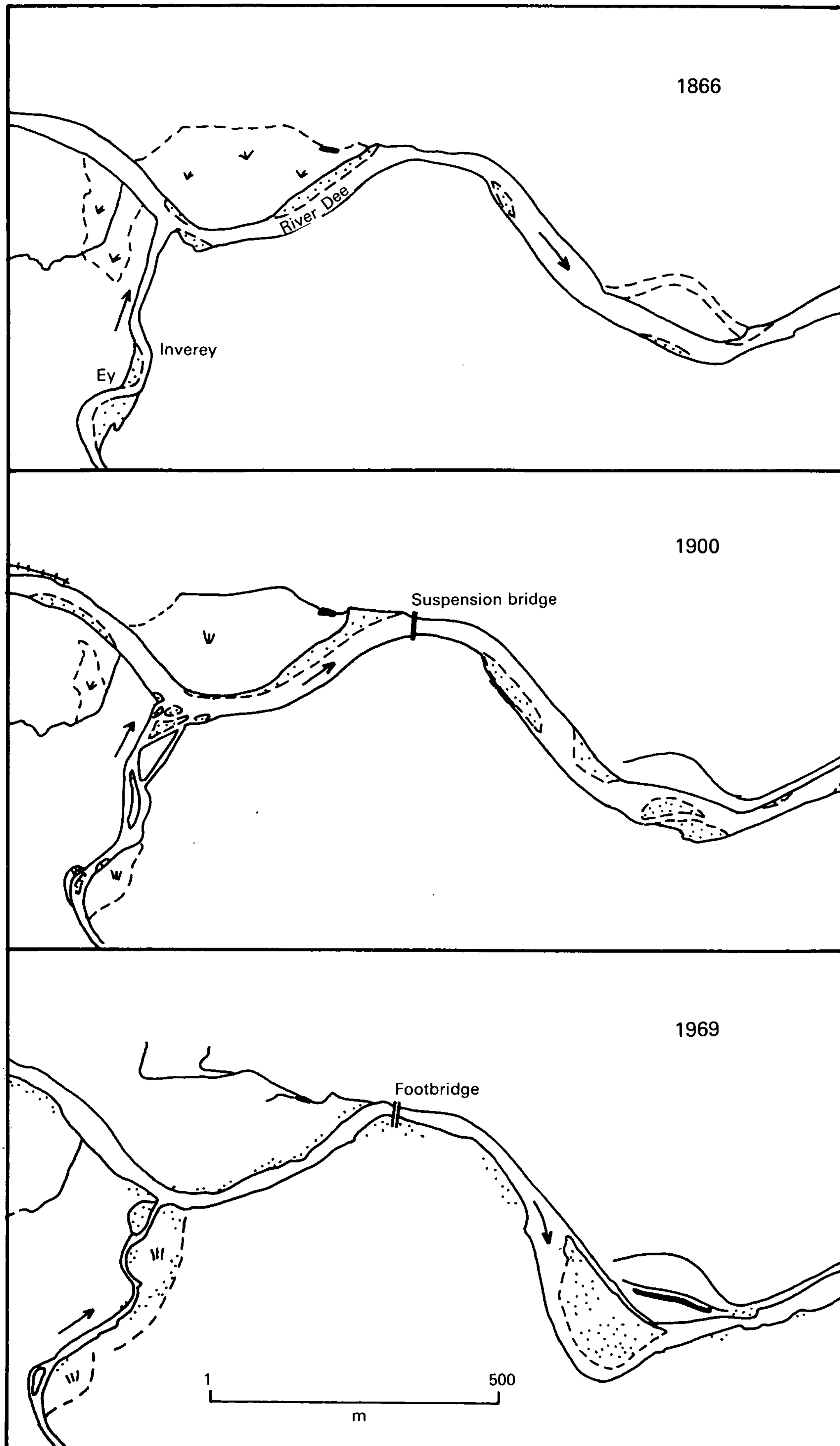


Figure 7. Example of channel change on the River Dee since the mid-19th century: Inverey reach, 1866-1969

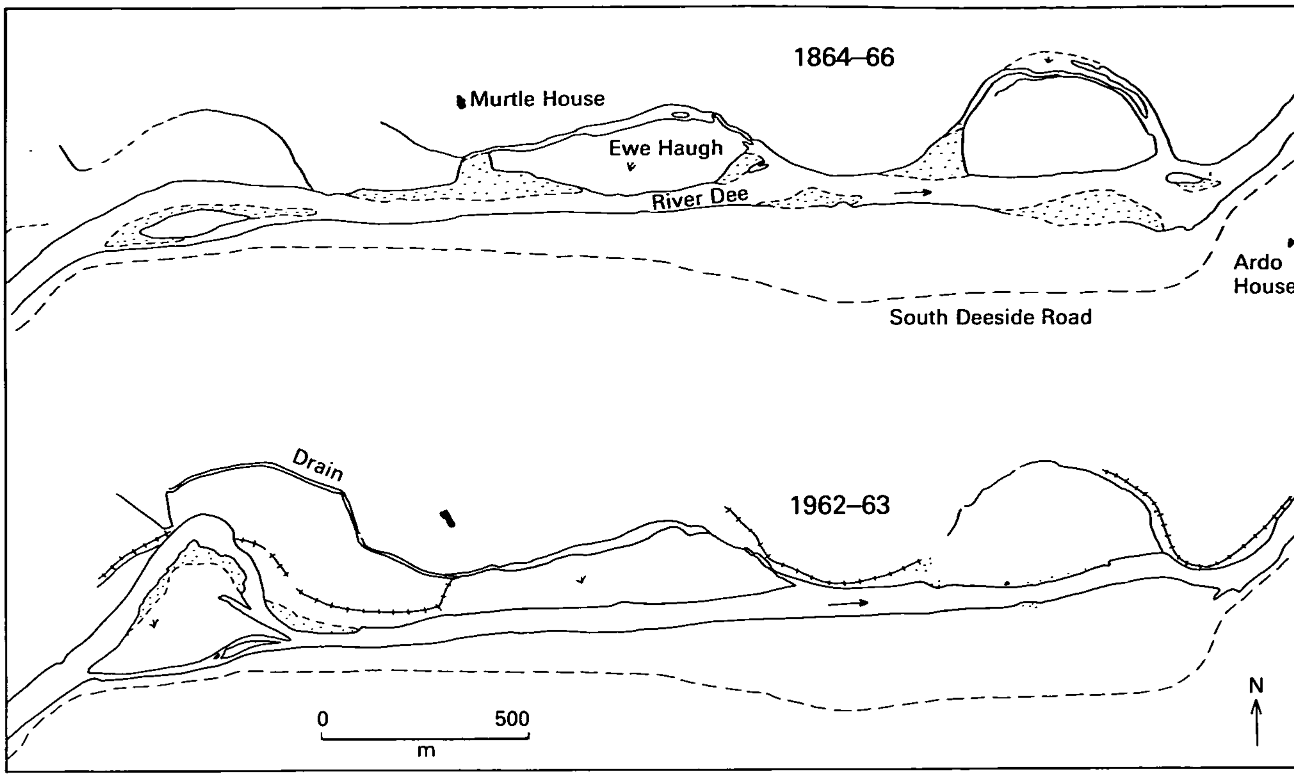


Figure 8. Example of channel change on the River Dee since the mid-19th century: Murtle reach 1864/66-1962/63

(Table 1i). Measurements taken from 14 zones of significant channel change on the Dee indicate that net rates of bank retreat have averaged 0.70 ± 0.67 m yr^{-1}, ranging from as little as 0.04 m yr^{-1} to as much as 2.3 m yr^{-1}. The latter retreat occurred in the Murtle reach between the 1864/66 and 1962/63 surveys and represented the development of a meander extending some 225 m across the floodplain. Rates of bank retreat have been highly variable between sites, while net annual rates of retreat have varied by up to 6 times at individual sites through time.

The zones of bank retreat, meander development and channel expansion appear, however, to be consistently matched by adjacent zones of sedimentation and bank accretion. Numerous examples of channel narrowing and bar abandonment to form floodplain deposits during the historic period can be identified on the Dee. Measurements of these changes at 22 sites (Table 1ii) indicate that net rates of bank accretion have averaged 0.72 ± 0.48 m yr^{-1}, a rate of change almost identical to the rates of change estimated for bank retreat.

Hence, where channel change has occurred, the net rates of change produced by erosion and deposition are of a similar order of magnitude. This similarity in rates of bank retreat and accretion may mean that patterns of erosion and deposition in the Dee since the mid-19th century have developed in a state of dynamic equilibrium, or 'passive disequilibrium' (Ferguson 1981), with no overall degradation or aggradation in the river. The absence of any major overall change in the Dee may reflect the relative coarseness of the bed and bank material, the resistance of confining boundaries to the narrow floodplain, and the absence of any significant change in hydrological regime caused by any changes in catchment climate or land use. However, this hypothesis of no long-term, overall, progressive change in the Dee needs further testing. In addition, recent and present-day channel changes also need to be determined at selected vulnerable sites to establish whether or not rates of channel change have remained consistent, despite possible changes in hydrological conditions since the 1950s (Warren 1985). A further important research topic lies in the development of a predictive model for channel change in relation to the threshold discharges required for geomorphic changes at a given site throughout the hydrological year (Harvey *et al.* 1979; Gregory & Madew 1982). Many reaches of the Dee remain unstable and liable to dramatic modification during annual flood events; some means of predicting site susceptibility and likely geomorphic responses to given flood conditions would prove invaluable to all users and managers of the river and its floodplain.

6 Conclusion

The Dee catchment covers an area of 2100 km^2 and is dominated by granites and schists forming the main upland massifs of the catchment, rising to Ben Macdui at 1309 m above OD. The whole catchment was ice-covered during the last glaciation, providing a legacy of extensive glacial and fluvioglacial deposits,

Table 1. Estimated net rates of bank erosion and bank accretion on the River Dee, 1864-1969

i. Net rates of bank erosion

River reach (tributaries italicized)	Grid reference	Period of survey	Mean annual net rate of bank retreat (m yr^{-1})
Glen Dee	NN 984 955	1900-1969	0.07
Ey	NO 087 897	1866-1900	1.02
Dee, east of *Ey* confluence	094 894	1866-1900	0.29
	094 894	1900-1969	1.68
Quoich confluence (1)	119 905	1866-1900	0.91
	119 905	1900-1969	0.62
Quoich confluence (south)	124 907	1866-1900	0.65
Quoich confluence (north)	122 907	1866-1900	0.29
	122 907	1900-1969	1.23
Invercauld	178 919	1866-1900	0.18
	178 919	1900-1969	0.04
Drum (west)	813 983	1864-1965/66	0.42
Drum (east)	821 988	1864-1965/66	0.10
Murtle (west)	NJ 868 012	1864/66-1962/63	2.30

ii. Net rates of bank accretion

River reach River reach	Grid reference	Period of survey	Mean annual net rate of bank accretion (m yr^{-1})
Glen Dee	NN 984 955	1900-1969	0.36
Ey	NO 086 895	1866-1900	1.53
	086 895	1900-1969	1.41
Quoich confluence (1)	119 902	1900-1969	1.23
Quoich confluence (2)	119 903	1866-1900	0.53
	119 903	1900-1969	0.74
Quoich confluence (3)	119 905	1866-1900	0.09
	119 905	1900-1969	1.13
Quoich confluence (4)	124 907	1866-1900	0.03
	124 907	1900-1969	0.64
Braemar (west)	153 926	1900-1969	0.59
Slugain confluence	158 927	1900-1969	0.70
Braemar (east)	161 923	1900-1969	1.09
Invercauld	172 919	1866-1900	0.32
	172 919	1900-1969	0.25
Aboyne (west)	522 978	1865/66-1969	0.57
Aboyne (centre)	533 982	1865/66-1969	0.39
Aboyne (east)	542 981	1865/66-1969	0.84
Drum (west)	816 985	1864-1965/66	0.54
Drum (east)	820 986	1864-1965/66	0.25
Murtle (west)	NJ 821 012	1864/66-1962/63	1.84
Murtle (east)	NJ 888 016	1864/66-1962/63	0.86

including outwash sediments infilling the main valleys. These sediments have been dissected into a series of terraces, comprising coarse sands, gravels and cobbles which accumulated in high-discharge braided meltwater streams, and which formed during deglaciation. The Dee and its tributaries thus flow through a variety of bedrock types, till, slope deposits, outwash, alluvial sands and gravels on the floodplain, and artificial embankments, each bank type responding differently to fluvial erosion, and influencing river morphology. The Dee is a gravel-bed river, comprising an armoured bed of coarse granite and schist pebbles, and exhibits an irregular long profile with steep, narrow sections alternating with low gradient sections where the valley floor opens out and bedrock basins have been infilled.

The Dee exhibits straight, meandering and braided reaches, characterized by irregular patterns of pools, riffles and bars. Pool-riffle spacing in the Dee conforms to that of most other rivers, averaging 5.5 times channel width, although high variability in spacing reflects the dominance of local geomorphic controls on flow and sediment conditions. The Dee is a low sinuosity river, averaging only 1.27, with a meander spacing of 609 m. Meander wavelength (λ) was found to be related to mean annual flood (Q_{ma}) by the function $\lambda = 93.3\ Q_{ma}^{0.52}$, and to channel width (W) by $\lambda = 37.8\ W^{0.91}$. Predicted meander amplitudes associated with measured wavelength and width far exceed the available floodplain width, resulting in the development of a range of confined meander forms. Bars and islands in the Dee are derived from the deposition of lateral, point and confluence bars, but most bars and islands have been dissected and reworked by flood flows, and some have become abandoned and vegetated. Significant changes in channel course have occurred at numerous sites since the mid-19th century, through bank retreat, meander evolution, bar accretion, chute channel formation and island development. Net rates of bank retreat in 14 reaches have averaged 0.7 m yr^{-1}, while net rates of bank accretion in 22 reaches have averaged 0.72 m yr^{-1}, suggesting that patterns of erosion and deposition in the Dee have been operating in a state of dynamic equilibrium, with no long-term progressive change.

This paper presents the results of a preliminary survey of the geomorphology of the Dee and its catchment. Five important fields of study can be identified as requiring further detailed investigation.

i. *River terraces and valley fill deposits* need to be fully surveyed to determine in detail their morphological and sedimentological characteristics; boreholes through the valley fill are necessary, together with more precise dating of the deposits and further palaeohydrological analysis of the terrace/infill sequence.

ii. *Bank materials and rates of erosion* need to be determined through a detailed survey of the physical characteristics and spatial distribution of the different bank materials, together with detailed monitoring of bank retreat rates (using field and air surveys) at selected, vulnerable sites.

iii. *Bed sediments and bedforms* need to be studied in detail to determine the size, shape, lithology, orientation of bedload sediments as indicators of source inputs, downstream variations, extent of armouring, rates of transport, and threshold velocities. The range of bar types, and rates of bar and sediment movement also need to be determined.

iv. *Hydraulic relations* between the main flow parameters (width, depth, slope, velocity, discharge, sediment discharge), geometric characteristics of channel planform (sinuosity, wavelength, meander form), bedforms and patterns of change all need to be clearly established for the Dee, mainly as a basis for developing a model of channel dynamics.

v. *Channel changes* over long-term, historical and short-term timescales need to be analysed for a large number of reaches on the Dee and its tributaries, together with analysis of the associated geomorphic, hydraulic and human controls on these changes, as a basis for developing a predictive model of channel change.

7 References

Anderson, M. G. & Calver, A. 1980. Channel plan changes following large floods. In: *Timescales in geomorphology*, edited by R. A. Cullingford, D. A. Davidson & J. Lewin, 43-52. Chichester: John Wiley.

Baird, P. O. & Lewis, W. V. 1957. The Cairngorms floods, 1956. *Scott. geogr. Mag.*, **73**, 91-100.

Bremner, A. 1912. *The physical geology of the Dee Valley.* Aberdeen: Aberdeen University Press.

Bremner A. 1922. Deeside as a field for the study of geology. *Deeside Field*, **1**, 33-36.

Bremner, A. 1925. Limits of the valley glaciation in the basin of the Dee. *Trans. Edinb. Geol. Soc.*, **11**, 61-68.

Bremner, A. 1931. The valley glaciation in the district round Dinnet, Cambus O'May and Ballater. *Deeside Field*, **5**, 15-24.

Bremner, A. 1942. The origin of the Scottish river system. *Scott. geogr. Mag.*, **58**, 15-20, 54-59, 99-103.

Brown, I. D. 1985. Water abstraction from the River Dee. In: *The biology and management of the River Dee*, edited by D. Jenkins, 111-116. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Charlton, F. G. 1982. River stabilization and training in gravel-bed rivers. In: *Gravel-bed rivers*, edited by R. D. Hey, J. C. Bathurst & C. R. Thorne, 635-657. Chichester: John Wiley.

Charlton, F. G., Brown, P. M. & Bensson, R. W. 1978. *The hydraulic geometry of some gravel rivers in Britain.* (Report no. IT 180.) Wallingford: Hydraulics Research Station.

Church, M. & Jones, D. 1982. Channel bars in gravel-bed rivers. In: *Gravel-bed rivers*, edited by R. D. Hey, J. C. Bathurst & C. R. Thorne, 291-338. Chichester: John Wiley.

Clapperton, C. M. & Sugden, D. E. 1972. The Aberdeen and Dinnet glacial limits reconsidered. In: *Northeast Scotland geographical essays*, edited by C. Clapperton, 5-11. Aberdeen: Aberdeen University Press.

Clapperton, C. M. & Sugden, D. E. 1977. The Late Devensian glaciation of north-east Scotland. In: *Studies in the Scottish Late-glacial environment*, edited by J. M. Gray & J. J. Lowe, 1-14. Oxford: Pergamon.

Dury, G. H. 1977. Peak flows, low flows, and aspects of geomorphic dominance. In: *River channel changes*, edited by K. J. Gregory, 61-74. Chichester: John Wiley.

Edwards, K. J. 1975. Aspects of the prehistoric archaeology of the Howe of Cromar. In: *Quaternary studies in north-east Scotland*, edited by A. M. D. Gemmell, 82-87. Aberdeen: Aberdeen University Press.

Ferguson, R. I. 1981. Channel forms and channel changes. In: *British rivers*, edited by J. Lewin, 90-125. London: Allen & Unwin.

Ferguson, R. I. & Werritty, A. 1983. Bar development and channel changes in the gravelly River Feshie, Scotland. In: *Modern and ancient fluvial systems*, edited by J. D. Collinson & J. Lewin, 181-193. Oxford: Blackwell Scientific.

Fraser, W. E. 1963. Geology and structure. In: *The northeast of Scotland*, 3-15. Aberdeen: British Association for the Advancement of Science.

Gregory, K. J. & Madew, J. R. 1982. Land use change, flood frequency and channel adjustments. In: *Gravel-bed rivers*, edited by R. D. Hey, J. C. Bathurst & C. R. Thorne, 757-781. Chichester: John Wiley.

Harvey, A. M., Hitchcock, D. H. & Hughes, D. J. 1979. Event frequency and morphological adjustment of fluvial systems in upland Britain. In: *Adjustments of the fluvial system*, edited by D. D. Rhodes & G. P. Williams, 139-167. London: Allen & Unwin.

Hey, R. D. & Thorne, C. R. 1984. Flow processes and river channel morphology. In: *Catchment experiments in fluvial geomorphology*, edited by T. P. Burt & D. E. Walling, 489-514. Norwich: Geo Books.

Institute of Geological Sciences. 1977. *Sand and gravel resources of the Grampian region.* (IGS report 77/2.) London: HMSO.

Johnstone, G. S. 1966. *The Grampian highlands.* 3rd ed. (British regional geology.) London: HMSO.

Leopold, L. B. 1982. Water surface topography in river channels and implications for meander development. In: *Gravel-bed rivers*, edited by R. D. Hey, J. C. Bathurst & C. R. Thorne, 359-388. Chichester: John Wiley.

Leopold, L. B. & Wolman, M. G. 1957. *River channel patterns: braided, meandering and straight.* (Professional paper no. 282-B.) U.S. Geological Survey.

Leopold, L. B., Wolman, M. G. & Miller, J. P. 1964. *Fluvial processes in geomorphology.* Oxford: Freeman.

Lewin, J. & Brindle, B. J. 1977. Confined meanders. In: *River channel changes,* edited by K. J. Gregory, 221-233. Chichester: John Wiley.

Lowe, J. J. & Walker M. J. C. 1977. The reconstruction of the Late-glacial environment in the southern and eastern Grampian Highlands. In: *Studies in the Scottish Late-glacial environment,* edited by J. M. Gray & J. J. Lowe, 101-118. Oxford: Pergamon.

McConnochie, A. I. 1900. *Deeside.* Aberdeen: L. Smith.

Natural Environment Research Council. 1975. *Flood studies report.* 5v. London: NERC.

Newson, M. D. 1981. Mountain streams. In: *British rivers,* edited by J. Lewin, 59-89. London: Allen & Unwin.

Simons, D. B. & Li, R-M. 1982. Bank erosion on regulated rivers. In: *Gravel-bed rivers,* edited by R. D. Hey, J. C. Bathurst & C. R. Thorne, 717-754. Chichester: John Wiley.

Sissons, J. B. 1967. *The evolution of Scotland's scenery.* Edinburgh: Oliver & Boyd.

Smith, J. S. 1981. The scenery of the Grampian Region. *Deeside Field,* **17,** 11-16.

Sugden, D. E. & Clapperton, C. M. 1975. The deglaciation of Upper Deeside and the Cairngorm Mountains. In: *Quaternary studies in north-east Scotland,* edited by A. M. D. Gemmell, 30-38. Aberdeen: Aberdeen University Press.

Thorne, C. R. & Lewin, J. 1979. Bank processes, bed material movement, and planform development in a meandering river. In: *Adjustments of the fluvial system,* edited by D. D. Rhodes & G. P. Williams, 117-137. London: Allen & Unwin.

Vasari, Y. 1977. Radiocarbon dating of the Late-glacial and Early Flandrian vegetational succession in the Scottish Highlands and the Isle of Skye. In: *Studies in the Scottish Late-glacial environment,* edited by J. M. Gray & J. J. Lowe, 143-162. Oxford: Pergamon.

Warren, J. S. 1985. Hydrology of the River Dee and its tributaries. In: *The biology and management of the River Dee,* edited by D. Jenkins, 23-28. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Werritty, A. 1984. Stream response to flash floods in upland Scotland. In: *Catchment experiments in fluvial geomorphology,* edited by T. P. Burt & D. E. Walling, 537-560. Norwich: Geo Books.

Werritty, A. & Ferguson, R. I. 1980. Pattern changes in a Scottish braided river over 1, 30 and 200 years. In: *Timescales in geomorphology,* edited by R. A. Cullingford, D. A. Davidson & J. Lewin, 53-68. Chichester: John Wiley.

Willetts, B. 1985. River engineering and the control of erosion. In: *The biology and management of the River Dee,* edited by D. Jenkins, 105-110. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Wyness, F. 1950. *Royal Deeside.* Aberdeen: Deeside Field Club.

Hydrology of the River Dee and its tributaries

J S WARREN
North East River Purification Board, Aberdeen

1 Introduction

The River Dee drains a catchment of 2100 km^2 on the eastern side of the Grampian Mountains. In the first 20 km, the land falls 974 m from the summit of Ben Macdui to the river gauging station at Mar. In the remaining 90 km, the river falls a further 335 m before discharging to the sea at Aberdeen.

This paper first shows the dimension of the water resource by illustrating the spatial distribution of the precipitation within the catchment, and converting this to monthly averages. It then draws attention to the particular nature of the river regime by contrasting it with the regime of the River Ugie (discharging 40 km to the north) and comparing the 'effective rainfall' of the Dee catchment with its discharge characteristics.

The distribution of the data collection sites is also examined, and may assist readers to assess the availability of material for further study.

2 Rainfall, climatological and river records

2.1 Rainfall

Rainfall records appear to have commenced in the Dee valley with the establishment of a rain gauge at Braemar in 1856. Since then, the records of a further 70 rain gauges have been added to the archive. Not all of these gauges are extant. Girdleness discontinued recording in 1982 after 120 years, and Drum Castle in 1975 after 109 years.

A number of rainfall stations also record climatological data such as temperature, windspeed, and so on. From time to time, special research is initiated by government- or university-sponsored bodies and additional data are collected. These special projects often become the base for a scientific paper, but their findings rarely form part of any national archive. For example, both the Central Electricity Generating Board and the Meteorological Office have automatic climatological stations on the hills in catchments adjacent to the Dee. The CEGB was studying the relationship between performance and power lines. The Meteorological Office is recording weather conditions on the hills and evaluating their sensors and instrumentation. Research is also being carried out in the Cairngorms by the Institute of Hydrology on the physical processes of snowmelt.

River levels have been recorded in the Dee catchment since 1892, but the early records are sparse and sporadic. Some early river levels were recorded at the old Bridge of Dee and in Park Estate, and (for varying periods) at Balmoral, Dinnet and Cults. At present, the catchment is served by 10 flow recording stations (Table 1, Figure 1). Several sites are also gauged intermittently in support of special projects, such as the acid rain investigation and low flow yield studies.

Table 1. Flow recording stations in the River Dee catchment in 1984

Station	Grid reference	Catchment area (km^2)	Year records commenced
Mar	NO 098 895	289	1982
Polhollick	343 965	690	1975
Woodend	632 960	1370	1929
Park	798 983	1844	1972
Littlemill	324 956	30	1970
Invergairn	353 971	150	1978
Invermuick	364 947	110	1976
Charr	624 834	42	1957
Tillyfumerie	663 888	84	1976*
Heugh Head	688 928	230	—**

*Height records not yet converted to flow
**Under construction

2.2 Climate and precipitation

Precipitation within the Dee valley ranges in structure from haar on the coastal strip, which for this purpose can be ignored, to heavy convectional rain with intensities in excess of 25 mm h^{-1}. Snow accounts for a significant proportion of the precipitation which goes into storage, although it is of lesser intensity than that expected of rain. Annual precipitation ranges from 700 mm on the coast to over 2000 mm in the mountains (approximately 1000 mm over the catchment as a whole).

The bulk of the catchment's precipitation is provided by Atlantic depressions. In winter, these pass up the west coast of Scotland, their associated troughs and frontal systems passing over the Grampian Mountains. Autumn precipitation is largely convectional and borne on the wind circulation in the rear of depressions to the east of Scotland. Much of this precipitation is intercepted by the surrounding hills, and in winter is deposited as snow. The snow may run off precipitately with a change of air mass, but more commonly accumulates on the hills until the gentle thaws of spring.

Figure 2 shows the annual average isohyets in mm over the Dee catchment for the standard period 1941-70. The main points are the light precipitation on the coast compared with the surrounding hills and the area of comparatively light precipitation between Banchory and Ballater. In 1941-70, the average monthly precipitation in the catchment above Woodend did not drop below 70 mm or rise above 125 mm (Figure 3). As would be expected, the winter months were wetter, but the spring was rather drier than mid-summer. With a difference of only 55 mm of

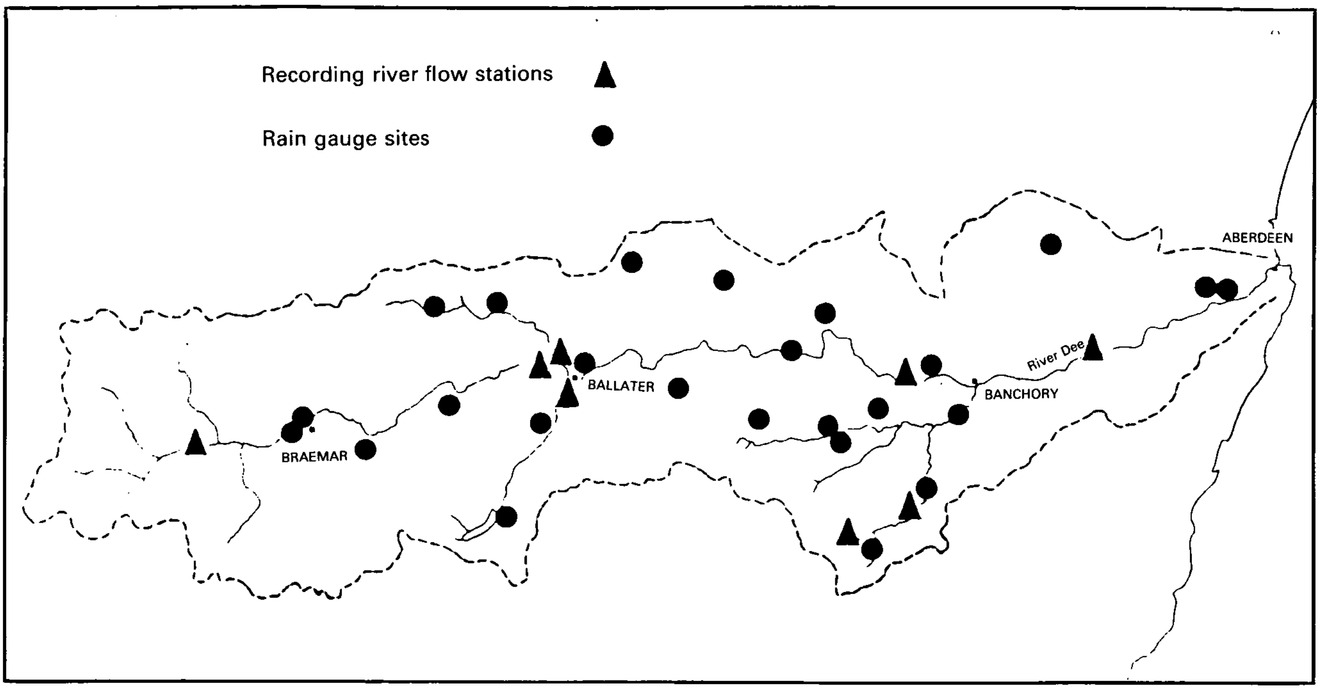


Figure 1. Rainfall and river flow stations within the Dee catchment in use in 1984

rainfall equivalent, the Dee catchment cannot be said to have a well-marked seasonal variation of actual precipitation.

However, if the average evapotranspiration is taken into consideration, the seasonal variation of 'effective precipitation' becomes apparent. Effective precipitation is defined as 'the proportion of actual precipitation which remains after the losses to the atmosphere by evaporation and transpiration have been subtracted' (MacDonald & Partners 1975), ie the precipitation available to run immediately down the river channel or to be held in storage. A diagram of effective precipitation would look very similar to that of a 'simple' river regime (see below, and Figure 3).

3 River regime

A 'simple' river regime exhibits one period of both high and low flows annually. In Britain, this would be due to the effective rainfall in summer being lower than that

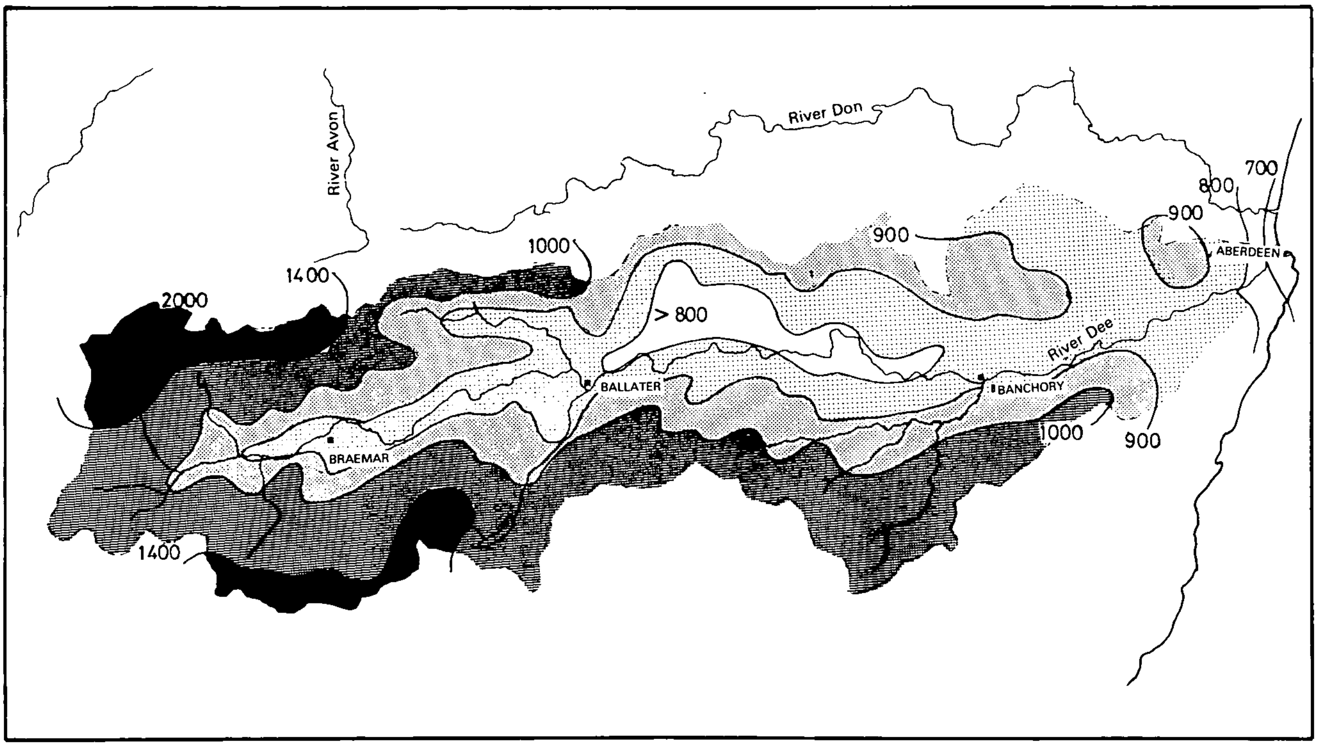


Figure 2. Annual average rainfall in the Dee catchment, 1941-70

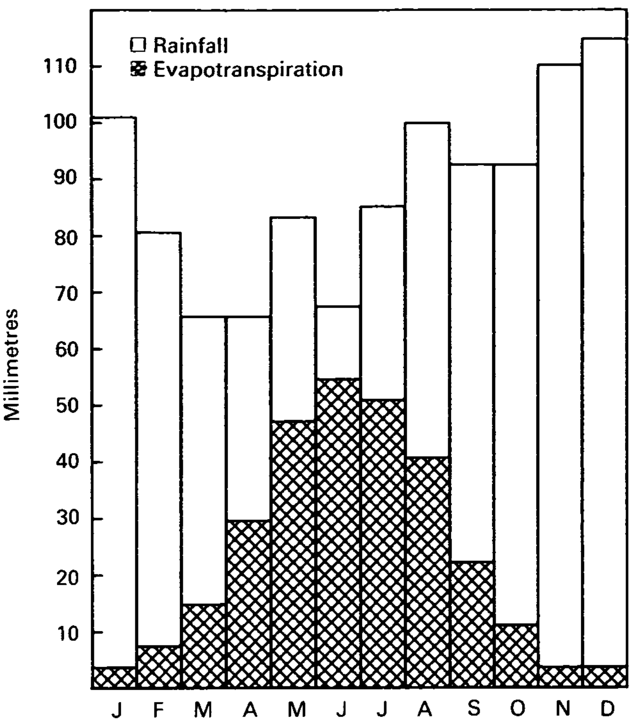


Figure 3. Average monthly rainfall and evapotranspiration above Woodend, 1941-70

of winter, with no appreciable storage of snow in the upper catchment to augment spring river flows. The regime of the Dee, however, is not 'simple', but moderately complex, and it conforms to that regime known as 'alpine'. Figure 4 compares the regimes of the Dee and Ugie. The units used in this diagram are litres per second per km^2 (l s^{-1} km^{-2}) of catchment and the difference between the 2 values is due to the difference in rainfall in the 2 catchments. The mean monthly flows of the Ugie conform in pattern to that of a simple regime, whilst those of the Dee exhibit a 'hump' or an increase of flows in the spring when the snow stored in the upper catchment itself melts and runs off.

4 Runoff

Figure 5 shows the mean monthly flows for the Dee at Woodend for 1941-70 plotted in the same units (mm of rainfall equivalent) and on the same graph as the effective precipitation for the catchment. In August to February, effective precipitation exceeded runoff. In these months, water was stored both as increased groundwater and as snow on the hills. In March and April, flows increased whilst effective precipitation became less. This increase in flow was due to snowmelt which continued for a further 3 months, although it was only rarely detectable on the Woodend hydrograph during July. At this time of the year, small variations of flow could be attributed to either snowmelt or diurnal evapotranspiration.

It is difficult to be specific about the amount of snow stored in the upper catchments, as it varied spatially both vertically and horizontally. For relatively small catchments, an estimate may be made by eye. The rainfall equivalent of lying snow would be about one

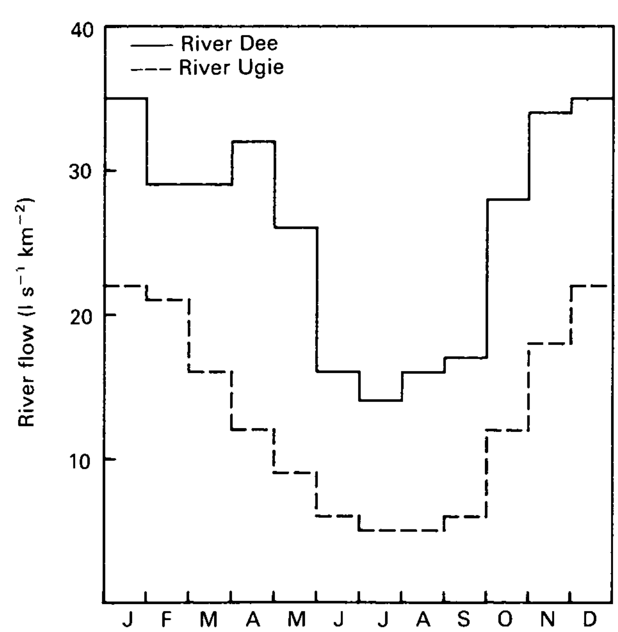


Figure 4. Average monthly river flows in the Dee at Woodend, 1930-77, and Ugie at Inverugie, 1977-79

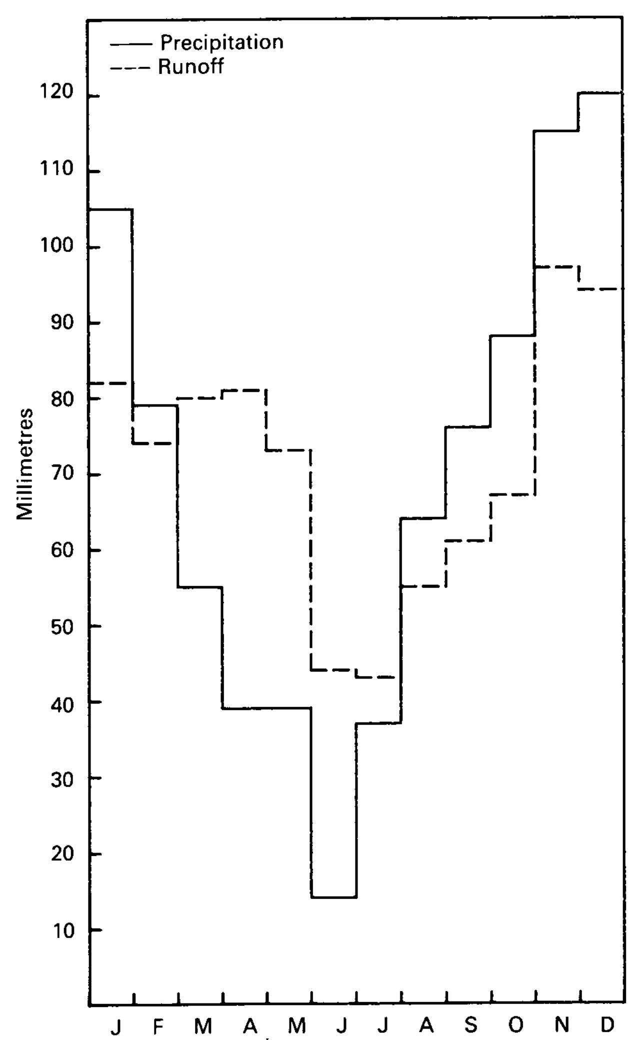


Figure 5. Effective precipitation and runoff at Woodend, 1941-70

tenth of the snow depth, with older snow having greater density than fresh falls. It has been calculated that an experimental catchment at an elevation of 950 m on the western side of the Cairngorm Mountains discharged 1250 mm of rainfall equivalent of snowmelt in 1984. At Woodend, the rainfall equivalent of snow for the entire catchment was in the order 80 mm or 109.6 Mm^3 of water.

Sections of the 1984 hydrograph for Woodend (Figure 6) are included to show the effect of diurnal snowmelt on river levels in April and the decrease of this effect by June. The areas between the peaks and troughs in this hydrograph are due entirely to snowmelt. The area below the troughs is due to groundwater discharge. The hydrological day starts at 0900 hours and this time is marked in Figure 6 by the vertical line on the horizontal scale. Discharge is indicated by the vertical scale. The first peak shown, which would have occurred about 0300 h on 26 April, represents a discharge during the 24-hour period of 2 Mm^3 of water due entirely to snowmelt. By June, the contribution to flow due to snow was barely detectable and the peak occurred at approximately 1400 h, thus taking about 24 h to travel from the upper catchment to Woodend.

Daily mean flows in rivers are usually examined by means of a flow distribution diagram plotted on Log × Probability paper. This diagram gives the percentage of daily means that are equal to or greater than a certain figure. Selected values from a flow distribution diagram for Woodend are listed in Table 2. Further values could be obtained by replotting the values given and interpolation.

Table 2. Flow distribution for Woodend, 1973-83

Daily mean flow	
Cumecs	% = or greater than*
4	99.7
10	90
20	54
30	42
40	28
50	20
100	5
200	0.9
500	0.02

*% of all daily mean flows on which this value (cumecs) was reached or exceeded

5 High flows

A most useful method of expressing flood statistics is by referring to the 'return period'. For example, a flood equal to or greater than 100 cumecs ($m^3 s^{-1}$) can be expected to occur at Woodend every year (selected data in Table 3), and is therefore said to have a one-year return period. Statistically, a flood of 1500 cumecs can be expected to occur once every

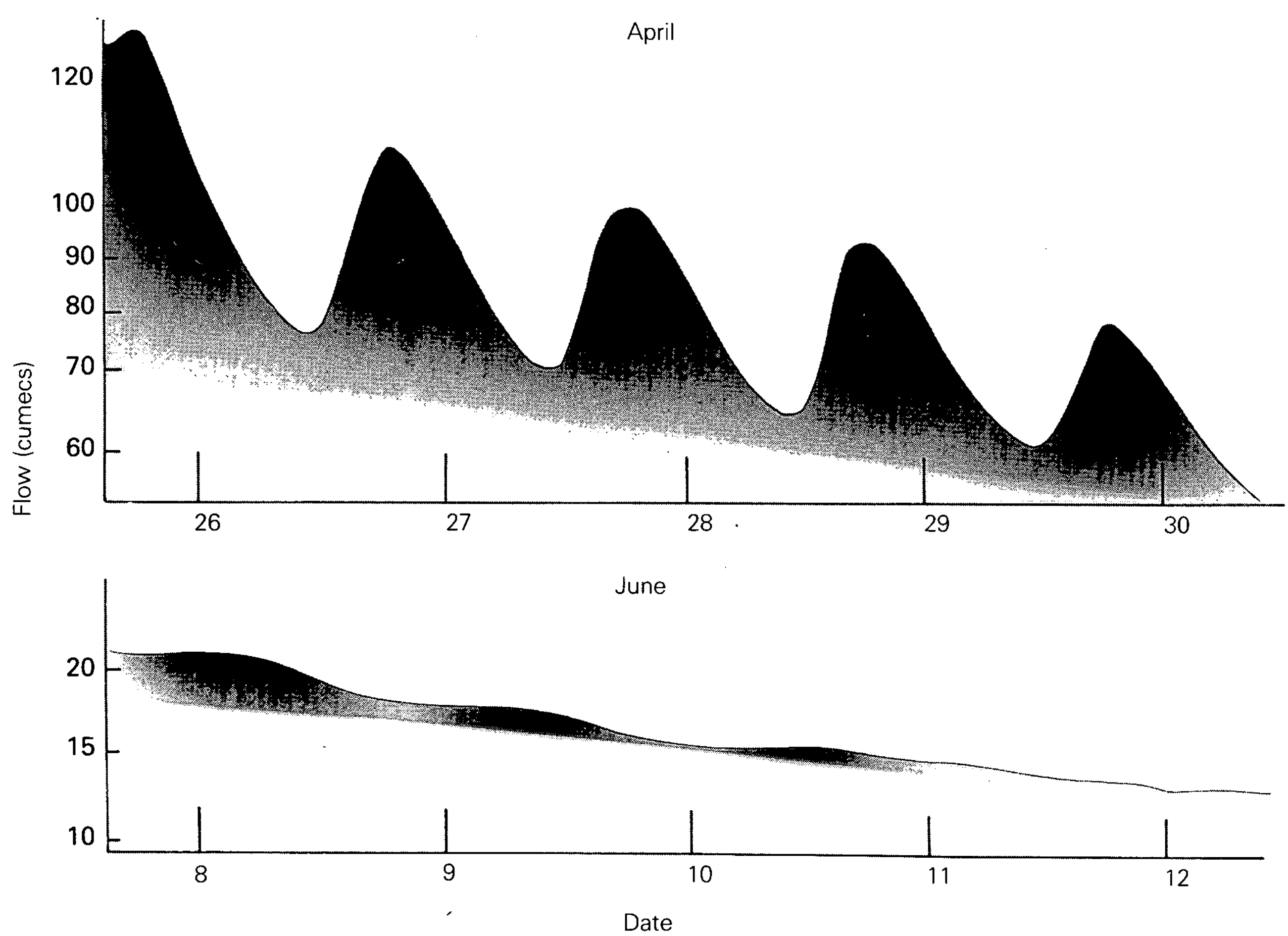


Figure 6. Hydrographs for the Dee at Woodend in April and June 1984, showing snowmelt

Table 3. Estimated high and low flow return periods for Woodend

Return period (in years)	Annual extreme flow (cumecs) High	Low
1	100	13
5	500	6
10	600	5.4
20	800	5
50	1200	3.5
100	1500	—

100 years, and this would be said to have a 100-year return period. Return periods for events at any location are usually plotted on Log × Probability paper and it is best to refer to these diagrams if a full range of return periods is to be examined.

Wyness (1968) records a spate on the Dee in 1738, and found that similar floods occurred on the Dee with 'startling regularity every 30 years'. A flood with a 30-year return period would give a flood flow of approximately 1000 cumecs at Woodend. Although a 30-year return period is a statistical concept and does not mean that a flood of this magnitude will return at 30-year intervals, it gives a datum by which to judge higher floods.

The 1829 flood is estimated to have had a maximum discharge of 1900 cumecs at Woodend (NERC 1975), but this value is probably over-estimated. However, it was certainly in excess of 1000 cumecs. Reliable records of floods (in terms of flow) do not exist between 1829 and 1929, but the flood of 1920 was almost certainly over 1000 cumecs; 1920 is almost a multiple of 30 years from 1829. Two more floods over 1000 cumecs have occurred since then, the first in 1937, followed by a space of 17 years before the second flood in 1951, which is again nearly 30 years since 1920.

If one ascribes anything other than chance to Wyness's observations, a flood of 1000 cumecs is imminent. Examination of the Woodend record for 1930-1984 shows that there were 5 floods greater than 500 cumecs in the first 25 years, and that there have been 8 greater than this value since, but none over 1000 cumecs as previously indicated.

By using water levels alone, as opposed to flow figures, we can extend the continuous record back to 1920. December and January were the months in which the greatest number of occurrences took place (Table 4), although not necessarily the months which produced the highest floods. In contrast, June did not produce a single flood event. It can be concluded that rarely does the annual maximum flood occur in the months of seasonal snowmelt, although many are associated with heavy rain and a change of air mass which also melts snow. The flood of 1937 which occurred in January was probably due to this cause. However, the extreme flood of 1829 occurred in August and was associated with intense convectional precipitation, as was the flood of 1920.

Table 4. Annual maximum flood for Woodend, 1920-83

Month	J	F	M	A	M	J	J	A	S	O	N	D
Events	13	3	3	2	1	0	1	5	4	8	7	17

Table 5. Annual minimum daily mean at Woodend, 1930-84

Month	J	F	M	A	M	J	J	A	S	O	N	D
Events	0	0	1	0	2	5	16	14	10	5	0	1

An analysis of hydrographs within the catchment may provide mean relationships between various locations, which can often be invaluable in estimating the height and time of arrival of a flood at a downstream site, given the height and time of its peak at some position upstream. For example, a peak of 400 cumecs at Woodend can be expected to have risen to 500 cumecs when arriving at Park one hour later. Peaks of lesser magnitude travel correspondingly more slowly. This is a mean relationship and the contribution made by the intervening catchment may differ slightly from flood to flood. Similar relationships exist between all stations within the Dee catchment, but this example is sufficient to show the varied information that may be gleaned from the hydrographs.

6 Low flows

July or August are usually the months in which the lowest flows are recorded in the Dee. However, in years with low summer rainfall, the recession of the hydrograph may extend into September or even October. Low flows have also occurred in winter due to potential runoff being locked in snow, frozen groundwater and river ice. Table 4 shows one occasion between 1930 and 1984 when the lowest annual flow occurred in March. This was in 1963 during a particularly hard winter. The December occasion was in 1958.

The magnitude and occurrence of minimum daily mean flows may be examined with the aid of a low flow frequency diagram (cf selected data in Table 3), which is very similar in structure to the flood frequency diagram. These diagrams for the Dee, and indeed for all rivers in the north-east, are kept constantly under review by the River Purification Board.

There has been much discussion in recent years about the possibility that summer flows are becoming progressively lower. It has been suggested that changes of land use, increase of drainage, or forestry activities are to blame. Figure 7 shows the annual minimum daily mean flows for Woodend from 1930 to 1984. For the 25 years 1930-54, the minimum did not fall below 5 cumecs. In the succeeding 25 years, 1955-79, it dropped below this figure on 7 occasions, which may suggest that summer flows are getting lower. However, no significant statistical trend has been identified.

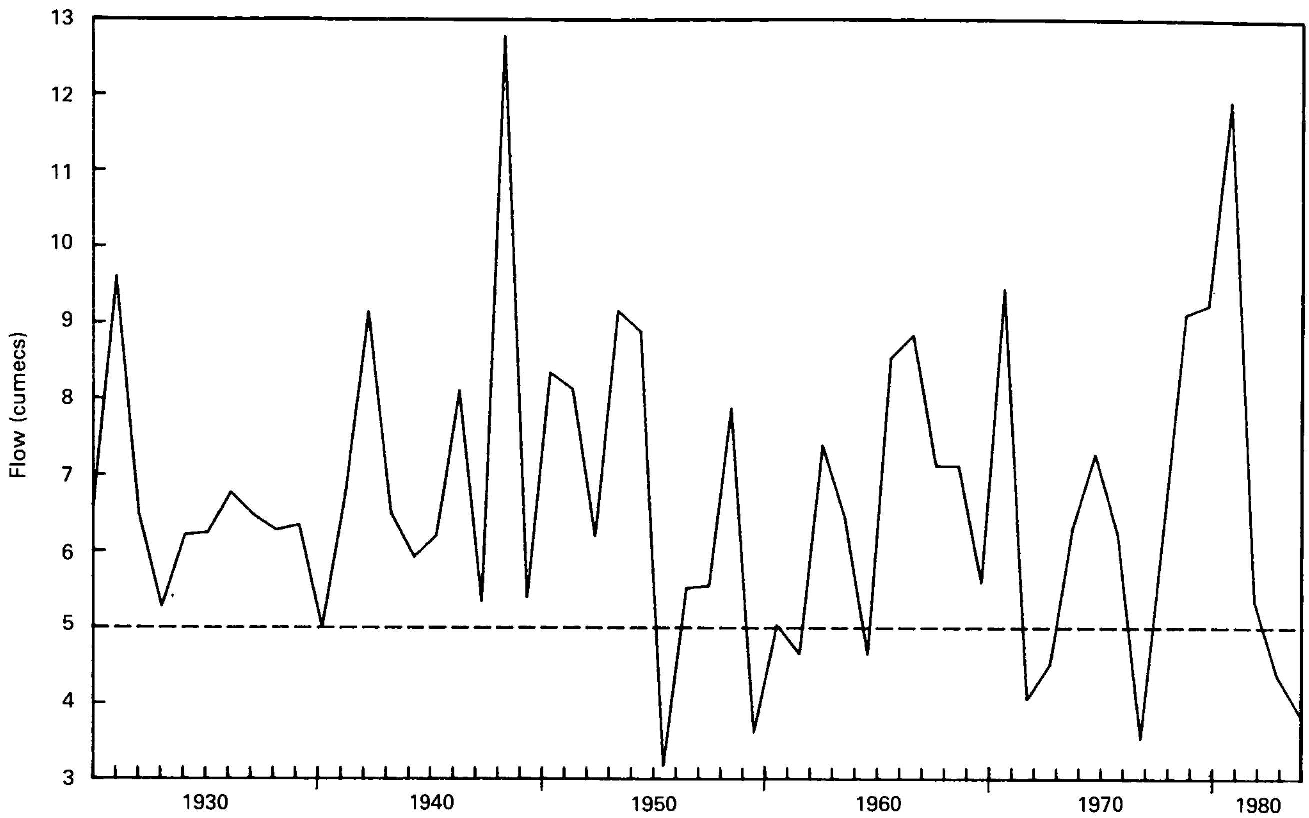


Figure 7. Annual minimum daily mean flows at Woodend, 1930-84

In 1975, Sir M MacDonald and Partners carried out a regional study of water resources on behalf of the North East of Scotland Water Board. They concluded that the period prior to 1972 should be subject to a correction applied on a sliding scale from 1934 until 1972. These corrections effectively reduced the computed annual minimum daily flows by approximately 2 cumecs. Figure 7 incorporates these corrected minimum flows. A student of low flows in the Dee should be aware that there are 2 sets of records for the period 1934-72. The National Archive will hold the original records, although these are now likely to have been converted from the imperial units in which they were taken.

Referring to the early records, Sir M MacDonald and Partners state 'in view of the various uncertainties, a sophisticated correction procedure is hardly justified'. However, subsequent records appear to indicate that some correction is justified, and I conclude that the lower summer flows since 1955 really were lower than originally assumed. Whether this phenomenon was due to changes in catchment characteristics or to changes in climate deserves further investigation.

7 Summary

The Dee is the major drainage basin on the eastern side of the Cairngorms. Average annual rainfall varies between 700 mm on the coast to 2000 mm on the hills where over 25% may fall as snow. Snow remaining in the upper catchment over winter and providing excess runoff during the spring gives the river an 'alpine' regime.

At Woodend, no flows below 3 cumecs or 2.2 $l\ s^{-1}\ km^{-2}$ of catchment have been recorded. Ninety per cent of Woodend flows are above 10 cumecs and 5% are above 90 cumecs. The highest flood recorded was in 1829 and has been estimated to have produced a flow of 1900 cumecs at Woodend, or 1387 $l\ s^{-1}\ km^{-2}$.

Quantitative records of hydrological phenomena within the catchment exist from 1829, although early records are sparse. The present-day network of hydrological sensors is sufficient for overall resource management, but would require augmenting for special or specific studies.

8 References

MacDonald, Sir M. & Partners. 1975. *Regional water resources study for the North East of Scotland Water Board.* Vol. 2. Cambridge: Sir M. MacDonald & Partners Ltd.

Natural Environment Research Council. 1975. *Flood studies report.* Vol. IV. London: NERC.

Wyness, F. 1968. *Royal valley, the Aberdeenshire Dee.* Aberdeen: Alex P. Reid.

Land use within the catchment of the River Dee

J S SMITH
Department of Geography, University of Aberdeen

1 Introduction

The paper establishes the origins and physical character of the environment of the catchment of the Dee. The human exploitation patterns over the last 5000 years are examined and demonstrated to have had, at the least, minor impact throughout the catchment, notably on the characteristics of soil and plant communities. The major impacts have been concentrated on lower Deeside where agrarian efforts have been concentrated, and where the intensity of usage has been greatest. In the upper parts of the catchment, the frontier of permanent settlement has receded since the middle of the 18th century, and the intensity of usage has subsequently diminished. The improving movement in agriculture and the Victorian development of sporting land uses are regarded as particularly formative periods in the development of the contemporary cultural landscape. It is argued that the historical changes in land use discussed, while clearly affecting the lives of the contemporary inhabitants and substantially modifying the character of Deeside landscapes, were not dramatic or rapid enough to have substantially modified the Dee's discharge or water quality, although a number of natural habitats were either reduced in area or eliminated.

2 Physical environment

The planimetric shape of the Dee catchment is rectangular, about 140 km long and averaging 20 km broad, but tapering markedly eastwards over the last 25 km. Its physiographic character is an incised major valley set within a series of dissected plateau surfaces, valley benches and inland basins. The Dee valley westwards of Kincardine O'Neil is narrow and entrenched, but eastwards the middle and lower reaches open out with the channel flowing through a series of pre-Quaternary basins with lowland characteristics, notably Cromar and Feughside.

Less than 20% of the overall catchment lies below 244 m above OD, arguably a significant altitude for successful ripening of cereals at this latitude, and this more agriculturally productive ground lies mainly in the last 35 km of the catchment's long axis. The major elements of catchment scenery are generally of pre-Quaternary age (Smith 1981), a feature which distinguishes Deeside from most other parts of the Scottish highlands which tend to exhibit a greater degree of glacial modification of their physical landscape.

The headwaters of the Dee originate in the Cairngorms. These hills collectively form the largest area of continuous high ground in Britain, thus acting as a major originator of weather events whose effects are transmitted downstream into middle and lower Deeside in terms of flood peaks. The overall length of the catchment and its east-west orientation results in its upper parts, especially the valley floors, experiencing a relatively continental climate, with a combination of wide annual ranges of temperature and comparatively low rainfall. Exceptionally low temperatures are recorded in valley floor situations in winter, and at Braemar air frosts may occur from late August onwards. Increasing altitude, on the other hand, dramatically shortens the growing season and both in the past and at present markedly affects both the characteristics and the utilization of the biogeographical resource.

Reconstruction of the natural environment of the catchment prior to human interference is facilitated by the general uniformity of the geological base (Maizels 1985), which consists of very extensive areas of acidic granites with restricted outcrops of base-rich hornblende schists and metamorphic limestones. The latter are located on the eastern flanks of the Strachan basin, on the valley floor between Aboyne and Birse, and as localized outcrops on the *Baddoch*, the *Clunie* and the flanks of Morrone in the Braemar area. Although largely concealed by glacial drift, the metamorphic limestones are mirrored by the distribution of lime kilns. Hornblende schists outcrop notably in the Morven mass, and in less extensive outcrops on the benches and plateaux of the middle *Muick*. While the summits of the highest hills carry skeletal soils, bedrock outcrops and peat, in the valleys the parent materials tend to be dominated by soils developed on fluvioglacial sands and gravels containing high proportions of granitic materials.

The surviving oakwoods at Dinnet and Craigendarroch, albeit semi-natural, recall the character of the original lowland climax woodland prior to human settlement. Historical accounts dealing with Culblean in Cromar confirm the more widespread extent of oak woodland even in the historical past. The present natural climatic treeline of native conifers lies around 700 m above OD, although the tree stumps of pine around the flanks of the Cairngorms are evidence of a still higher treeline during the climatic optimum (Nethersole-Thompson & Watson 1974).

While the changing post-glacial climate must have produced altitudinal migration of the natural life zones, by far the most important factor affecting the present characteristics of the natural biogeographical resource in terms of surviving natural woodland and soil characteristics has been human exploitation patterns over the last 5000 years. These changes, which were ultimately to affect, in varying degrees, almost the whole Dee catchment, are likely to have had at least minor repercussions on water and sediment budgets. However, the only hard evidence published to date relates to the Cromar area (Edwards 1979), and deals with the prehistoric farming and stock-rearing phase and its effects on rates of soil erosion. Recently published work by the Institute of Hydrology on the effects of extensive conifer afforestation in certain western upland catchments in Britain suggests that, as the canopy develops, water release from such catchments may decrease by up to 20%. It would be unwise to extrapolate such figures to a Deeside context, and, in any case, established sporting interests and shortage of plantable ground would seem to preclude further extensive afforestation in the foreseeable future.

3 Prehistoric land usage

Although the cumulative impact of human interference on the natural environment of the Dee valley decreases westwards, in terms of woodland cover only a few isolated but important stands of native forest survive today, the remainder having been cleared for cultivation, grazing and timber production. Inroads into the natural forests proceeded earliest on the eastern valley floor and terraces. Here, lighter fluvioglacial soils with initial brown forest soil characteristics were cleared as early as 3000 BC by the first pioneer farmers. The recent excavation of a substantial Neolithic timber hall nearly 23 m in length at Balbridie, near Crathes, is evidence not only of considerable agricultural activity in lower Deeside (Ralston 1984), but also of the availability of oak in quantity and size for construction activities. Like the Mesolithic hunter-gatherers they followed, these communities lived near the river, although seasonal mobility was an essential part of their *modus vivendi*. The work of Edwards (1979) at Braeroddach and Loch Davan on middle Deeside reveals that clearance and grazing accelerated rates of soil erosion in Cromar.

By the Bronze Age, evidence is firm for repeated cycles of clearance and regeneration, and the impressive density of field systems and tracks in Cromar (Ogston 1931) is supplemented by additional evidence of agricultural activity surviving beyond the present limit of cultivation. According to Edwards' sites, the pollen evidence suggests 'extensive and sustained' usage of the ground for both pastoral and agricultural activities.

However, the total package of prehistoric field monuments on Deeside suggests that permanent human endeavour was concentrated in those parts of the catchment east of Ballater, although sites do occur as far west as Crathie.

4 The medieval period

By the medieval period, with increasing human population, colonization on Deeside extended westwards to conflict with largely recreational activities ongoing in the 'hunting forests' of Morven, Culblean, Strathdee and Mar on upper Deeside. In the days of Robert the Bruce, such hunting forests extended almost to the outskirts of the burgh of Aberdeen. The land grants of the Irvines of Drum and the Burnards of Leys included in their charters clauses involving a degree of conservation of these earliest of 'reserves'. The main thrust of management was the maintenance of 'vert and venison'.

The pressures on these medieval reserves, until the 16th century largely the property of Scottish Kings held via their trustees, were not only through direct clearance for agriculture, but for firewood, grazing animals and for useful domestic products such as agricultural implements and candle-fir. Indirect effects wrought by goats and other grazing animals must also have been substantial (Mather 1969). They clearly impeded the 'natural shifting of the forest stance' observed by Pennant in Ballochbuie as late as the 18th century. Increasing inroads into the natural woodland led to a decrease in species variety and resulted in the early demise of the wolf and brown bear.

Medieval Deeside was locally governed by the Earl of Mar, whose major power centre lay at Kindrochit Castle, Braemar, with a subordinate centre at Migvie, Cromar. The higher glens and mountains of upper Deeside were used seasonally and were actively conserved as hunting land for local aristocracy and royal visitors. In middle and lower Deeside, as the distribution of castles and tower houses shows, the land had been parcelled up amongst feudal barons, and the adjoining lands used agriculturally for subsistence purposes. The evident difficulties of obtaining prime timber for castle and tower house construction reflected the demise of the original woodland, long since broken up and cleared by increasing population pressures. As the 1696 Poll Book reveals (Walton 1950), population density closely mirrored the inherent productive capacity of the land. In Deeside, the best potential arable land lay either in the lowland basins of Cromar and Feughside, or on the alluvial and terraced bottomlands of the Dee and its major tributaries.

As the Earldom declined, so new powerful families intruded into Mar, notably the Farquharsons in upper Deeside, and the Gordons in middle Deeside. The clan groups which developed in Farquharson territory greatly increased agriculture and stock-rearing pressures in upper Deeside. In the upper parts of the valley and its major tributaries, the herds, notably black cattle, were at least as significant as crops in the local economy, and the production of the essential grain products on the arable ground was only possible through the often distant shealing of the stock during the summer. The Cromar population appears to have had shealing rights in upper Strathdon, while similar summer pasturing patterns on Deeside, notably in Glen Shee, Glen Callater and Glen Baddoch, extended the ground utilized, at least on a temporary basis.

5 Improved agriculture and recent land use

Conservation measures were introduced in Mar by the landowners at least as early as the 16th century, in an attempt to reduce grazing in the pinewoods and encourage regeneration. Although the population growth throughout Deeside was frequently checked by feuding and famine, gradually agricultural colonization pushed higher up the glens and hillsides, with shealings on occasion being taken into permanent agricultural occupation. By the 18th century, this land pressure, combined with a marked decline in the demand for deer stalking in the old grand style, meant that deer forests were confined to the most remote areas, while in the middle and lower Deeside catchments the new agricultural techniques of drainage and enclosure were creating a new agrarian landscape.

This phase of agricultural improvement was temporarily checked in upper Deeside at least by the military involvement of the clans during the Jacobite period (1689-1746), culminating in the appearance of 300 Invercauld Farquharsons at Culloden. Following the demise of the Stuart cause, a combination of land forfeiture and changing aspirations amongst the landowners introduced new attitudes to land use and estate management (Smith 1979). New lairds like the Duke of Fife acquired substantial lands in upper Deeside (Balmoral and Mar), and others (eg Farquharson of Monaltrie) subsequently regained their forfeited properties. Together, they embarked on ambitious programmes of road, bridge and land improvement, including the development of the mineral waters at Pannanich (Smith 1983). Commercialism, that is the seeking of economic returns on investment, already apparent in the lowland pattern of individual farms set within apportioned and compact holdings, was mirrored in the upland areas by the first serious commercial plantations of conifers, the creation of estate arboreta, and the improvement of hill stock.

The fashion of deer stalking was revived in Deeside from the 1790s onwards, and by 1826 the first Mar Lodge, which was to be largely destroyed by the muckle spate in August 1829, was advertized for letting as the centre of 'the finest shooting district in Scotland' at £1,800 per year. Attempts to stock the high glens like *Lui* as sheep walks were quickly abandoned in favour of more lucrative shooting lets, and extensive areas within the upland catchment previously used for extensive grazing or shealing were let either as deer forests or grouse moors. This resurgence of sporting land uses caused a withdrawal of agriculture from the highest tidemark of the early 18th century, and effectively ended the shealing system. The purchase of Balmoral in the 1850s by the Prince Consort provided a further burst of publicity to the land use of sporting lets, and shooting lodges staffed by a seasonal population appeared in even the remotest glens.

A marked feature of the Victorian period on Deeside, particularly well exemplified in Glen Tanar, was the effect a single laird's tastes could have on the cultural landscape (Mather 1969). Over the same period, tree planting became increasingly popular, initially with Scots pine and larch, and later with North American conifers. Since 1919, the Forestry Commission have acquired and planted land (eg at Alltcailleach), while several private estates have long regarded forestry as an integral part of estate land use, notably at Glen Tanar and Invercauld. There has been substantial replanting of those areas felled during the 2 World Wars, and also of ground devastated by the great 1953 gale.

6 Contemporary land use and population trends

The altitudinal and environmental contrasts existing within the Dee catchment are reflected in the varied nature of the agricultural economy and current land use (Table 1). Middle and upper Deeside are characterized by the dominance of upland and hill farms, while east of Kincardine O'Neil farming takes on the character of lowland agriculture. The key restrictive features are shortness of growing season, the lack of improved ground for cultivation and cropping, and a seasonal moisture deficit. In the west, stock rearing is the traditional farming economy, while eastwards cropping and occasionally dairying are dominant. While these patterns reflect the environmental limitations for agriculture, recent agricultural trends also reflect national and European agricultural policies, as a result of which farmers perhaps determine their economies through their pockets rather than with their hearts. In the upland areas where units are substantial and span a variety of terrain, scope remains for landowners to seek a measure of integration between the array of land uses on a particular estate (eg between forestry and stock rearing), but only if the mechanism of subsidy support is devised with such aims in mind.

Table 1. Land uses in the catchment of the River Dee, Grampian, in 1980 (sources: June 1980 Agricultural Returns, Ordnance Survey maps and unpublished information)

	Area (km^2)	% of catchment
Towns and villages	27.2	1.3
Standing water	7.0	0.3
Cropland	137.2	6.5
Grassland	231.9	11.0
Commercial woodland	226.2	10.7
Other woodland	38.0	1.8
Rough grazings*	1112.1	52.9
Deer forest*	320.4	15.3
Total	2100	100

*Deer forest and rough grazings overlapped

Generally, maximum populations on Deeside were attained in the early 18th century in the upland parishes, and in the early 19th century in the hill-edge and lowland parishes, reflecting the continued pace of agricultural reclamation up to the hill edge. However, by the second half of the 19th century, with the exception of the small burghs and the newly created railway villages like Lumphanan and Torphins, many of which also functioned as Victorian summer resorts, the present pattern of decline in landward rural populations had become almost universal. Improved efficiency and mechanization in the present century, and particularly since the Second World War, have greatly reduced the number of people employed on the land. Amalgamation of farm holdings also contributes to the process of rural depopulation.

An increasingly important dimension of established land use patterns, both on the riverside and in the hills, has been the demands of weekend visitors, notably from Aberdeen and Dundee. Their usage and access to the land resource increasingly enters into the land use decisions of both farmers and landowners. Inevitably, the question arises whether such informal access and utilization require a measure of formalization, or indeed may be tapped for estate revenue. The establishment of the Glen Tanar Charitable Trust, together with a Visitor Centre and Countryside Ranger in middle Deeside, may well be a pointer towards more formalized access in upper Deeside in the future. One result of increased scientific knowledge of the Dee catchment is the identification and scheduling of regionally and nationally important nature conservation sites. It is important to meld nature conservation interest with both the land use practices of the people who make their living by the land and the requirements of visitors who seek their recreation there.

7 Discussion

While this conference concentrates on the river channel and its immediate environs, a total catchment viewpoint is the classic unit of study of geomorphologists, watershed engineers and geographers. Work on modelled catchments, notably in North America, has demonstrated that major changes in land use such as deforestation, afforestation and even agricultural drainage have downstream effects on channel and floodplain form and water quality, via the proportion of water and sediment released from the appropriate catchment. Much of this work, however, is derived from studies of extremely dramatic manipulated land use changes on very small modelled catchments, rather than on real-world situations like the Dee.

Changes in land use beside the Dee, while far reaching over the lengthy period of time outlined above, have been relatively slow, and the characteristics of the catchment are large and contrasting. With the notable exception of water abstraction, particularly appropriate in 1984 when water flows reached the lowest figure since records began in 1929, the Dee and its tributaries remain unregulated. It is a wild river, by comparison with many of its highland and European counterparts. In nature conservation terms, the natural instability of water channels creates many interesting albeit ephemeral habitats, eg on point bars, backwaters and mid-channel bars, even within the floodplain. Total regulation through engineering works precludes the emergence of these new habitats, and therefore may be regarded as deleterious to the total biological package, although a farmer concerned with problems of bank erosion and periodic flooding would view regulation in a rather different way.

At present, it seems unlikely that any major changes in land use within the catchment will occur which would produce any significant effects on the Dee's natural biology and regime. On the other hand, rationalization of Common Market agricultural production to match European demand would clearly sound the death knell to a large part of marginal Scottish agriculture. It would leave a void to be filled by either forestry or recreation, or a combination of both.

The likely effects of extensive conifer plantation in middle and upper Deeside on water yields as the trees reach maturity may be argued to be substantially less than the 20% decrease estimated for the wetter west of the country where ground-storey vegetation is grass rather than heather. Nonetheless, the Deeside catchment lacks the appropriate evapotranspiration measurements to enable meaningful predictions to be calculated. Although the proximity of both commercial plantations and native woodlands to the main public roads in upper Deeside suggests a heavily forested catchment, measurements summed per km square using the most recent Land Ranger 1:50 000 Ordnance Survey sheets (early 1980s) reveal that the catchment west of Kincardine O'Neil (catchment area 1365 km^2) carries 147 km^2 woodland (a cover of 10.8%), while the remainder (catchment area 735 km^2) carries 117 km^2 woodland (a cover of 16%). A key figure not available at present is the area of ground west of Kincardine O'Neil which remains unplanted and below the economic treeline.

With increasing leisure time, demand for waterside access on Deeside seems likely to increase, and it is notable that such access points on lower Deeside, where demand is potentially greatest, are very few (eg Potarch). Informal waterside access is long established on the *Feugh*, the *Quoich* and the lower *Tanar*.

Writing in 1840, the minister of Drumoak parish commented that 'the super-abundant waters of about 900 square miles feed its current, but so clean are its gravelly banks and pebbly channel that its waters rival in purity the most limpid streams in Scotland . . . this beautiful river, although superior to its gentler neighbour, the Don, in the value of its salmon fishings, has never, like it, been rendered serviceable to the manufacturer; nor does it compensate this unprofitableness to the manufacturer by rivalling the Don in usefulness to the agriculturalists, for instead of fattening his meadows with a rich alluvium, its inundations carry off the best part of the soil and deposit in its place a bed of sand possessed of little vegetative power; while its wintry torrent, unwilling to be restrained, contends powerfully with the embankments which have been raised to protect the haughs from its destructive ravages, and occasions great trouble and expense to the proprietors, for repairing the breaches which it frequently makes' (New Statistical Account, Drumoak, 1841).

The papers in this symposium illuminate the extent to which this characterization of the Dee in terms of cleanness and irregularity of regime remains true today. The land use within the Dee catchment, which is the logical response to the environmental setting of valley, hill edge and mountain, makes the catchment scenically attractive and ecologically diverse. Although this diversity of land use is traditionally the response of farmers to difficult agricultural environments, the pattern is ultimately dependent on the Common Agricultural Policy.

While nature conservation and recreation will be increasingly important land uses in Deeside in the 21st century, it is to be hoped that policies will be administered with a view to retaining a working agricultural population in the catchment, as there are limitations to the attractiveness and usefulness of a wholly depopulated countryside. The present situation seems to offer the best compromise between a measure of resource productivity and a measure of ecological diversity. The pressures on the Dee and its channel and channel-side habitats are likely to come from demands for water abstraction and waterside recreation, rather than from agricultural land uses.

8 Summary

While the management strategies of the catchment over the past 5000 years may be described in general terms, a lack of basic data on these systems and on past physical and biological conditions within the Dee and its tributaries makes it impossible to comment authoritatively about the effects of history and land use on the channel. The major changes in the nature of the plant communities described spanned thousands of years, and therefore the published data on small modelled catchments in comparable latitudes which deal with rapid and large-scale changes in land use do not seem to be relevant. The attributes of lack of regulation which make the Dee increasingly important at a time when many major rivers in Europe have been developed for reservoir construction and navigation have been perceived to conflict with full agricultural usage of the floodplain. The natural instability of the major part of the channels of the Dee and its tributaries and their irregularity of regime create interesting channel and floodplain habitats. The value of the total Dee biological package is increased by the range of biogeographical zones through which it flows. Major changes in catchment land uses in the future, eg extensive afforestation, depend on national and Common Market strategies, rather than on the inclinations or tastes of the individual farmer or landowner. The most likely changes for the future, in the absence of deliberate policies formulated to achieve the contrary, are those of limited afforestation, further rural depopulation of the agricultural areas, and the provision of increased and probably formalized opportunities for recreation, both in waterside and hill locations. It would be unfortunate if the present land use diversity which is scenically attractive and ecologically diverse should dramatically change in favour of less diverse systems. Prime consideration should be given to the maintenance of a working agricultural population within the catchment. The requirements of nature conservation and informal recreation might be more acceptable to farmers and landowners if the reduction in land use opportunity they frequently bring with them could be financially recompensed.

9 References

Edwards, K. J. 1979. Palynological and temporal inference in the context of prehistory with special reference to the evidence from lake and peat deposits. *Journ. archaeol. Sci.*, **6**, 255-270.

Maizels, J. K. 1985. The physical background of the River Dee. In: *The biology and management of the River Dee*, edited by D. Jenkins, 7-22. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Mather, A. 1969. The development and characteristics of present land use. In: *Royal Grampian country*, edited by K. Walton. Aberdeen: Department of Geography, University of Aberdeen.

Nethersole-Thompson, D. & Watson, A. 1974. *The Cairngorms.* London: Collins.

Ogston, A. 1931. *The prehistoric antiquities of the Howe of Cromar.* Aberdeen: Third Spalding Club.

Ralston, I. B. M. 1982. A timber hall at Balbridie farm. *Aberdeen Univ. Rev.*, **168**, 238-249.

Ralston, I. B. M. 1984. Notes on the archaeology of Kincardine and Deeside district. *Deeside Field*, **18**, 73-83.

Smith, J. S. 1979. War and peace in the Braes of Mar. *Aberdeen Univ. Rev.*, **161**, 36-43.

Smith, J. S. 1981. The scenery of the Grampian Region. *Deeside Field*, **17**, 11-16.

Smith, J. S. 1983. Lairds and landscape in middle Deeside. *Aberdeen Univ. Rev.*, **169**, 40-45.

Walton, K. 1950. Distribution of population in Aberdeenshire, 1696. *Scott. geogr. Mag.*, **66**, 17-26.

The chemistry of the river system

K B PUGH
North East River Purification Board, Aberdeen

1 Introduction
This paper describes the chemical quality of the water of the Dee, its tributaries and its related waters in 1980-84.

Draining the south-east side of the Cairngorm range, falling 1310 m in 140 km from its source eastwards to the sea at Aberdeen, collecting water from a total catchment area of 2100 km^2, and having a long-term average flow of approximately 50 cumecs, the Dee is surpassed in size only by the Tweed, Tay and Spey, and is thus Scotland's fourth largest river. Rising at the Wells of Dee (NH 938 989) and Pools of Dee (NH 973 008) and receiving contributions from the *Lui, Clunie, Gairn, Muick, Tanar, Dye* and *Feugh* (Figure 1), the river drains high-altitude mountain and moorland with bare rock or hill peat, and, successively, heather, conifer and deciduous woodlands and, finally, lightly stocked pasture interspersed with small pockets of arable land. Generally, the soils, derived from granitic parent material, are sandy, podzolic and freely drained. Thus, with an absence of heavy industry, and suffering only the mildest of insults from agriculture, tourism and urbanization (the human population of Braemar, Ballater, Aboyne and Banchory together totals less than 10 000), the Dee remains oligotrophic from source to estuary. It is one of the few British rivers that can still claim such status throughout its length.

2 Analytical methods and site selection
Apart from the measurement of temperature and the chemical fixation of dissolved oxygen in the field, all determinations were conducted in the laboratory. For routine surveys, samples of river water were returned from the field in clean (acid washed and then copiously rinsed with de-ionized water), sample-rinsed glass bottles without the addition of preservatives, and their analysis was commenced within 24 hours. Standard methods of water analysis are employed (Standing Committee of Analysts, various dates).

For studies of the acidification of headwaters and for surveys of base and trace metal status of the rivers, samples were drawn into similarly cleaned polypropylene bottles. Bottles receiving samples for the metal surveys were pre-dosed with Analar concentrated nitric acid, and the bottles filled with sample to yield a final acid concentration of approximately 0.5%. For the acidification studies, the analysis of all determinands, except the metals, was performed on untreated samples, and thereafter Analar nitric acid was added to the remainder of the sample to a final concentration of 0.5% before metal analysis. The metal analysis was performed on unfiltered samples.

Determination of metals was by atomic emission or absorption spectrophotometry with atom excitation in a flame or electrothermal graphite furnace, as appropriate.

Sampling sites for routine river surveys were strategically selected to provide an assessment of the whole length of the Dee, as well as the tributaries in the catchment. Account was taken of the position of effluent discharges, water abstraction and the confluence of tributaries in this selection. There was frequently a correspondence between sites for chemical, biological and hydrological data collection within the programmes of work of the River Board (cf Warren 1985; Davidson *et al.* 1985).

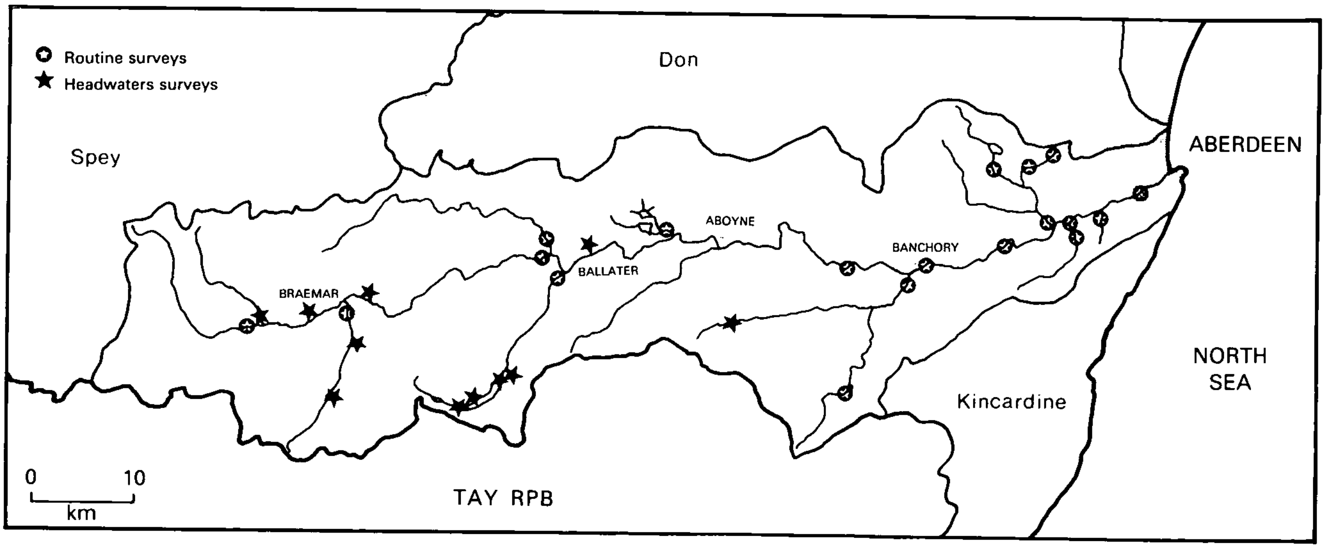


Figure 1. Sites used for chemical sampling in streams in the Dee catchment in 1980-84 (cf Table 1)

3 Water quality

For general purposes, river water quality in the north-east of Scotland is described by reference to a water quality index (WQI) (Scottish Development Department 1976; Bolton *et al.* 1978). Chemical water quality is thereby classified according to placement on a scale of whole numbers from poorest (0) to best (100) quality. With this system, cognisance is taken of 9 major riverine characteristics (dissolved oxygen, BOD (biochemical oxygen demand), ammonium-N, pH, total oxidized nitrogen, orthophosphate-P, suspended solids, conductivity and temperature).

3.1 The River Dee

Figure 2 illustrates the mean water quality indices of up to 56 samples drawn from each sampling site (Table 1) in 1980-84. The main watercourse was of high quality (WQI ≥ 94) throughout its length, with only one slight depression (WQI = 92) observed at Silverbank, immediately downstream of the discharge of effluent from Banchory sewage treatment works. The effects of this discharge were quickly attenuated by virtue of the high dilution generally available.

3.2 The tributaries

All the tributaries in the upper and middle reaches of the catchment (*Clunie, Muick, Gairn, Dye* and *Feugh*) were likewise of pristine character. There was a slight depression of quality in the *Dinnet* which drains the Loch Kinord/Davan complex (see below).

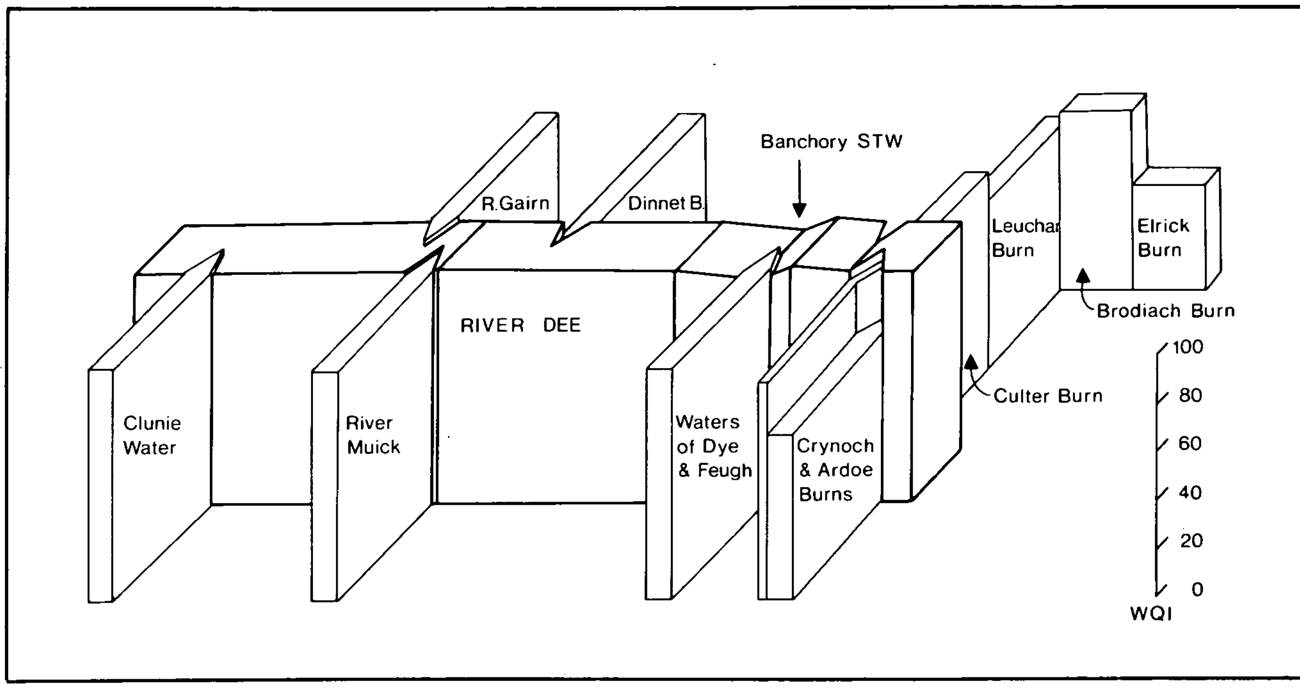


Figure 2. Water quality indices for the Dee and its tributaries

Table 1. Sites for sampling the quality of river water in the catchment of the Dee in 1980-84

River (tributaries italicized)	Site	Grid reference	Water quality index			
			Range	Mean	SD*	n[†]
Dee	Linn of Dee	NO 061 897	98-89	94	3	17
"	Polhollick	NO 344 966	100-89	96	3	17
"	Woodend	NO 632 960	100-81	95	4	56
"	Silverbank	NO 716 963	100-75	92	7	56
"	Park Bridge	NO 797 983	100-91	97	2	17
"	Milltimber	NJ 858 003	100-83	95	4	56
"	Aberdeen	NJ 928 036	100-87	95	4	56
Clunie	Braemar	NO 151 913	100-89	95	4	17
Gairn	Bridge of Gairn	NO 352 971	100-93	97	3	17
Muick	Bridgend	NO 366 948	100-87	95	4	17
Dinnet	Mill of Dinnet	NO 468 992	98-83	91	4	17
Dye	Bogendreep	NO 663 910	100-83	95	5	17
Feugh	Bridge of Feugh	NO 702 950	100-81	95	5	17
Leuchar	Milton of Garlogie	NJ 783 068	89-27	67	14	56
Leuchar	Roadside of Garlogie	NJ 783 054	91-30	69	14	56
Brodiach	Mill of Brotherfield	NJ 834 047	83-60	75	7	14
Elrick	Burnside	NJ 827 059	60-20	43	12	14
Culter	Kennerty Mills	NJ 839 003	91-67	82	5	56
Crynoch	Millton Bridge	NJ 858 001	96-77	89	4	56
Ardoe	A943 Bridge	NJ 893 016	91-27	68	14	56

*SD = Standard deviation   [†]n = Number of observations

The *Elrick*, a small stream draining the Westhill Industrial Estate, received several polluting discharges apart from surface water runoff. Consequently, its quality was much reduced (mean WQI = 43). It drained into the larger *Brodiach*, where quality improved (mean WQI = 75) as dilution and self-purification exerted their ameliorating influences. In turn, the *Brodiach* drained into the *Leuchar*, the discharge stream from the Loch of Skene. The *Leuchar* exhibited some of the characteristics of its eutrophic source, and hence a lower mean WQI (= 67). There was a gradual improvement in quality, again because of self-purification and increased volume flow, as this stream drained into the *Culter* (mean WQI = 82), and thence to the Dee at Peterculter.

The *Crynoch* and *Ardoe*, though exhibiting depressed water quality because of septic tank discharges, were so small that they had little effect on the quality of the main watercourse.

characteristics. The *Ardoe*, as well as receiving nutrient enrichment from septic tank discharges and some agricultural activity (silage and fertilizer runoff), was impounded by a small dam behind which vegetable matter accumulated in large quantities and then decomposed, thus generating further nutrient ions.

A few small streams of variable water quality drain the Aberdeen urban area, and discharge into the harbour and the tidal reaches of the river below the Bridge of Dee. These streams also had a negligible effect on the main river, and surveys of the harbour area confirmed that nutrient-depleted fresh water entered the harbour under Victoria Bridge.

3.3 Lochs Kinord and Davan

The results of a survey in June 1982 (Table 3) confirm Marren's (1979) description of these lochs. Kinord (surface area 0.82 km^2; mean depth 1.52 m), whose main feeder is the *Vat* draining the Culblean Hill

Table 2. River water quality in the Dee catchment (mean values for 1980-84)

Watercourse	BOD	SS	NH_4-N	TON	NO_2-N	PO_4-P	Si	Cl	Alk	Cond	pH range
Dee — Linn of Dee	0.6	1	0.028	0.12	0.003	0.007	1.82	4	13	40	6.2-7.3
— Aberdeen	0.9	3	0.038	0.78	0.008	0.013	2.86	11	22	93	6.4-8.2
Clunie	0.8	1	0.028	0.11	0.003	0.007	1.90	4	22	63	6.9-7.4
Gairn	0.7	1	0.022	0.08	0.003	0.007	3.36	6	21	62	6.9-7.5
Muick	0.7	2	0.029	0.27	0.005	0.007	2.73	6	16	52	6.7-7.5
Dinnet	1.2	2	0.044	0.91	0.012	0.010	3.05	23	30	162	6.7-7.6
Dye	0.8	1	0.024	0.35	0.005	0.025	3.66	9	15	70	5.3-7.4
Feugh	0.9	1	0.031	0.53	0.005	0.021	3.67	9	16	76	5.8-7.5
Leuchar	5.2	16	0.139	2.73	0.033	0.042	4.06	29	42	252	6.7-9.9
Brodiach	1.1	6	0.110	4.75	0.044	0.023	7.03	56	39	386	6.8-7.7
Elrick	5.7	15	1.36	2.74	0.140	0.139	7.80	124	42	643	6.2-7.0
Culter	1.7	5	0.056	3.39	0.026	0.024	4.88	31	35	256	6.9-8.5
Crynoch	1.2	4	0.039	1.72	0.014	0.018	3.43	27	44	229	7.1-8.1
Ardoe	2.3	7	0.331	3.28	0.056	0.142	4.98	33	49	291	6.8-7.7

All results expressed in mg l^{-1} (except conductivity — µSiemens cm^{-1} — and pH)
SS = Suspended solids Alk = Alkalinity (as mg $CaCO_3$ l^{-1}) Cond = Conductivity

Table 2 lists the detailed water characteristics of the catchment. The low nutrient status of the Dee and the tributaries of its upper and middle reaches is self-apparent. With BOD concentrations less than 1 mg l^{-1}, ammonium-N concentrations less than 50 µg l^{-1}, total oxidized nitrogen (TON) concentrations less than 1 mg l^{-1}, microgram quantities of nitrite-N and orthophosphate-P, and conductivities less than 100 µSiemens cm^{-1}, the waters may be described as oligotrophic. With increasing distance down the catchment, the silicate concentration increased. This increase reflects progressively greater weathering (natural and agriculturally induced) and drainage. The water quality data returned for the *Dye* are consistent with those reported by Reid *et al.* (1981) in their studies of the weathering rates in the soils of that catchment.

By extreme contrast, the *Elrick* was polluted; it had high BOD, ammonium-N, phosphate and chloride concentrations, and conductivity. The remaining burns, except those draining Lochs Davan and Skene, fell between these extremes and exhibited the anticipated

granite, was virtually oligotrophic. A minimal diatom film was observed through clear water on submerged stones and rocks, but aquatic vegetation was absent. By contrast, Davan (surface area 0.42 km^2; mean depth 1.22 m), whilst not exhibiting major differences in nutrient chemistry, had both a higher alkalinity and a higher total ion concentration (conductivity), and a carpet of aquatic vegetation, which elevated the pH during the daylight hours. There are 3 small feeder streams to Loch Davan. The largest of these, *Milton of Logie*, drains the agricultural Howe of Cromar carrying with it not only minor quantities of fertilizer runoff but treated effluent from the Logie Coldstone sewage treatment works. The effect was minimal and, at worst, Loch Davan should be considered only slightly mesotrophic. (A high chloride concentration and conductivity observed in the *Glendavan* and near its mouth in Loch Davan was found to be due to leachate from a new stockpile of road salt/grit nearby.)

The *Dinnet* (= *Monandavan*) which carries the effluent from both lochs to the Dee was therefore slightly

Table 3. Water quality in Lochs Davan and Kinord in June 1982

Sampling site	TOC	NH_4-N	TON	NO_2-N	PO_4-P	Total P	Si	Cl	Alk	Cond
Loch Davan (mean of 4 samples)	5.7	0.036	0.0	0.009	0.006	0.028	0.89	36 (64)*	35	212 (303)*
Lochhead	3.8	0.013	0.05	0.003	0.002	0.019	2.37	12	16	96
Glendavan	4.0	0.024	0.46	0.008	0.004	0.023	4.42	210	26	828
Milton of Logie	3.4	0.023	2.01	0.017	0.007	0.029	5.81	17	33	171
Loch Kinord (mean of 4 samples)	5.8	0.033	0.03	0.000	0.006	0.024	1.32	12	17	81
Vat	1.3	0.035	0.03	0.003	0.003	0.014	4.15	8	11	59

All results expressed in mg l^{-1} (except conductivity — µSiemens cm^{-1} — and pH)
TOC = Total organic carbon TON = Total oxidized nitrogen Alk = Alkalinity (as mg $CaCO_3$ l^{-1}) Cond = Conductivity
*One high value removed from the mean — cf text
Names of feeder streams in italics

nutrient-enriched relative to the oligotrophic water of the main river and its upper tributaries (Table 2).

3.4 The Loch of Skene

Since 1970, and perhaps even earlier, the Loch of Skene (surface area 1.2 km^2; mean depth 1.43 m) has exhibited a summer phytoplankton bloom of nuisance proportions; the dominant organism of the bloom has latterly been a cyanobacterium, *Aphanizomenon flos-aquae*. In a bid to understand this system, River Board staff surveyed the loch from April 1978 to October 1979 (Owen 1983), and the situation observed then remains essentially unchanged today. Figure 3 presents a general summary of the variation of the loch chemistry with time.

Chlorophyll 'a' exhibited a pronounced maximum between June and September in each year, with associated smaller increases in spring and autumn. Microscopic examination of the phytoplankton indicated a succession; the smaller chlorophyll peaks were associated with the presence of a diatom population, with *Stephanodiscus* spp. dominating, whilst the major chlorophyll peaks were associated with *Aphanizomenon*. The latter became so prolific that its small filaments bound loosely together in bundles which eventually coalesced into substantial rafts.

Soluble reactive silicate concentrations reflected the periods of diatom ascendancy; for example, low mean values (160 µg l^{-1}) were recorded in May in both years. During the summer, *Aphanizomenon* dominated and, as the diatom population declined, the silicate concentration increased rapidly to values between 5000 and 6000 µg l^{-1}, before decreasing again in the autumn.

This loch had moderately soft water with an overall annual mean calcium concentration of 19.7 mg l^{-1} (range 17.4-23.9). The buffering capacity of the loch was thus not particularly great.

Soluble orthophosphate and total oxidized nitrogen showed interesting differences in the timing of their highest and lowest concentrations, relative to phytoplankton periodicity. Orthophosphate certainly declined slightly during periods of diatom growth, for example from a winter concentration of 33 µg l^{-1} to a spring value of 7 µg l^{-1}. However, dramatic and sustained increases in orthophosphate occurred during the peak *Aphanizomenon* growth periods, reaching as much as 255 µg l^{-1} before declining rapidly as the autumn diatom blooms occurred.

Total oxidized nitrogen (TON) behaved in a completely different manner. Periods of peak phytoplankton production coincided with low TON, and *vice versa*. Low values of 50-100 µg l^{-1} occurred frequently during the summer *Aphanizomenon* growth peaks, in contrast to recorded winter maxima in excess of 3000 µg l^{-1}.

Each decline in chlorophyll 'a' was followed by an increase in ammonium nitrogen concentrations. In each year, these concentrations were highest after the decline of *Aphanizomenon* growth peaks, reaching mean concentrations as high as 481 µg l^{-1}.

Generally, each peak of chlorophyll 'a' coincided with a rise in pH. These elevated values, between pH 9.5 and 10.0, persisted for many weeks in summer, and values as high as pH 11.0 were recorded.

During the study, an attempt was made to assess the nutrient inputs to the loch. Some of these inputs arose from the small sewage treatment works serving the villages of Dunecht (population 104) and Kirkton of Skene (population 242), which discharge to the *Kinnernie* and *Kirktonbridge* draining into the loch. Owen (1983) concluded that these 2 sewage works contributed 12% orthophosphate, 47% total inorganic nitrogen and 10.9% BOD to the total annual inputs to the loch, and considered these of minor importance relative to the whole loch catchment. The sum of the many small domestic and farm effluent discharges and, perhaps, the agricultural use of fertilizers in the catchment, was more important than the sewage works in contributing nutrients to the Loch of Skene.

The Loch of Skene is thus the largest body of eutrophic water in the whole of the Dee catchment, and has a wide annual fluctuation in chemistry and

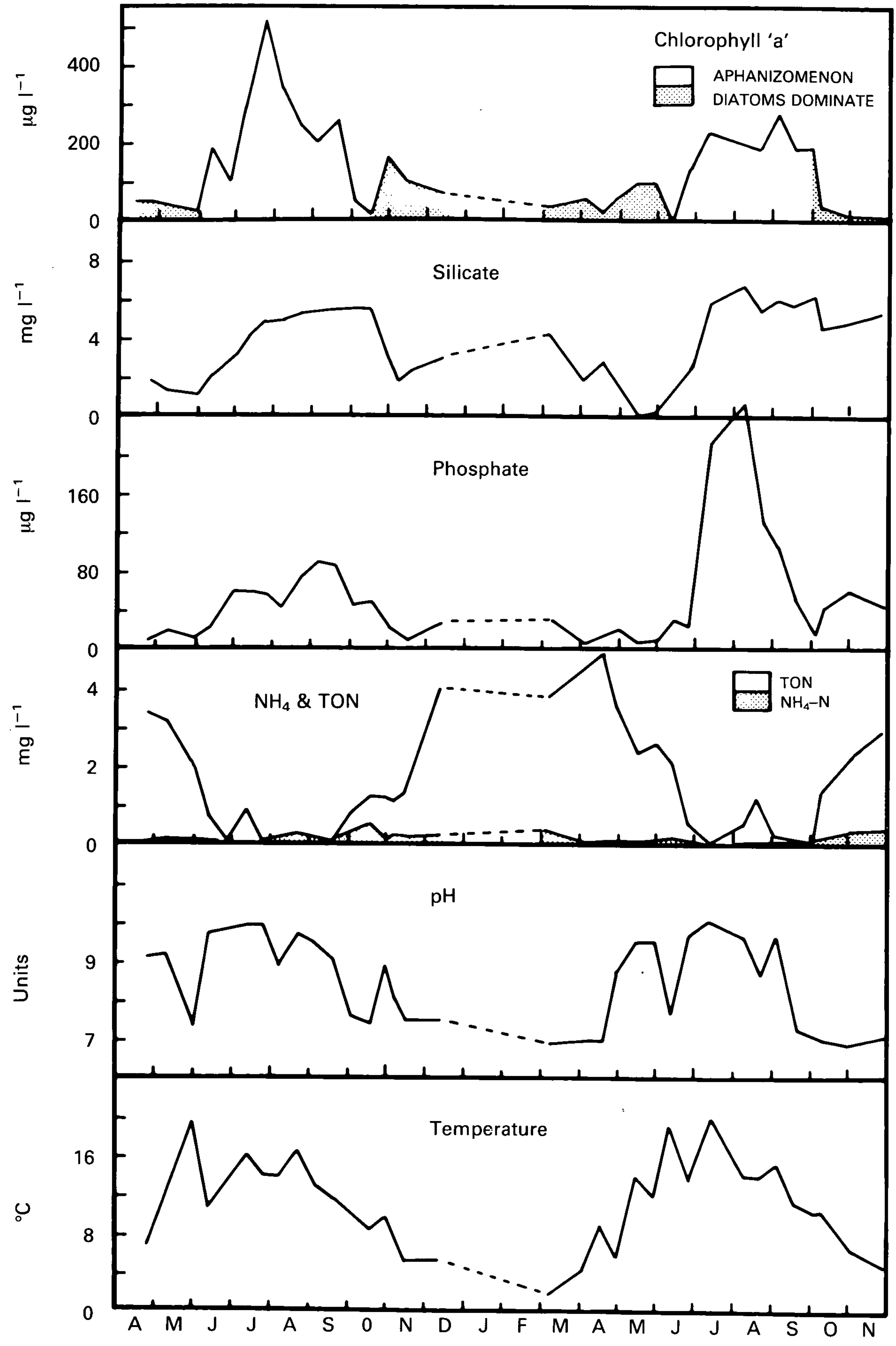


Figure 3. Water chemistry in the Loch of Skene

biology. It finally discharges via the *Leuchar* (Table 2), which similarly had the most fluctuating chemical quality of all the monitored watercourses. Happily, as reported above, the quality of the loch water, even at its worst, improved during its passage along the *Leuchar* and *Culter* so that the loch had no notable influence on the quality of the Dee itself.

4 Base and trace metals in the catchment

Starting in May 1984, surveys of the metal status of river water at selected sites in the Dee catchment have been made every 3 months. Whilst it is too early to comment on the seasonal variation of the data, Table 4 gives an indication of the order of magnitude of the concentrations found in the 2 surveys done so far. To aid assessment, the water quality standards (maximum allowable concentration (MAC) or guideline (GL) concentration) set by the EEC Directive (80/778) for direct abstraction for potable supplies are also reported. Clearly, the results confirm the chemically depleted nature of the main watercourse and the *Muick*, and parallel the nutrient enrichment (by weathering, natural eutrophication and pollution) of the tributaries in the lower part of the catchment. The Milltimber site on the Dee is one of 7 in the north-east of Scotland routinely sampled under the auspices of the Department of the Environment Harmonised Monitoring Scheme. These sites are at the most accessible, lowest, non-tidally influenced point on the major rivers, and serve as a summation of their water quality. Table 5 compares the rivers of the area and illustrates the meagre composition of the water of the Dee catchment with respect to the metal elements. Only the data for the Spey are comparable.

5 Surveys of headwaters

The growing concern about the 'acid rain' phenomenon prompted a long-term monthly baseline monitoring exercise in order to assess changes with time in water quality (several anions and cations apart from hydrogen are of interest) in those streams most likely to be at risk. Accepting that there are several processes by which streamwater might become acidified, apart from wet and dry deposition from the atmosphere, it was reasoned that acidification would be most pronounced in those poorly buffered waters draining the thin soils on the acidic granite of the Cairngorm range. Accordingly, 82 sites in the Spey and the Dee catchments were sampled chemically and biologically (invertebrate analysis) in August 1983. Nearly all the sites were in small headwater catchments and most were above the treeline in order that the effects of afforestation could be eliminated from the assessment. A minimum number of contrasting sites was included.

Table 4. Base and trace metals in waters in the Dee catchment (means of 2 surveys in 1984)

Sampling site	Ca	Mg (mg l^{-1})	Na	K	Cu	Zn	Mn	Fe ($\mu g\ l^{-1}$)	Al	Cd	Pb
Dee — Woodend	2.33	0.63	2.83	0.56	3.16	3.62	16.7	43	85.0	trace	0.73
— Milltimber	4.42	1.14	4.22	0.65	0.84	1.89	13.0	89	86.7	trace	0.22
— Aberdeen	4.90	1.32	4.91	0.72	0.92	2.12	19.4	125	114	trace	1.23
Muick — Bridgend	2.27	0.92	2.78	0.45	1.35	2.85	10.2	139	114	trace	0.62
Dinnet — Mill of Dinnet	9.23	2.50	15.6	1.00	1.98	1.39	122	722	68.2	trace	0.45
Brodiach — Mill of Brotherfield	27.5	6.96	23.0	4.10	6.86	5.40	154	725	140	0.152	0.79
Culter — Kennerty Mills	20.4	5.83	19.6	3.28	4.42	3.47	65	450	111	trace	0.67
Crynoch — Millton Bridge	21.9	5.75	16.5	3.63	3.60	3.97	135	513	178	trace	0.72
Drinking water†	100*	50	150	12	100*	100*	50	200	200	5	50

†Maximum allowable concentrations (except * = Guideline concentrations) in water for direct abstraction for potable supplies (as defined by EEC Directive 80/778)

Table 5. Base and trace metals in the rivers of north-east Scotland (means of 2 surveys in 1984)

	Lossie Arthur's Bridge	Spey Fochabers	Deveron Bridge of Alvah	Ugie Inverugie	Ythan Ellon	Don Grandholm Bridge	Dee Milltimber
mg l^{-1}							
Ca	27.6	3.5	16.0	15.7	17.7	18.0	4.4
Mg	3.3	1.9	5.3	5.9	6.6	5.1	1.1
Na	15.3	7.2	13.5	20.7	17.0	14.2	4.2
K	2.6	0.9	1.8	2.6	2.5	2.1	0.7
$\mu g\ l^{-1}$							
Cu	6.7	1.2	5.7	7.9	2.7	3.0	0.8
Zn	2.3	1.2	3.2	5.9	3.7	6.0	1.9
Mn	47	22	26	93	52	52	13
Fe	296	146	158	691	311	208	89
Al	74	41	61	215	90	154	87
Cd	0.07	trace	0.07	0.09	trace	0.12	trace
Pb	0.15	trace	0.54	0.62	0.30	1.52	0.22

Alkalinity provides an indication of the ability of a river water to buffer changes in acidity. The accumulated survey data were grouped on the basis of alkalinity and very tentatively described as shown in Table 6. Of the 15 sites in the 'At Risk?' category, 11 were in the upper Dee catchment. Only one site, the Dubh Loch above Loch Muick, exhibited a value (pH 5.4) below pH 5.6, the value returned when carbon dioxide is in free exchange equilibrium with de-ionized water, and below which acidification is assumed. Only one other site exhibited a value less than pH 6.0.

Table 6. Classification of results of a survey of headwaters in the Cairngorms in August 1983

	Alkalinity	Number of sites	(%)
'At Risk?'	< 10 mg l^{-1}	15	(18)
'Medium Risk'	11-29	45	(55)
'No Risk'	> 30	22	(27)
	Total	82	(100)

89 = Loch Muick Outlet and Site 92 = *Glas Allt*, a feeder stream to Loch Muick) returned the lowest pH values, which were only marginally above the cut-off value of pH 5.6. Clearly, these sites need close scrutiny and the processes of their acidification (if, indeed, such a trend emerges) could form an interesting research project. Whilst the results for the remaining sites gave no cause for alarm, their chemistry and biology will continue to be monitored. The biological (invertebrate) assessments revealed depleted faunas, but these have been ascribed to the extreme oligotrophy rather than to the effects of acid rain (M Davidson, pers. comm.). This conclusion is supported by the fact that several of the sites are below loch outlets, and are thus buffered from the effects of acid rain.

6 Summary

Scotland's fourth largest river catchment, the Dee, is, for the most part, in pristine condition. In 1980-84, the main river and the upper tributaries (*Clunie, Muick, Gairn, Dye* and *Feugh*) exhibited a high degree of oligotrophy. Some of the tributaries of the middle and lower reaches (*Dinnet, Leuchar, Ardoe* and *Crynoch*) experienced nutrient enrichment by fertilizer runoff and/or effluent discharged from scattered septic tanks and a few small sewage works serving the local communities. However, the latter tributaries were so

Table 7. Sites in the Dee catchment investigated in the 'Headwaters survey programme'

Site number	Grid reference	Stream name	Alkalinity* (mg l^{-1})	Altitude (m)	Area (km^2)
89	NO 300 842	Loch Muick outlet	4	400	38
92	NO 276 825	*Glas Allt*	5	400	6
79	NO 118 912	*Quoich*	6	340	60
101	NO 069 898	*Lui*	8	350	61
102	NO 155 883	*Callater*	14	370	36
97	NO 525 904	*Feugh*	16	240	21
103	NO 159 932	*Slugain*	17	340	18
93	NO 387 975	*Tullich*	33	210	19
91	NO 309 852	*Allt Darrarie*	35	410	15
80	NO 134 833	*Baddoch*	38	410	23

*Alkalinities determined during the August 1983 survey

Samples are now drawn monthly from 3 or 4 'At Risk?', 3 or 4 'Medium Risk' and 3 'No Risk' sites in each of the Dee (Table 7) and Spey catchments. Table 8 contains the mean results obtained since May 1984 for some of the more important ions for the sites in the Dee catchment. Again, the data confirm the meagre chemistry and poorly buffered nature of the upper catchment. The sites in the *Muick* sub-catchment (Site

Table 8. Quality of river water in the headwaters of the Dee catchment (mean values from monthly surveys May-September 1984)

		'At Risk?' sites				'Medium Risk' sites			'No Risk' sites		
Site number*		89	92	79	101	102	97	103	93	91	80
Alk	mg l^{-1}	3	3	6	7	16	12	13	27	24	31
pH		5.71	5.75	6.49	6.60	7.03	6.75	6.97	7.19	7.10	7.28
SO_4	mg l^{-1}	3.5	3.0	2.8	2.8	3.4	5.3	3.6	4.4	2.9	4.5
Na	mg l^{-1}	2.1	2.3	2.7	2.4	2.0	4.7	3.5	5.5	4.0	2.6
K	mg l^{-1}	0.3	0.2	0.3	0.3	0.5	0.5	0.4	0.6	0.8	0.9
Ca	mg l^{-1}	1.2	0.7	1.5	1.8	4.8	3.1	2.8	5.7	4.3	10.7
Mg	mg l^{-1}	0.5	0.4	0.4	0.4	1.0	0.8	0.9	3.0	2.4	2.3
Al	µg l^{-1}	96.7	64.6	55.2	64.0	33.4	63.9	33.4	131.0	48.9	27.2
Zn	µg l^{-1}	4.9	1.1	1.1	1.0	3.0	2.3	1.3	4.3	1.3	0.9
Mn	µg l^{-1}	21.1	3.5	1.0	2.3	6.6	30.6	1.9	64.6	14.9	2.9
Fe	µg l^{-1}	64.7	5.0	10.1	25.0	69.3	138.4	20.1	304.8	127.9	35.1

*See Table 7 for site definition

small relative to the main watercourse of the catchment that they exerted a negligible effect on the quality of water in the Dee. Relative to the rest of the north-east of Scotland, pollution in the catchment was minimal and only the newly developing Westhill Industrial Estate (immediately to the west of Aberdeen) depleted water quality, but then in a minor stream where its effects were quickly attenuated.

In parallel with the oligotrophy, the waters of the catchment were poorly buffered and exhibited low concentrations of base and trace metals, reflecting the predominantly acidic, granitic geology of the area. The headwaters, particularly in the *Muick* catchment, *may* have been subject to acidification and at risk in the context of acid rain (but this hypothesis was not proven and requires continued monitoring).

Of the major pieces of standing water (Loch Muick forms 80% of the standing water in Grampian Region), only the Loch of Skene was eutrophic, with a consequent annual proliferation of diatoms (*Stephanodiscus* spp.) and then a blue-green alga (*Aphanizomenon* spp.), the latter to massive proportions. Again, the *Leuchar* which drained the loch was relatively small, and dilution by the *Brodiach* and self-purification during its passage along the *Culter* ensured negligible effects in the main watercourse. As already implied, the Dubh Loch and Loch Muick were the most acidic bodies of water. Lochs Kinord and Davan were virtually oligotrophic, and at worst should be considered only slightly mesotrophic.

The size and chemical nature of the Dee set it apart from many other rivers, and suggest that care be exerted in its management to maintain its status and to preserve a fine example of a river which is oligotrophic from source to mouth.

7 Acknowledgements

The author gratefully acknowledges the work of his colleagues and staff in the generation of the data reported in this paper, and thanks the River Inspector and the North East River Purification Board for permission to publish it.

The conclusions and views expressed are those of the author and not necessarily those of the Board.

8 References

Bolton, P. W., Currie, J. C., Tervet, D. J. & Welsh, W. T. 1978. An index to improve water quality classification. *Wat. Pollut. Control,* **77,** 271-284.

Davidson, M. B., Owen, R. P. & Young, M. R. 1985. Invertebrates of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 64-82. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Marren, P. 1979. *Muir of Dinnet. Portrait of a National Nature Reserve.* Aberdeen: Nature Conservancy Council.

Owen, R. P. 1983. *Causes and effects of nuisance populations of phytoplankton in the Loch of Skene, Aberdeenshire.* Aberdeen: North East River Purification Board.

Reid, J. M., MacLeod, D. A. & Cresser, M. S. 1981. Factors affecting the chemistry of precipitation and river water in an upland catchment. *J. Hydrol. (Amst.),* **50,** 129-145.

Scottish Development Department. 1976. *Development of a water quality index.* (Report ARD 3.) Edinburgh: Scottish Development Department, Engineering Division.

Standing Committee of Analysts. (Various dates.) *Methods for the examination of waters and associated materials.* London: HMSO.

Warren, J. S. 1985. Hydrology of the River Dee and its tributaries. In: *The biology and management of the River Dee,* edited by D. Jenkins, 23-28. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Vegetation of the River Dee

N T H HOLMES
Nature Conservancy Council, Peterborough

1 Introduction
Between 1978 and 1982, the Nature Conservancy Council (NCC) commissioned surveys of British rivers to provide not only the basis for a classification of plant communities in Britain (Holmes 1983), but also a detailed picture of the communities of individual rivers. This paper presents the data from the River Dee and assesses them in relation to 1041 other rivers surveyed throughout Scotland, Wales and England.

Although lakes, rivers and streams represent less than 1% of the land surface of Britain, they are the most ubiquitous of our remaining natural, or semi-natural, habitats. Unlike many terrestrial habitats which are totally destroyed by man's activities, rivers tend to be modified rather than destroyed. Such modifications often change the character of the vegetation found within a river, and pollution, drainage, river regulation, water abstraction, hydro-electric schemes and recreational activities are often the causes of such changes.

The 2 factors which have greatest influence on the communities of plants in rivers are current velocity and geology. These 2 factors interact to provide a wealth of variety both in terms of the substrates they create on the bed of rivers for plants to root in, and of the chemistry of the water in which the plants are bathed and supported. Details of the relationships of plants in rivers to the physical and chemical environments in which they occur are to be found in Butcher (1933), Haslam (1978), Westlake (1973), and Whitton (1972). However, it is the current of rivers which separates them from other open water habitats such as lakes and ponds. Currents within a river may vary dramatically in velocity from site to site, and from time to time, yet they constantly flow in a unidirectional manner. This constancy of direction assures a steady supply of nutrients and particulate matter down a river over a variety of physical features.

Wildlife habitats are frequently classified into types according to the plants found within them. Rivers are no exception (Butcher 1933; Haslam 1978; Haslam & Wolseley 1982; Holmes 1983), but they are notoriously difficult to classify because they frequently change dramatically from source to mouth. The floral assemblages of upland sections often have little in common with those in the lower reaches. In general, the higher the altitude at which rivers rise, and the longer their length, the greater the plant variety. Even greater variety occurs if rivers traverse different geological strata. Because harder rocks are generally found at higher altitudes than soft rocks, and because the latter yield nutrients more readily, the trophic status of rivers generally increases on passing downstream.

The *Nature Conservation Review* (Ratcliffe 1977) describes over 700 key nature conservation sites in Britain, and 20 sites are included because running water represents a key interest therein. The Dee is one of the 20 and is described as 'the finest example of a large oligotrophic river in Britain'.

The Dee is one of 4 large rivers described in the *Review*; the others are the Spey, Tweed and Wye. Compared with the Dee, all are described as considerably more nutrient- and base-rich and they rise at much lower altitudes. The Spey comes closest to the Dee in character, because it too flows over resistant rocks; these rocks are either deficient in nutrients or incapable of releasing them readily. However, the nutrient-poor water of the Spey as it flows through Loch Insh in the upper half of its catchment is richer than that of the Dee in its lowermost reaches.

2 Vegetation of the River Dee
The plant communities of the Dee received scant attention in the past. In the pioneering work on British rivers by Butcher (1933), vegetation surveys were not done in Scotland. In the late 1960s and early 1970s, the Dee was included as part of the national surveys designed to find and assess sites of nature conservation importance. This programme culminated in the production of the *Nature Conservation Review*, with the Dee included as a nationally important site. Since that time, Haslam (1982) has surveyed several hundred rivers and tributaries, yet the Dee escaped her attention, probably because it was included within the *Review*. The neighbouring Spey, Ythan and Don were, however, surveyed.

3 Method
The survey sites are 1 km lengths of river, each site being 5-10 km apart. Surveying is done only during low flows when water is clear and visibility good. For such surveys, it is imperative to wade into the river wherever it is shallow enough; this too can be achieved safely only during low flow periods. Plants in rivers are most obvious between May and September and surveys are confined to these periods. Algal samples are not taken but all species visible to the naked eye, and (theoretically) identifiable in the field, are recorded. The survey at each site includes the whole river and its immediate bank from one side to the other. The upper limit of the bank for inclusion within the survey was the estimated height of the river running at mean water level. Details of the methodology are given by Holmes (1983).

3.1 Survey of the River Dee

The vegetation survey of the Dee was done in September 1979 and 14 sites were investigated (Table 1). The main channel of the river had its plants recorded separately from those found at the edge of the water on the banks. Within each site, records were made from 2 consecutive 0.5 km lengths, and the abundance of each individual species was scored on a dominance-rarity scale of 1-5. This score relates the abundance of one species against all the others present within the section; it cannot be used for assessing the standing crop of individual species or the whole community. A second abundance score was also employed which indicates the actual percentage area covered by individual species.

During surveys of each 1 km length, records were made of the stability of the river, the substrate, depth, width and velocity characteristics of the channel, the slope and structural make-up of the banks, and the land use immediately adjacent to the river.

Table 1. Sites of 1 km length surveyed on River Dee for macrophytes in September 1979. The grid reference refers to the 'exact point in km length': ie 0.5 = middle of 1 km length, 0.0 = upstream limit of 1 km, 0.99 = lower limit of 1 km length

Site name		Grid reference
1 Whitebridge	0.5	NO 019 884
2 *Lui Water* confluence	0.5	NO 071 896
3 Elbow of river at Braemar	0.5	NO 013 915
4 Invercauld bridge	0.5	NO 185 910
5 Rinabaich, left bank tributary	0.5	NO 303 961
6 Ballater, right bank tributary	0.5	NO 366 949
7 Greystone, elbow in river	0.5	NO 430 964
8 Boghead, stream left bank	0.0	NO 471 689
9 Aboyne, B9094 bridge	0.5	NO 524 978
10 Potarch, B993 bridge	0.5	NO 607 973
11 Banchory, Silverbank	0.5	NO 713 960
12 Park House	0.5	NO 784 976
13 Peterculter, B979	0.99	NJ 858 003
14 Cults, derelict bridge	0.0	NJ 897 026

4 Results

Table 2 lists the species found in the 14 sites surveyed. The relative abundance of each species is indicated by the scale of 1-5. As few species were present in abundance, the actual abundance figures for individual species have been omitted but an indication of the total standing crop for the whole 1 km length is given at the bottom of the Table. The data for the 2

Table 2. Species recorded from 14 1 km sites on the River Dee. Numbers refer to the relative abundance on a scale 1-5, 1 being rarest and 5 being dominant. The Table simplifies data held by NCC on the relative abundance of the above species within the channel and on the immediate banksides

	Sites down the River Dee													
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Chamaesiphon spp.					2							3	1	1
Nostoc parmelioides							1			1	1	2		
Phormidium spp.		2	2	1	2	1	1							
Tolypothrix penicillata	4													
Lemanea fluviatilis	2	4	1	2	1	1		1	2	2	2	1	1	1
Rhodochorton violaceum					1	1	1	1					1	1
Vaucheria sessilis			1								1	1		1
Didymosphenia geminata	2					2								
Tetraspora spp.											1			
Prasiola crispa	1						1	1					1	
Stigeoclonium tenue												1	1	1
Filamentous green algae	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Collema spp.						1								
Dermatocarpon fluviatile							1	1		2	2	3		1
Verrucaria praetermissa				1			1	1	1	2	3	1	1	1
Other *Verrucaria* spp.			1	1	2	1	2	2	3	5	5	3	5	
Anthelia julacea	5	1												
Blasia pusilla	1	1	1											
Conocephalum conicum							1					1		
Cephalozia bicuspidata	1	1												
Chiloscyphus polyanthos						1	1	1	1	1	2	1	2	2
Hygrobiella laxifolia	1	1	1											
Marchantia polymorpha														1
Marsupella emarginata	3	2	1	2	1									
Nardia compressa	3	4	1	2										
Pellia endiviifolia										1		1	1	1
P. epiphylla	3	4	1	2	2	2	2	1	2					
Preissia quadrata		1												
Scapania gracilis		1												
S. undulata	4	5	1	4	1	1	2	1	1	1			1	1
Solenostoma cordifolium	3	4	1	2										
S. triste	3	4	1	2	1	1	1	1	1					

Table 2—continued

Species	Sites down the River Dee													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Anomobryum filiforme		1												
Amblystegium fluviatile						1	2	1	2	1	2	3	3	4
A. riparium											1			1
Atrichum tenellum					1		1							
Aulacomnium palustre								1						
Barbula recurvirostra										1				
Blindia acuta	1	3	1	2	2	4	1	1	1					
Brachythecium mildeanum				1										
B. plumosum	1	1			1	1								
Bryum alpinum	1	1	1		1									
B. argenteum		1												
B. pallens			1											
B. pseudotriquetrum	1	2	1	3	2	4	4	1	3	4	1	2	1	
Calliergon cuspidatum				1	1	1	3		3	3		3	1	
C. giganteum										1			1	1
Climacium dendroides												1		
Dichodontium pellucidum				1			1							
Dicranella palustris		1	1	2	1	1								
D. rufescens			1		1									
Drepanocladus revolvens			1	1	1	1								
Fissidens viridulus										1				
Fontinalis antipyretica	1	2	2	4	3	4	4	4	1	5	5	5	5	5
F. squamosa	1	1	1	4	3	4	2			3	4	2		1
Gymnostomum aeruginosum				1			1							
Hygrohypnum luridum							1							
H. ochraceum	1		1	2	1	4	2	1	1	4	4	5	1	
H. smithii						1								
Hyocomium armoricum	1	2	1	2	1	1								
Mnium hornum		1				1								
Oligotrichum hercynicum	1	1												
Philonotis fontana	1		1		1									
Plagiomnium rostratum							1					1		
Pogonatum nanum			1		1									
Polytrichum commune	1													
P. juniperinum														1
Racomitrium aciculare	2	3	2	5	5	5	4			2	1			
R. aquaticum							1							
Rhizomnium punctatum				1										
Rhynchostegium riparioides	1	1	1	2	2		5		1	2	2	2		1
Schistidium agassizii		1	1	4	2	4	1	1						
S. alpicola	1	2	2	3	3	3	4	2	1	4	5	2	1	1
Scorpidium scorpioides	1		1							1		1		
Sphagnum spp.	3	1			1									
Achillea ptarmica		1		2	2	1	2	1	3	2	2	2	2	2
Angelica sylvestris			1			1		1	1	1	1	1	1	
Callitriche hamulata			1	1	1							1	1	1
C. stagnalis			1									1	1	1
Caltha palustris		1		1	2	1	1	1	2	2	2	2	2	2
Equisetum arvense			1		1	1		1		1		1	1	1
E. fluviatile			1				1		1	1	1			1
Filipendula ulmaria			1	1	1	1	1	1		2	3		1	1
Galium boreale			1		2	2			1		1			
Littorella uniflora			1	1		1			1	1	1	3	1	
Lupinus nootkatensis				1	1	2	1		2	1				1
Mentha aquatica			1	1	1	2	1	3	3	2	1	2	2	2
Mimulus guttatus × luteus						1					1	1		
Myosotis scorpioides					1	1		2	2	2	2	2	2	2
Myriophyllum alterniflorum			5	2	2	2	1	2	2	5	1	4	2	
Petasites hybridus											1			
Polygonum amphibium													1	
Potentilla erecta	1	1	1											
Ranunculus aquatilis													1	
R. flammula	1	2	2	2	2	2	2	2	3	3	3	2	3	2
Ribes rubrum						1					1			
Rorippa sylvestris										1	3	3	1	2
Sagina procumbens			1				1		1					
Salix spp.	1	1	1	1	2	3	2	1	2	1	1		3	4

Table 2—continued

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Sites down the River Dee													
Stachys palustris													1	1
Stellaria alsine														1
Symphytum officinale														1
Tussilago farfara	1		2	2	2	4	1	2	1	1		1	1	1
Valeriana officinalis					1	1			1	1		1	1	1
Veronica beccabunga	1													
Viola tricolor						2	1	1	1	2				
Other tree genera	1	2	1	1	1	1	2	1	3	1	2	1		
Other dicotyledons	5	1	1	1	1	1	1	1	2	2	1	1		1
Agrostis stolonifera			1	1	1	1	2	2	2	4	2	3	5	3
Anthoxanthum odoratum	4	5	5	1	2	1	2							
Carex aquatilis													1	
C. binervis	1													
C. demissa	1	1	2	2	1	1	1	1	1	1				
C. echinata	1	1	1		1									
C. flacca	1			1			1							
C. hirta														1
C. lepidocarpa				1	1	1			1					
C. nigra	1	2	5	2	2	2	3	1		1	1			
C. ovalis			1			1	1							
C. panicea	1	2		1	1									
C. remota											1			
C. rostrata			3	3	2	2	1	1	1	1	1	2		
Deschampsia cespitosa	2	2	2	2	3	3	2		2	1	1	1	1	1
Eleocharis palustris			1				1			1	1	2	3	1
Glyceria fluitans		1	2	1		1	2	1	2	1	1	1	5	2
G. maxima												1	5	3
Iris pseudacorus						1								
Juncus acutiflorus	1	4	5	5	3	4	4	5	5	5	1	2	3	2
J. articulatus		1												
J. bufonius											1	1	1	1
J. bulbosus	1	1	4	1	1	1	1	1	1	1		1		
J. effusus			1	2	2	1	1		1	2			1	
J. squarrosus	1	1					1							
Molinia caerulea	2	2	4	4	2				2	1				
Nardus stricta	5	5	5	5	2		2	1	2	1				
Narthecium ossifragum	5	1												
Phalaris arundinacea									2	2	5	5	5	5
Potamogeton polygonifolius			1											
Scirpus fluitans			1			1								
Sparganium angustifolium			1											
S. erectum										1	1		1	1
Trichophorum cespitosum	2	2	1											
Other monocotyledons	2	2	1	1	1	1	1	4	2	3	1	3	1	1
River vegetation cover (%)	**8**	**2**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**
River algal cover (%)	**10**	**<1**	**1**	**5**	**3**	**1**	**3**	**5**	**5**	**<1**	**1**	**1**	**1**	**3**
Bankside cover (%)	**15**	**3**	**12**	**5**	**5**	**1**	**5**	**1**	**3**	**10**	**4**	**5**	**20**	**7**

0.5 km lengths within each site have been amalgamated, as have the records for the riverside species and those on the bank.

The diversity of plants within the different stretches is shown in Figure 1. Each diagram shows the number of species recorded and the proportion of the total species assemblage represented by large algae and lichens, mosses and liverworts, vascular cryptogams, dicotyledons and monocotyledons. Figures 2 and 3 show substrate, flow characteristics and the slope of the river at individual sites.

4.1 Details of the aquatic flora

4.1.1 Flora of river above Whitebridge

By Whitebridge, the Dee has already tumbled its way along 20 km of a precipitous and steep-sided course, which rises high in the Cairngorms at over 1200 m above OD. The flora is sparse, either wiped clean by erosive floods in spring and summer or frozen and gouged by ice pushed down the river in winter. On rocks within the channel which are afforded protection by larger boulders upstream from them, small patches of the delicate liverworts *Hygrobiella laxifolia, Cephalozia bicuspidata* and *Anthelia julacea* are found.

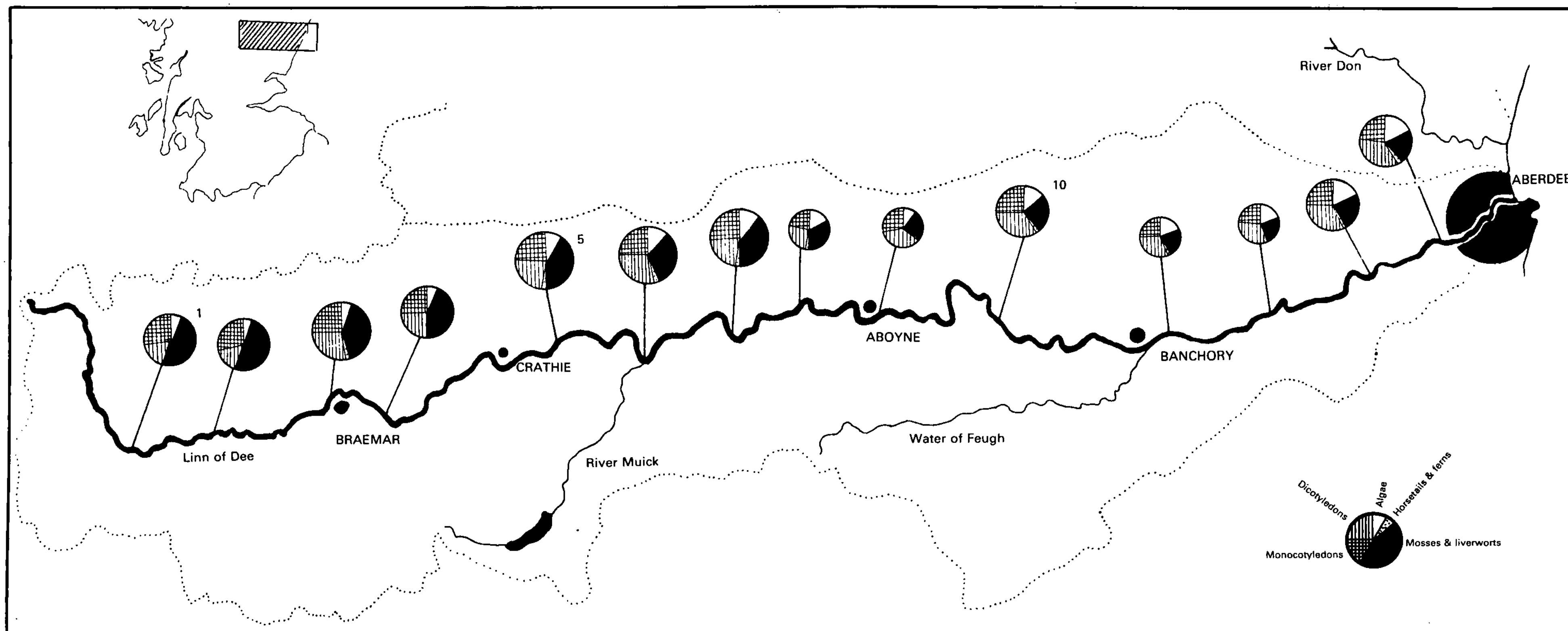


Figure 1. Plant community structure in the 14 1km stretches of the River Dee. The larger the pie, the more species

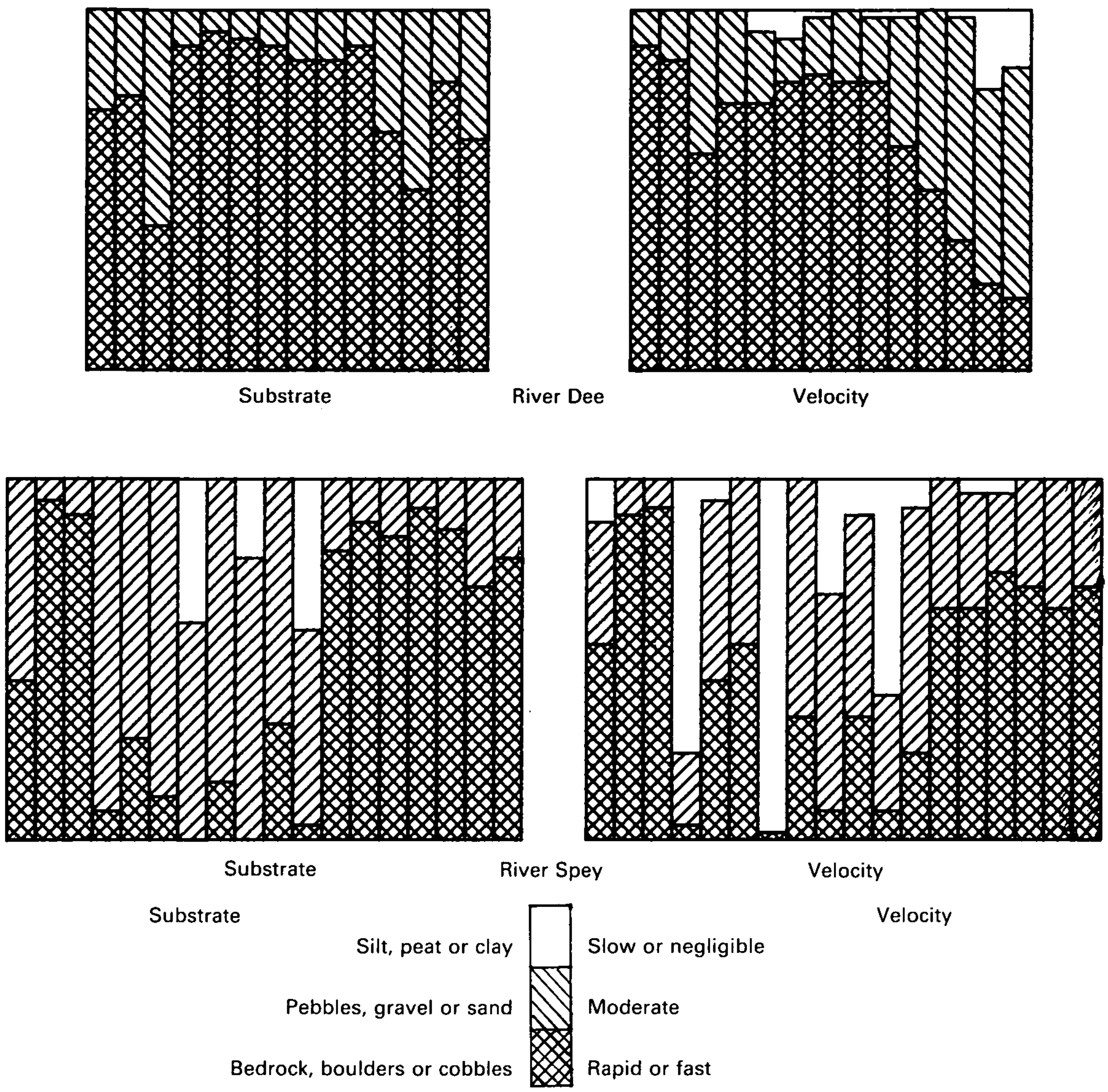


Figure 2. Substrate and velocity characteristics of 14 1 km sites of the River Dee compared to 18 sites surveyed on the River Spey. Each column shows the proportion of each category as a percentage of the whole;

Amongst these may also be found the stunted, wiry growths of the moss *Blindia acuta*. Where pebbles and cobbles are not cemented between large boulders or sheet rock, they are rolled over by the force of the water and are uncolonized by perennial species.

The largest rocks are occasionally colonized by larger liverworts and mosses, *Nardia compressa* being the most conspicuous as it occurs on permanently, as well as occasionally, submerged rock surfaces. The intermittently submerged parts of rocks are colonized by *Scapania* and *Marsupella* species, as well as by the mosses *Racomitrium aciculare* and *R. aquaticum*. The drier surfaces of large boulders within the channel are also colonized by a variety of lichens, liverworts and mosses. *Barbula* species and *Andreaea rothii* are conspicuous.

During the warmer summer months when the water runs clear, a number of algae take advantage of the bare rock surfaces underwater. Early in the year, when the temperature of the water is barely above freezing, thin silvery-brown slimy films cover stones; these are usually chrysophytes mixed with an assortment of small diatoms. As the temperature increases, filamentous green algae replace them. The green algae rarely have sufficient nutrients or time to produce large standing crops. Two algae, in particular,

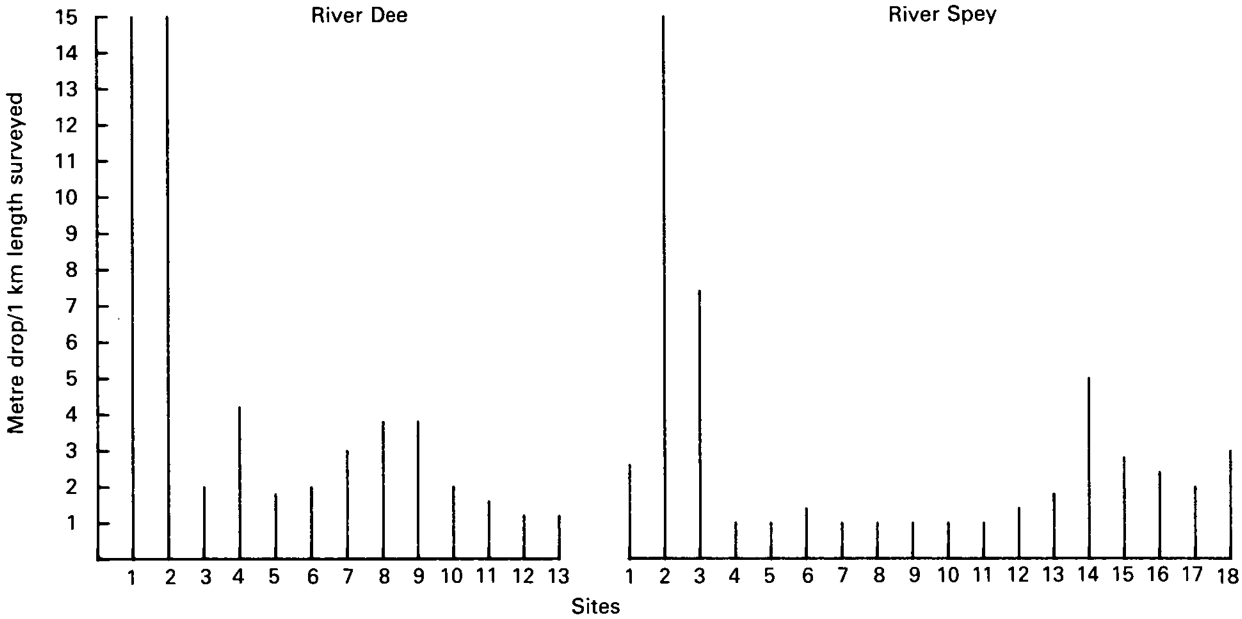


Figure 3. Slope characteristics of the River Dee compared to the River Spey in sites surveyed for plants

are worthy of note. *Tolypothrix* is a drab blackish-brown cyanophyte (a blue-green alga). It grows in small, interwoven, wool-like colonies on rock surfaces exposed to the force of the current. It has special cells within its filaments called heterocysts which can 'fix' nitrogen. These plants are ideally suited for life in the extreme upper reaches of streams above the line of cultivation or afforestation. *Haematococcus* is a unicellular green alga with a bright red pigment which overshadows its chlorophyll. It grows only in the small water-filled depressions in sheet rocks and boulders which are temporary rock pools above the high water mark of the river. These pools turn bright red as they warm rapidly in the long summer days and their temperatures reach levels 3 times higher than that of the river.

Marginal vegetation in the upper reaches of the Dee is usually sparse as the edges are often strewn with boulders and disturbed by the rapid rises and falls in level. Where large boulders occur, bryophytes are sparse, but where gravels and sand are trapped between these boulders a mixture of bryophytes and higher plants can survive. The richest plant communities occur where the edge of the river laps against heathland with boulders embedded in the thin soils. The rocks are often covered by the liverworts and mosses listed for Site 1 in Table 1. Species such as *Bryum pseudotriquetrum, Philonotis fontana, Brachythecium rivulare* and *Polytrichum commune* also grow on the occasional sandy gravels which are mixed with the peat and the soil at the edge.

The higher plants which dominate the river's edge are predominantly those which inhabit the surrounding land. *Nardus, Anthoxanthum, Erica, Calluna* and *Trichophorum* are common, whilst *Viola palustris, Potentilla palustris, Pinguicula vulgaris* and *Narthecium ossifragum* are commonest at the riverside.

The small tributaries and flushes which enter the main river in the upper 20 km show a full range of characteristics, which span from precipitous drops of 600 m in less than 1.5 km to small flushes draining the narrow strip of boggy heathland on the valley floor. The former are either completely devoid of vegetation or only sparsely colonized by bryophytes previously mentioned, or occasionally by *Racomitrium lanuginosum* and rare species such as *Hygrohypnum molle, Andreaea nivalis* and *Marsupella condensata*. The latter have richer floras which contrast with that of the main river because of the lack of erosive floods. Apart from *Sphagna*, the flushes are often dominated by higher plants which can tolerate acidic or dystrophic conditions. *Potamogeton polygonifolius* is the only truly aquatic plant to thrive, but *Potentilla erecta, Juncus bulbosus, Drosera rotundifolia, Carex nigra, C. rostrata, Eriophorum angustifolium* and *Ranunculus flammula* may be found invading from the edges.

4.1.2 Whitebridge to Lui water confluence; sites 1 and 2

Between Whitebridge and *Lui*, the Dee flows through a narrow U-shaped glacial valley and begins its characteristic, shifting, meandering course (Figures 2 & 3). Because sheets of bedrock are common, the river has some stability. Elsewhere, boulders, cobbles and pebbles are strewn across the valley amongst gravel and coarse sand. The steep slope of the river results in high current velocities in association with large rock substrates. The valley is a mixture of grassy moorland, heathland and coniferous forests, and this affects the flora of the river.

Where the bed of the river is not continually overturned by floods, a productive bryophyte community thrives, with *Marsupella, Nardia, Scapania* and *Solenostoma* common (Table 2). On smaller boulders, *Anthelia* and *Blindia* dominate, but these are frequently covered in algal growths during the summer. Where the river shifts its course, piling great heaps of boulders and gravels where it flowed only the day previously, transient filamentous green algal and slimy diatom growths are the only taxa to survive. These differences are illustrated in the different cover values for sites 1 and 2, the former having a much more constrained, and therefore more stable, channel and a more productive, stable, perennial flora.

The flora of the banks also reflects the stability of the river and whether it is contained within a permanent channel. Where constant changes in course occur, the flora is very sparse and only a few quick-growing, long-rooted, annuals are present. In more stable areas, where gravel and rocks combine, a rich bryophyte and angiosperm assemblage develops. The bryophytes occur on the rock surfaces, on the peat-stained sandy gravels between the rocks, and on the steep, heavy soil banks themselves. The rocks are preferentially colonized by the same species as occur within the river, but on the gravels *Brachythecium rivulare, Philonotis fontana, Bryum pseudotriquetrum, Bryum alpinum, Anomobryum filiforme, Dichodontium pellucidum* and *Oligotrichum hercynicum* are present. On the earth banks and where peat is exposed, the mosses *Campylopus flexuosus, Polytrichum* species and *Dicranella heteromalla* occur alongside liverworts such as *Pellia epiphylla, Preissia quadrata* and *Blasia pusilla*. The last mentioned is perfectly adapted to these nutrient-poor habitats because it harbours its own colonies of the cyanophyte *Nostoc* which can fix atmospheric nitrogen.

The flowering plants on the banks of the river are predominantly those which also occur in the habitats adjacent to the river. The most typical are summarized in Table 2. In addition to those listed are heathland species such as *Erica tetralix* and *Calluna vulgaris*, trees such as *Betula pendula* and alpine *Salix* species, together with *Pinguicula vulgaris* on moss cushions and *Pedicularis palustris* on margins with a permanently retained high water level due to boulders impeding flow downstream. Although *Nardus stricta* is dominant, a wide variety of sedges is present and several occur preferentially at the river's edge.

4.1.3 Inverey to Dinnet; sites 3-7

Between Inverey and Dinnet, the Dee drops from 350 m to 150 m above OD, making an average descent of under 3 m km^{-1}. This descent is remarkably gradual and even (Figure 3), but within the section some stretches fall less than 1 m km^{-1}. Another feature of this long stretch of the Dee is that it flows within a narrow glacial valley with steep sides rising from the valley floor for about 50 km. Around Braemar, the river meanders extravagantly along the widest part of the valley floor which approaches 1 km wide. However, 10 km downstream, it is confined to a permanent channel by steep wooded slopes which rise directly from the river banks.

Land use within this section of the Dee is predominantly rough grassland, but scrub and arable cultivation are interspersed among the grasslands. Almost without exception, the lower slopes of the hills which rise from the valley floor are covered with trees. In places, these trees are purely deciduous, in others they are mixed assemblages, and in others they are pure conifer plantations. In this section, the adjacent habitats begin to have less effect on the flora of the river.

Figure 2 shows that the river bed is composed of coarse substrates and that velocity is rapid or fast. Only occasionally are there sluggish sections where water is impounded by natural rock obstacles. The excessive meandering over the wide valley floor near Braemar manifests itself in the substrate features; site 3 has fewer boulders and large rocks than any other section of the river, and instead is dominated by pebbles and gravels.

The flora of the river in this section maintains many of the alpine features prevalent upstream. Many of the mosses and liverworts are still present, but these gradually become less important on passing downstream (Figure 1). Filamentous algae still dominate the unstable substrates because they can begin growth after the worst of the winter and spring floods. Perennial bryophytes are very sparse. Although in localized and sheltered stretches they may cover up to 20% of the rock surfaces, in general the mean cover of perennial plants for the whole section is only around 2%.

As the common liverworts of sites 1 and 2 disappear, their place downstream in the river is generally taken by mosses. *Blindia acuta* still grows in flattened, wiry cushions on stones in torrents, but it is now associated with other mosses instead of liverworts. Both *Fontinalis squamosa* and *F. antipyretica* are widely distributed, but the former shows a distinct preference for torrential currents and deep water. The latter tends to grow in totally submerged habitats as well as in those subject to periodic submergence. In this respect, it shares the alternately wet and dry rock surfaces with *Rhynchostegium riparioides, Hygrohypnum ochraceum, Racomitrium aciculare, Schistidium alpicola* and *S. agassizii*. The last mentioned is a common species of Scandinavian meltwater rivers (Nyholm 1956), but until 1967 had not been recorded from Britain (Birks & Birks 1967). At that time, it was known only from waterlogged hollows on Ben Lawers. In 1975, however, it was found to be common in torrent stretches of the River Tees (Holmes 1976) in Upper Teesdale. Since that time, the author has found it in over 10 large rivers in the highlands of England, Wales and Scotland.

Truly aquatic plants are rare in the river, *Callitriche hamulata* and *Myriophyllum alterniflorum* being the only widespread species. Both occur only where gravels are compacted between large stones and where the bed of the river does not constantly move in response to floods. At Braemar, they are the dominant river plants but they still fail to cover more than 1% of the river. In isolated sheltered stretches of the river, other submerged aquatic flowering plants occur also. These include *Littorella uniflora, Scirpus fluitans, Juncus bulbosus* and *Callitriche stagnalis*. All but the first mentioned prefer peat interspersed amongst the substrate, as well as slack water velocity. They are thus characteristic of backwaters where the channel has changed course and where gravel and cobble spits protect small pockets of standing water retained in the old channel.

The bank flora in this stretch of the Dee is much more distinct from that of the adjacent land than it was in the upper reaches. Shingle and rocks constitute 75% of the banks, whilst earth accounts for 15% and coarse sands account for the remaining 10%. Where rocks predominate, it is the bryophytes which dominate the flora, but where finer deposits are cemented between larger rocks flowering plants prevail. In these stable areas, perennials such as *Juncus acutiflorus, Carex nigra* and *C. rostrata* are common. These upright stands create bank stability and retain organic matter to create mini-niches suitable for such plants as *Caltha palustris, Galium boreale* and *Ranunculus flammula*. Whilst these species rarely occur except where the water laps at their roots, another contrasting community exists on the fast-draining shingles dominated by cobbles and pebbles. Only annuals or tenaciously rooted plants can survive in such environments because they are as frequently destroyed as they are created. Three species are characteristic of the area: *Viola tricolor, Tussilago farfara, Lupinus nootkatensis*. The latter is a rare naturalized plant which thrives on the shingles of a few Scottish rivers.

4.1.4 Dinnet to Banchory; sites 8-10

From Dinnet to about 10 km upstream of Banchory, the Dee continues to meander across a gravel, flat-bottomed, U-shaped river valley. Above Banchory, the river becomes confined to a much narrower valley with wooded slopes rising directly from the banks. The slope of the river channel increases marginally, but substrate and water velocity characteristics remain similar to upstream (Figures 2 & 3). This section of the river also sees an intensification of agricultural use in the valley floor and a decrease in conifer afforestation on its slopes.

Because of the gradual downstream changes in physical characteristics and in land use, the flora of the river also changes slightly. Gone are the species characteristic of the upper 2 sites, and those that characterized the reaches between Braemar and Dinnet are also less frequent. Although filamentous green algae still dominate the river in summer, encrusting and foliose lichens are also present. Above the permanent water mark, *Dermatocarpon fluviatile* is seen, whilst several species of encrusting *Verrucaria* occur permanently submerged.

This section of the river is not noteworthy for the abundance of any particular species, but is a transition area where the alpine elements are all but replaced by those characteristic of lowlands. *Juncus acutiflorus* remains dominant on the banks, but, instead of being associated with *Anthoxanthum, Nardus* and *Molinia*, it gradually becomes associated with *Phalaris arundinacea* and *Agrostis stolonifera*. Similarly, *Fontinalis* is the dominant bryophyte, but, instead of being associated with liverworts *Racomitrium aciculare* and *Schistidium agassizii*, it is found more commonly with *Schistidium alpicola* and *Amblystegium fluviatile*. The latter is associated with more basic rocks and is indicative of the influence exerted by the metamorphosed limestone which outcrops in the Dinnet area.

4.1.5 Banchory to Aberdeen; sites 11-14

From Banchory to its mouth, the Dee flows within a wider valley, with more gently inclined slopes. The agricultural land use intensifies but never encroaches directly on to the bank vegetation. The velocity of the river gradually decreases in parallel with the decrease in slope (Figures 2 & 3), yet the substrate of the river shows less dramatic changes.

The increased richness of the surrounding land, which makes the lower Dee suitable for more intense agricultural use, also has an effect on the flora of the river. Below Banchory, there is a genuine increase in trophic status of the community. Several new plant species are present which do not occur upstream. However, the most notable feature is that very little change occurs in the flora of the river itself, but all the changes are evident at the water/bank interface. The species of the banksides are therefore very different.

Because the substrate characteristics of the river itself have changed little (Figure 2), the dominant taxa in the Dee right to its discharge into tidal waters remain green algae, lichens and bryophytes. The banks, however, become more stable, and the vegetation incorporates detritus and other fine particles washed down by the river in spate. The result is a richer soil capable of supporting 3 types of reed, *Sparganium erectum, Phalaris arundinacea* and *Glyceria maxima*. All these 3 species occur where stable, richer banks are at least close to the low water level of the river so that their roots are constantly in contact with the water. Several other flowering plants are also confined to, or only common on, the banks of the lower reaches of the Dee. This situation contrasts markedly with that for the plants within the channel itself.

5 Tributaries of the River Dee and standing waters
No detailed surveys of the tributaries have been done by either the author or by Haslam. However, above Braemar, the character and flora of tributaries such as *Lui, Ey, Quoich* and *Clunie* are similar in many respects to that of the Dee itself. Bryophytes, particularly liverworts, dominate. Below Braemar, the characteristics of the large tributaries frequently differ from those of the main river, and further investigations are required. Of particular concern are the *Muick*, which discharges from Loch Muick and therefore should have a relatively stable flow regime; the *Feugh* system, which drains a less steeply sloping valley with a wide and fertile river corridor; and the *Leuchar*, which drains flat land to the north of the Dee and discharges from Loch of Skene.

The lack of knowledge concerning these potentially very different watercourses requires remedy, as they probably represent a totally different riverine wildlife resource. They are doubly important because their influence on the main river flora is almost nil and very local. This situation contrasts with the influence of tributaries on other rivers such as the Tweed (Holmes & Whitton 1975), and they may be of unique scientific interest. In the case of the Tweed, the *Teviot* completely changes the floral assemblage of the main river below its inflow.

Within the Dee system are a number of lakes and other areas of standing water which have floras in marked contrast to that of the Dee itself. Indeed, some are far richer in aquatic plants. However, the Dee neither flows through any of them nor is its flora influenced in any way by them. The standing waters all discharge into small tributaries and, as these enter the Dee, their influence is totally eclipsed by the overriding size and power of the main river. In this respect, the Dee has a most unusual flora because neither the standing waters within the catchment nor its tributaries exert any influence on the floral assemblages of the main river.

Although the botanical importance of mountain and moorland lochs and pools, as well as the more lowland lochs such as Kinord, Davan and Skene, cannot be overlooked, they may be treated as entities in their own right and they are not considered in this paper.

6 Discussion
The *Nature Conservation Review* (Ratcliffe 1977) described the Dee as the finest example of an oligotrophic river in Britain, at a time when few comparative surveys had been undertaken. Since then, national vegetation surveys have been carried out by NCC in an attempt to classify rivers according to their plant communities (Holmes 1983). This classification allows the flora of the Dee to be put into a national perspective and its significance for nature conservation assessed.

Over 1000 sites were investigated on over 100 rivers throughout Britain, with data collected in a standard manner using a checklist of species. Analyses of the data used 223 taxa, and sites were classified by a standard program called TWINSPAN (Hill 1979). The analyses split the 1055 sites initially into 2 unequal groups of 656 and 399, the former lowland and more chemically rich and the latter more upland and less rich. The second split then divided these 2 groups into 4 major groups of significance. Group A had sites characteristic of lowland areas and a rich geology and chemistry; group B had sites associated with sandstone or hard limestones and intermediate chemistry; group C had sites associated with resistant rock and nutrient-poor water; group D had sites associated with highlands and acid, nutrient-poor water. The programme then produced 56 meaningful community types. Details on the distribution throughout Britain of these communities, and their plant assemblages, are given in Holmes (1983). The relationship of these communities to water chemistry and the physical environment of rivers is given in Holmes and Newbold (1984) and Holmes (in prep.).

Although Butcher (1933) had pioneered work on classifying British rivers according to their flora, by 1977 there existed only a descriptive account which did not include rivers in Wales and Scotland. The *Nature Conservation Review* developed the classification further and the publications of Haslam (1978, 1982) added immeasurably to the knowledge of the flora in the rivers of Britain. The classification of plant communities in rivers by Holmes (1983) is possibly the first rigorous analytical study which provides an objective classification enabling the significance of plant communities to be evaluated.

The Dee was one of 19 Scottish rivers which flow into the North Sea to be surveyed. A meaningful evaluation of the floral assemblages of the Dee is possible only if they are compared to relatively large rivers of a similar size in Britain.

Table 3 lists the plant community types found in the Dee alongside 5 other large rivers which flow in a generally west to east direction before discharging into the North Sea. Table 3 shows that 4 of the 56 national community types were evident in the Dee and 20 in the combined 88 sites surveyed on the 6 rivers. The 4 community types to which the sites on the Dee were assigned by the TWINSPAN analyses were:

Sites 1 and 2 (Whitebridge to *Lui* confluence), assigned to community type D3ii, a national river vegetation type described by Holmes (1983) as 'moorland rivers with boulders and adjacent peat';
Sites 3-7 (Inverey to Dinnet) assigned to community type D1i, described as 'mountain rivers with gravel margins';
Sites 8-10 (Dinnet to Banchory) assigned to community C4iii, described as 'highland rivers with gravel and peat';

Table 3. Six large rivers surveyed in Scotland which flow into the North Sea. From left to right are listed the vegetation types of the rivers from source to mouth as given in Holmes (1983). Emboldened sites are oligotrophic, single underlined sites are meso-eutrophic communities and double underlined sites are eutrophic

Findhorn	**D2i**	**D2i**	**D2i**	**D1i**	**D1i**	C4iii	C4iii	D1i	C1iii	C1iii	C1iii	C4ii									
Spey	**D4i**	**D3ii**	**D4i**	C4iii	**D4i**	C4iii	C3i	C4iii	C3i	C3i	C3i	C3i	C4i	C2v	C2v	C2v	C1i	C4i	C4i		
Don	**D1i**	**D1i**	C4ii	C4iii	C4iii	C4iii	C4i	B1i	B1i	B1i	B1i	B1i	B1i	B1i							
Dee	**D3ii**	**D3ii**	**D1i**	**D1i**	**D1i**	**D1i**	**D1i**	C4iii	C4iii	C4iii	C4i	C4i	C4i	C4i							
Teith	**D3i**	**D1ii**	C4iii	**D1ii**	C2iv	C1iii	C2iii	A2ii													
Tweed	**D1i**	C4iii	C4iii	B1iii	B1iii	B1iii	B1iii	B1iii	B1iii	B2i	B2i	B2i	B2i	B2i	B2i	B2i	B2i	B2i	B2i	B2i	A1iii

Sites 11-14 (Banchory to tidal influence) assigned to community C4i, described as 'large oligotrophic Scottish rivers'.

The Dee is shown by the analyses to have a floral assemblage which in the upper half of the river is definitely oligotrophic but in the lower reaches becomes no more than oligo-mesotrophic (Holmes & Newbold 1984). In this respect, it had features in common with the Findhorn and the Spey, but the individual community types were frequently different. All 3 rivers illustrate that the accepted normal progression for large rivers rising in highlands is not always met, and some do not go from oligotrophic uplands to mesotrophic middle reaches and then to meso-eutrophic or eutrophic communities in the lower reaches. The more generally accepted pattern of downstream succession of communities is seen, however, in the Don and Tweed.

Although there are 3 examples in north-east Scotland of oligotrophic large rivers, the national surveys indicate this type of river to be rare; the only other large river in Britain found to have such a low trophic expression in its flora was the Conway in north Wales (Holmes 1983). However, it is not uncommon for small rivers in England, Wales or Scotland to contain only an acidic, ultra-oligotrophic flora (ie New Forest streams in Hampshire or precipitous rivers in western Scotland).

National surveys have thus confirmed that the Dee is most unusual, but more detailed comparisons are required to see how its flora relates to other large rivers in eastern Scotland.

Table 4 lists the community types found in the 6 rivers listed in Table 3; by cross-reference it is possible to see how the floral assemblage of the Dee relates to others in the area.

The Don is the nearest large river to the Dee. The upper reaches of the Don are less oligotrophic and its lower reaches approach eutrophic status. The Don lacks the alpine elements of the Dee flora, and the upper reaches of the Don have a flora akin to that found between *Lui* and *Dinnet* on the Dee. This is the community of oligotrophic, gravel-edged, rivers and not one of boulders. Whereas the Dee retains an oligotrophic (D) plant community until about 150 m above OD, the Don loses its oligotrophes at about 350 m. Below this level, the Don has 3 different types of mesotrophic (C) communities but all are very closely related and similar to those of the lower reaches of the Dee. The 7 sites surveyed on the lower half of the Don were all classified in the meso-eutrophic community B1i. Reference to Table 4 shows the general lack of bryophytes, particularly alpine ones, and the abundant occurrence of flowering plants with requirements for greater physical stability of their environment and higher nutrient levels. Indicative species include *Solanum dulcamara, Elodea canadensis, Polygonum amphibium, Lemna minor, Potamogeton crispus* and *Glyceria maxima*.

The Spey rises in mountainous country with an oligotrophic expression in its flora which changes to a mesotrophic flora as the river approaches the flat valley of Loch Insh Marshes. This mesotrophy is retained in the plant community expression throughout the remainder of the river. The most interesting feature of the flora of the Spey is that, although the trophic status of the river is only marginally different from that of the Dee, its physical structure results in subtle differences in plant communities. In the upper reaches, sites 1, 3 and 5 all have floral assemblages classified as D4i, described in Holmes (1983) as 'slow-flowing upland rivers', whilst site 2 is classified as D3ii, similar to that of the upper Dee. Reference to Figure 3 shows that the slope of the Spey valley is very different and the resultant differences in current and substrate characteristics (Figure 2) are responsible for the differences in floral composition. The most important differences between the Dee and Spey are seen in the middle reaches of the Spey around Loch Insh where its valley is broad and shallowly sloping (see Figure 3). Sites 7-11 on the Spey were surveyed in this area and 4 out of the 5 were classified as C3i. This community is described as characteristic of 'upland rivers of fen and bog'. This community type is exceedingly rare in Britain and the characteristic species are given in Table 4. The most significant feature of the flora is the rich emergent fringing vegetation, which invades from the stable banks into the more slowly flowing water of the river itself. In the case of the Spey, *Carex aquatilis* is diagnostic.

The Findhorn is a large river which also does not progress beyond a mesotrophic flora in its lower reaches. Like the Dee, 50% has an oligotrophic flora and 50% mesotrophic flora (Table 3). The differences in flora between the 2 are only subtle. The different community structures are explained by the upper sites of the Findhorn being surveyed where the river was not constrained to a definite channel as in the upper Dee. From sites 4-8, the Findhorn has a flora similar to that of the Dee between Balmoral and Banchory. However, below this, the community of the Findhorn is dominated by C1iii (described as 'upland, rapid rivers with acid water but rich substrates') instead of C4i which occurs in the lower Dee. These community differences indicate that the Findhorn flows over sandstone in the lower reaches, whilst the Dee continues its course flowing over less rich rocks.

Further south, the Teith also has an oligotrophic-mesotrophic expression but its assemblage differs completely from that of the Dee. Out of the 7 oligotrophic and mesotrophic communities recorded for the Teith, only one is of a type found on the Dee. The oligotrophic communities of the Teith are richer in flowering plants because of the stability of the river which results from its passage through 3 lochs. The mesotrophic communities in the lower reaches also differ from those of the Dee in being tree-lined, on richer geological strata and more stable. In the extreme lower reaches, it has a eutrophic plant community where the river flows over rich old marine deposits at the head of the Firth of Forth.

The Tweed is also a river of prime nature conservation importance and was awarded grade 1 status in the *Nature Conservation Review* (Ratcliffe 1977). The *Review* describes the river as eutrophic throughout its length because of its passage over rich geological strata, in contrast to that of the Dee. The communities shown in Table 3, and the species assemblage characteristic of those species shown in Table 4

Table 4. Species which characterize the 20 community types found in 6 rivers in Scotland which flow into the North Sea (see Table 3). For details see Holmes (1983). Letters indicate the frequency of individual species expected to occur in sites assigned to each community type. D = >75% recorded occurrence; A = 50-74% recorded occurrence; F = 20-49% recorded occurrence; blank = absent or up to 19% recorded occurrences. Emboldened communities are the 4 community types present in the River Dee

	British river community types																			
Species	**D1i**	D1ii	D2i	D3i	**D3ii**	D4i	C1i	C1iii	C2iii	C2iv	C2v	C3i	**C4i**	C4ii	**C4iii**	B1i	B1iii	B2i	A1iii	A2ii
Potentilla erecta	**A**	A	A	A	**A**	A														
Blindia acuta	**A**		A		**F**	F														
Carex demissa	**F**	F	A	F	**A**	F														
C. echinata	**F**		F	F	**A**	A														
Sphagnum spp.		F	F	F	**D**	D														
Potamogeton polygonifolius	**F**				**A**	A														
Polytrichum commune		A	A	D	**D**	A														
Scapania undulata	**D**	D	D	D	**D**	D						F								
Marsupella emarginata	**F**	A	D	D	**D**	F														
Nardia compressa	**F**	F	F	F	**A**	F														
Hyocomium armoricum	**A**	D	D	D	**D**	A		F	F	A		F								
Molinia caerulea	**A**	F	F	F	**A**	A	F								**A**					
Nardus stricta	**A**	F	A	F	**D**	A									**A**					
Viola palustris	**F**	F	F	A	**A**	D		F		F					**F**					
Anthoxanthum odoratum	**D**	D	A	D	**F**	A		F		F				F	**F**					
Lotus uliginosus	**A**	A	F	A	**A**	A		F	F					A	**F**					
Pellia epiphylla	**D**	D	D	D	**D**	D		D	D	D	A	A	**F**	F	**D**					
Solenostoma triste	**D**	D	D	A	**D**	F	F	D		D	F	F			**A**					
Brachythecium plumosum	**D**	D	D	A	**A**	A	A	A		D	F	F			**A**					
Bryum pseudotriquetrum	**D**	A	D	A	**A**	D	A	A		F	A	F	**F**	F	**D**					
Hygrohypnum ochraceum	**D**	D	D	D	**A**	F	A	D	D	D	D	A	**A**	F	**D**					
Philonotis fontana	**D**	F	A	F	**F**	F	F	F			F			F	**F**					
Racomitrium aciculare	**D**	D	D	D	**D**	A		A	A	D	F	F	**F**		**A**					
Ranunculus flammula	**D**	A	F	A	**D**	D	F	A	A	D	A	D	**A**	D	**D**					
Carex nigra	**D**	A	A	A	**A**	D	A	F		F	F	F	**F**	D	**D**					
Juncus bulbosus	**D**	D	A	A	**D**	D		F		F		F	**F**	F	**D**					
Hygrohypnum luridum	**D**	F	D				F	F		F				A	**F**					
Didymosphenia geminata	**A**		A				F							F	**F**					
Brachythecium rivulare	**A**	D	D	F			D	D	F	A	F			D	**A**					
Littorella uniflora	**F**	F				A				F	F	F	**F**		**F**					
Montia fontana	**A**	D	F			F		F		F	F			A	**A**					
Calliergon cuspidatum	**D**	F	A			F	A	A			A	F	**F**	A	**D**					
Dichodontium flavescens	**A**	F	D			F	A	F	A						**F**					
D. pellucidum	**D**	D	D			F	D	D		F	F			F	**F**					
Galium palustre	**A**	A	F	F	**F**	A		F	F	F		A	**F**	D	**A**	F	F			
Caltha palustris	**D**	D	F	F		A	D	A	F	D	A	D	**D**	D	**A**		F			
Carex rostrata	**A**				**F**	D						D	**F**	A	**A**	F				
Achillea ptarmica	**D**	D	A	F	**F**	D	F	F	F	F	D	D	**A**	A	**D**	F				
Tussilago farfara	**D**	A	A			F	A	D			F		**F**	D	**A**		F			
Schistidium alpicola	**D**	D	A	F	**F**	F	D	D	F	D	D	F	**D**	D	**A**	F	F	F		
Chiloscyphus polyanthos	**A**	D	A	F		F	A	D	D	D	A	A	**A**	F	**A**	F	A			
Callitriche hamulata	**A**	A			**F**	A		F	A	A	F	A	**D**	F	**A**	A	F			
Myriophyllum alterniflorum	**A**	A			**F**	D	F	F	F	F	A	D	**D**	D	**D**	D	D	A		
Sagina procumbens	**D**	A	A			F	A	D	F	F			**F**	A	**A**		F	F		
'Ferns'	**F**	A	D	A		A		D	D	A		F		A	**F**	F	A	F		
Lemanea fluviatilis	**A**	A	A	F	**F**	F	D	A	D	A	D		**D**	A	**A**	D	D	F		
Verrucaria spp.	**D**	A	A	A	**F**	F	D	D	S	D	D	F	**D**	D	**D**	D	D	D		
Fontinalis squamosa	**F**	A	F	A	**F**	F		A	D	D	D	F	**A**	F	**F**	A	A	F		
Amblystegium fluviatile	**F**						D	D	A	F	D		**D**	D	**A**	F	D	D		
Conocephalum conicum	**F**		F				A	D	D	A	A		**F**	F	**F**		D	F		
Marchantia polymorpha	**F**						A	F	F	F	F		**F**	F	**F**		F	F		

Table 4.—continued

	British river community types																			
Species	**D1i**	D1ii	D2i	D3i	**D3ii**	D4i	C1i	C1iii	C2iii	C2iv	C2v	C3i	**C4i**	C4ii	**C4iii**	B1i	B1iii	B2i	A1iii	A2ii
Senecio aquaticus	**F**	F				F		F					**F**	A	**F**	F	F			
Deschampsia cespitosa	**A**	D	A	A	**F**	A	A	A	A	F	A	D	**F**	A	**A**	F	F			F
Fontinalis antipyretica	**D**	A	D	F	**F**	F	D	D	A	A	D	D	**D**	D				D	D	D
Rhynchostegium riparioides	**D**	D	A	A	**F**	F	D	D	D	D	D	F	**D**	D	**D**	D	D	D	F	F
Filamentous algae	**D**	D	D	D	**D**	D	D	D	D	D	D	A	**D**	D	**D**	D	D	D	F	F
Salix spp.	**D**	D	A	D	**F**	A	D	D	D	D	A	D	**D**	D	**D**	D	D	D	A	D
Trees	**A**	A	F	D	**A**	F	A	D	D	D	D	A	**A**	A	**D**	A	D	A	A	A
Agrostis stolonifera	**D**	D	F	D	**F**	A	D	D	D	D	D	D	**D**	D	**D**	D	D	D	D	D
Juncus acutiflorus	**D**	D	A	D	**D**	D	D	D	D	D	D	D	**D**	D	**D**	D	D	D	F	A
J. effusus	**D**	D	A	D	**D**	D	F	D	A	D	D	D	**A**	D	**D**	D	D	F	F	D
Glyceria fluitans	**D**	D		A	**F**	D	F	A	A	A	D	D	**D**	D	**D**	D	A	A	F	F
Equisetum arvense	**A**	F		F		F	A	A	F	F	D		**A**	D	**A**	D	D	D		F
Mentha aquatica	**A**	F		F		F	D	A	D	F	D	D	**D**	D	**D**	D	D	D	A	A
Myosotis scorpioides	**A**	A		F	**F**	A	A	A	A	F	D	D	**D**	D	**D**	D	D	D	D	D
Filipendula ulmaria	**D**	A	F	F		A	A	D	D	A	D	D	**D**	D	**D**	D	D	A	F	A
Veronica beccabunga	**F**						A	A	F			F	**F**	A	**F**	D	F	A	D	D
Callitriche stagnalis		F	F	F	**F**	F		F	A	F		F	**D**	F	**F**	D	A	F	F	F
Dermatocarpon fluviatile		A	F	F		F		F	A	D	F	F	**F**		**F**		F			
Equisetum palustre		F				F	A	F		F	F			A	**F**					
Oenanthe crocata		F				F			A	D	F				**F**		F	F		
Thamnobryum alopecurum		F	F				A	A	A	F	F	F					F	F		
Angelica sylvestris	**F**	A		F		F	F	A	A	F	A	D	**D**	A	**A**	F	A	F	F	
Eleocharis palustris							A	F		F		A	**A**	D	**A**	A	F	D	D	
Iris pseudacorus							F			F			**F**		**F**		A	F		
Stachys palustris										F	F			F	**F**		A	F		
Equisetum fluviatile			A			D								D			A			
Carex remota			A						A	F	F				**F**					
C. aquatilis											A	D	**F**	F	**F**					
Phalaris arundinacea		A				F	A	A	D	D	D	D	**D**	D	**A**	D	D	D	D	D
Alopecurus geniculatus			A						F				**F**	A		A	D	F	F	A
Sparganium erectum		F							A			A	**A**	D	**F**	D	D	D	D	D
S. emersum		F				F						D							A	F
Potamogeton natans						F						D	**F**	A	**A**	F			F	F
Stellaria alsine								F	F	F	F			A	**F**	F				
Cinclidotus fontinaloides							D	F	F	F			**F**	F			D	D		
Mimulus guttatus							D	F	F		F		**A**	A			F	D		
M. guttatus × *luteus* hybrids										F	F		**F**	A	**F**		F			
Hildenbrandia rivularis							A	F						F		F	D	D		
Collema fluviatile								A								F	F	F		
Cladophora glomerata							D							F		A	D	D	D	D
Vaucheria sessilis							F	F	F	F	F	F					A	A	D	D
Solanum dulcamara									A							A	A	F	D	A
Nasturtium officinale									F				**F**	F	**A**	A	F	F	D	D
Rorippa sylvestris													**A**				A	D		F
Petasites hybridus																		A	A	
Ephydatia fluviatilis																	F	F	A	
Cladophora aegagropila																	D	D	D	
Lunularia cruciata																		A		
Impatiens glandulifera																		A	D	
Amblystegium riparium																	E	A	F	A
Brachythecium rutabulum																	F	A	F	F
Myriophyllum spicatum																			A	A
Ranunculus fluitans													**F**						D	F
Elodea canadensis												F	**F**			A	D	D	A	A
Polygonum amphibium																A	D	D	F	D
Lemna minor																A	F	F	A	A
Potamogeton crispus																F	D	D	A	A
Glyceria maxima																A			F	A
Enteromorpha spp.																		A	D	A
Ranunculus calcareus																	F	D	F	F
Myosoton aquaticum																		F	F	A
Epilobium hirsutum																	F	A	D	D
Scirpus sylvaticus																	A	A		A
Potamogeton perfoliatus																			F	A
P. pectinatus																			A	D
Zannichellia palustris																			A	F
Ranunculus sceleratus																			F	A
Carex riparia																			F	A
Veronica anagallis-aquatica																			F	A
Juncus inflexus																			F	A
Apium nodiflorum																			D	A
Scrophularia auriculata																			A	F
Rorippa amphibia																				A
R. palustris																				A
Scirpus lacustris																				A

confirm the differences, although it is difficult to understand how the uppermost reaches of the Tweed could be regarded as eutrophic. What is clear, however, is that the uppermost reaches of the Tweed have floral assemblages akin to those of the lower Dee, yet downstream the Tweed gradually increases in trophic status until it reaches eutrophy. The differences in flora between the 2 rivers clearly illustrate the combined effect of underlying rocks and of current, which result from the altitudinal source of the river and its descent from that height.

6.1 Conservation significance of the Dee

The selection of key sites for nature conservation is based upon a number of criteria, the principal 2 being naturalness and typicalness, together with criteria such as fragility, diversity of features and of flora and fauna, and rarity. If a representative series of rivers is to be included within the national framework of habitats, it is imperative to choose large and small examples which illustrate the variations of the resource on a national scale. In Ward's (1981) list of the 20 largest rivers in Britain, the Dee is ranked as no. 14. Its length of 116 km makes it the tenth longest, its area of 1370 km^2 makes it the twenty-first largest, and its mean discharge of 35.7 cumecs ranks it as eighteenth. Four other large rivers are considered to have high nature conservation significance. They are the Tweed, Spey, Wye and Avon, all of which have their interests described in the *Nature Conservation Review.*

It has already been shown that the flora of the Dee retains a uniquely low trophic status along its entire length, which is lower than in the Conway, Spey and Findhorn, rivers most closely resembling it. In addition, the plant communities of the Dee show a unique succession on passing downstream. The Dee can therefore be regarded as the river which exemplifies the oligotrophic, large, British river.

One of the 2 main site selection criteria thus puts the Dee at the very top of the list. The other, naturalness, may be the reason why. In Ward's list, the Dee ranks with the Spey as the most natural. For one reason or another, many of Britain's longest rivers have been exploited by man and their physical character changed. In so doing, their floral characteristics have changed also. The second of the 2 key nature conservation selection criteria again places the Dee at the top of the list.

Because the floral assemblage is such an important element in the selection of sites of high nature conservation importance, there can be no doubt that the Dee is a nationally important river.

7 Summary

National botanical surveys of British rivers have indicated that the River Dee has a unique assemblage of plants. Unlike most large rivers which rise in the uplands, the Dee increases its trophic status only marginally before discharging into the sea. For this reason, the flora begins as oligotrophic and then gradually increases to oligo-mesotrophic at its mouth. In this respect, it resembles only the Spey, Findhorn and Conway. In both naturalness and typicalness, the Dee is nationally important as a site for nature conservation.

8 References

Birks, H. H. & Birks, H. J. B. 1967. *Grimmia agassizii* (Sull. & Lesq.) Jaeg. in Britain. *Trans. Br. bryol. Soc.*, **5**, 215-217.

Butcher, R. W. 1933. Studies on the ecology of rivers. I. On the distribution of macrophytic vegetation in the rivers of Britain. *J. Ecol.*, **21**, 58-91.

Haslam, S. M. 1978. *River plants: macrophytic vegetation of water courses.* Cambridge: Cambridge University Press.

Haslam, S. M. 1982. *Vegetation in British rivers. Vol. I: Text. Vol. II: River maps.* (CST note 32.) Banbury: Nature Conservancy Council.

Haslam, S. M. & Wolseley, P. A. 1982. *River vegetation: its identification, assessment and management.* Cambridge: Cambridge University Press.

Hill, M. O. 1979. *TWINSPAN — a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Ithaca, N.Y.: Section of Ecology and Systematics, Cornell University.

Holmes, N. T. H. 1976. The distribution and ecology of *Grimmia agassizii* (Sull. & Lesq.) Jaeg. in Teesdale. *J. Bryol.*, **9**, 275-278.

Holmes, N. T. H. 1980. *Preliminary results from river macrophyte survey and implication for conservation.* (CST note 24.) Banbury: Nature Conservancy Council.

Holmes, N. T. H. 1983. *Typing British rivers according to their flora.* (Focus on nature conservation no. 4.) Banbury: Nature Conservancy Council.

Holmes, N. T. H. & Newbold, C. 1984. *River plant communities — reflectors of water and substrate chemistry.* (Focus on nature conservation no. 9.) Peterborough: Nature Conservancy Council.

Holmes, N. T. H. & Whitton, R. A. 1975. Macrophytes of the River Tweed. *Trans. Proc. bot. Soc. Edinb.*, **42**, 383-395.

Nyholm, E. 1956. *Illustrated moss flora of Fennoscandia. II. Musci, fasc. 2.* Lund: Gleerup.

Ratcliffe, D. A., ed. 1977. *A nature conservation review: the selection of biological sites of national importance to nature conservation in Britain.* 2v. Cambridge: Cambridge University Press.

Ward, R. C. 1981. River systems and river regimes. In: *British rivers,* edited by J. Lewin, 1-33. London: Allen & Unwin.

Westlake, D. 1973. Aquatic macrophytes in rivers: a review. *Polskie Archwm Hydrobiol.*, **20**, 31-40.

Whitton, B. A. 1972. Environmental limits of plants in flowing waters. In: *Conservation and productivity of natural waters,* edited by R. W. Edwards & D. J. Garrod, 3-19. (Symp. Zoological Society of London no. 29.) London: Academic Press.

Vegetation of the valley floor of the River Dee

J A FORSTER* and JACQUI GREEN
Nature Conservancy Council, 17 Rubislaw Terrace, Aberdeen
(**now University Office, University of Aberdeen*)

1 Introduction

This paper describes the vegetation present in the Dee valley in April-November 1979 and makes recommendations for its conservation. A survey was commissioned by the Nature Conservancy Council (NCC) because scarce types of semi-natural vegetation were known to occur in the lower reaches of the river, together with rare plants and invertebrates, eg Mackay's horsetail and Kentish glory moth, and it was desirable to record the location, extent and composition of these communities. Also, in considering river conservation and management, knowledge was needed about all the vegetation growing nearby.

The study area was defined so as to include only vegetation which was either directly influenced by river processes, such as erosion, deposition and flooding, or subject to management directly related to the river, eg salmon fishing, bank reclamation and water abstraction. In the upper reaches, the riverside vegetation differed little from that in the surrounding catchment area, and consequently the study area extended no higher up the Dee than Whitebridge at the foot of the mountain slopes.

Figure 1 gives a theoretical cross-section through the main valley showing typical features. The floodplain, ie the area subject to periodic inundation, where soils are the product of river-borne deposition, and where water tables are generally high, provided the obvious latitudinal delimitation to the study area, but this area was extended to include a strip up to 50 m wide on each side of the floodplain where semi-natural vegetation occupied adjacent slopes. The whole is described as the 'valley floor', and the total area studied was *c* 93 km^2 (Table 1).

1.1 General characteristics of the valley floor

Along the main river and its tributaries, landform and vegetation are closely related, not only because of the direct influence of the physical environment on the type of species present, but also because man's use of the land is a response to topography. The nature of these landforms and their relationship to the plant communities are briefly outlined as a prelude to the more detailed description of vegetation.

Deposits of shingle, to a greater or lesser extent stable, are common; Maizels (1985) describes the conditions under which they form. Land beyond the river banks, wherever the gradient is low, is liable to continuing deposition of sediment and detritus in floods. Most alluvial flats have relatively good soils, but, because of the vulnerability to flooding and, in places, the difficulty of surface drainage, cultivation can be difficult and some areas are consequently left as permanent grassland. Within the plain, swamp vegetation occurs in abandoned river channels and other wet hollows. Where only a narrow strip of floodplain lies between the river and a neighbouring bluff, difficulty of access has sometimes led to the retention of natural or semi-natural woodland or to the abandonment of agriculture and the establishment of secondary natural vegetation.

The edge of the floodplain is often bounded by steep slopes marking the limit of erosive activity of the main river. These slopes are often too steep or narrow to be worth cultivating, and are sometimes difficult to graze with domestic stock. Consequently, woodland has tended to develop. In the lower sections of the valley, these bluffs have often been planted, particularly with broadleaved trees (eg ash, wych elm or beech). In

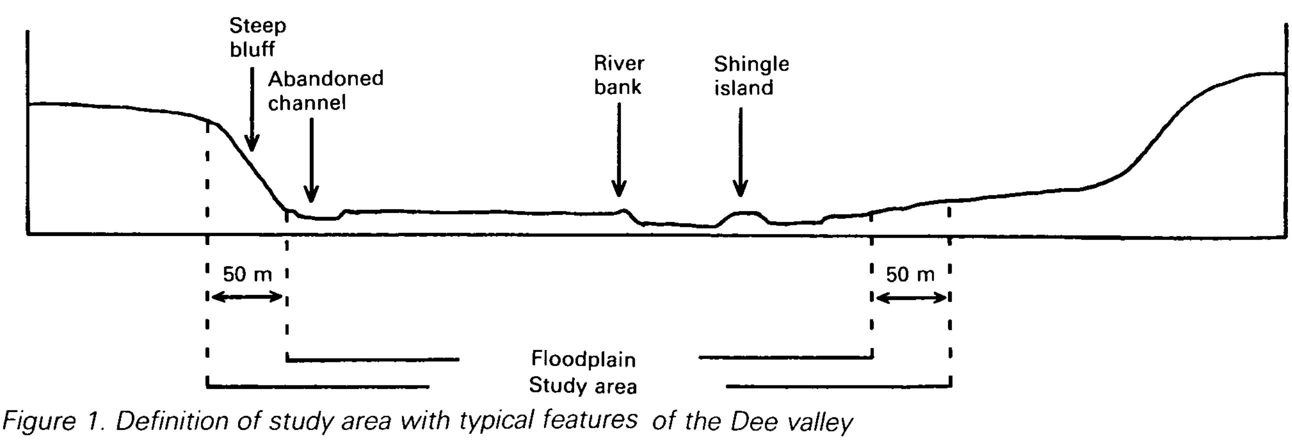


Figure 1. Definition of study area with typical features of the Dee valley

places, they contain some of the few examples of low-altitude natural woodland, for example the oak, birch and hazel wood at Quithel, between Aboyne and Kincardine O'Neil.

1.2 Data

The survey providing the main source of data for this paper was a qualitative description of the semi-natural vegetation of the valley floor. Because linearity in the disposition of riverside vegetation and great variability between sections of the valley were expected, the whole of the defined study area was examined. All areas of semi-natural vegetation were outlined from air photographs and the dominant plants then recorded on field visits. Plant communities in some representative 2 m × 2 m quadrats were assessed in order to relate the vegetation to earlier classifications (McVean & Ratcliffe 1962; Birse & Robertson 1976). Additional information was used for the valley of the *Feugh* and other tributaries. For this paper, the classification of the vegetation is simplified and English names are given to most units. Individual species are discussed only briefly. The plant community named by the dominant species is a convenient shorthand for a description of the site as a whole. The distribution and extent of coverage of identified types of vegetation were estimated within the valley floor of the Dee, and the valley was divided into sections according to the main villages.

Some of the vegetation types occurred in such small areas that they could often have been missed, and these types are likely to be under-recorded. There was also a considerable gradation between different types, and the separation of types where no sample quadrats were described was to some extent arbitrary. The paper is descriptive rather than analytical, as little work has been done to relate vegetation and environment in the study area. The full account of the study is available in the library at NCC, Aberdeen.

2 Results of the survey

2.1 Woods

2.1.1 Scots pine

Most of the pinewoods in the Dee catchment were planted, but some of the finest examples in Britain of native pinewoods occur in Glen Tanar, Ballochbuie and Mar (Steven & Carlisle 1959). We found it difficult in some cases to distinguish well-established pine plantations from the native woodlands on structural grounds alone; in these cases, such woods were called native. Two different types of pinewood were recognized: those which had an open canopy and were old, dominated by heather and *Vaccinium* species (the Pinetum Vaccineto-Callunetum of McVean & Ratcliffe), and those which had a more closed canopy and a field layer dominated by mosses or bilberry. The closed-canopy type was found only on the south bank of the river (ie it had a northerly aspect)

Table 1. Area (ha) of different sections of the valley floor of the River Dee occupied by different types of plant cover (<0.1% = trace)

COVER TYPE	Section of valley						
	Aberdeen to Banchory	Banchory Aboyne	Aboyne Ballater	Ballater Linn of Dee	Linn of Dee Whitebridge		
Length of River Dee in section (km)	31.5	22.1	20.6	40.7	6.5	TOTAL AREA ha	(%)
WOODLANDS							
Scots pine	0	191.6	162.8	764.6	53.2	1172.2	(12.6)
Conifer plantations	109.4	289.8	117.3	386.6	22.5	925.6	(9.6)
Birch	16.9	121.7	438.6	315.9	0	893.1	(9.6)
Oak	2.3	7.6	11.3	40.4	0	61.6	(0.7)
Alder	20.9	23.7	29.2	8.6	0	82.4	(0.9)
Willow	8.7	0.6	4.1	1.2	0	14.6	(0.2)
Mixed broadleaved woodland	73.8	42.1	5.6	19.1	0	140.6	(1.5)
Hazel	8.6	0	2.3	0	0	10.9	(0.1)
Aspen	0	0	0	8.7	0	8.7	(0.1)
ARABLE AND IMPROVED GROUND	1699.4	447.8	524.0	750.4	0	3421.6	(36.6)
SHORT GRASSLANDS AND DWARF-HERB COMMUNITIES							
Species-poor bent/fescue grassland	21.9	80.8	79.2	363.6	75.6	621.1	(6.7)
Species-rich bent/fescue grassland	1.6	3.6	0.8	60.3	0	66.3	(0.7)
Sheep's-fescue grassland and meadow-grass grassland	1.5	0	1.0	5.1	0	7.6	(0.1)
Dwarf-herb nodum	0	0	0	2.2	0	2.2	(tr)
MEADOW GRASSLANDS							
Tall-grass nodum	51.6	16.5	5.0	6.5	0	79.6	(0.9)
Tall-herb nodum	20.7	13.2	0.7	0.7	0	35.3	(0.4)
GORSE AND BROOM SCRUB	41.4	11.8	138.7	32.1	0	224.0	(2.4)
DWARF-SHRUB HEATH							
Species-poor heather moor	0	40.2	79.4	380.5	640.4	1140.5	(12.2)
Species-rich heather moor	0	0	43.3	16.2	0	59.5	(0.6)
Molinieto-Callunetum	0	0	0	27.0	1.6	28.6	(0.3)
MARSH AND SWAMP COMMUNITIES							
Heath rush nodum	0	0	0.3	8.3	0.8	9.4	(0.1)
Sedge nodum	0.6	0	0.7	2.4	0.7	4.4	(tr)
Soft rush nodum	0.2	0.4	5.3	18.1	0	24.0	(0.3)
SETTLEMENT	79.0	38.9	59.2	130.6	0	307.7	(3.3)
TOTAL	2158.5	1330.3	1708.8	3349.1	794.8	9341.5	

and only as far down the river as 250 m above OD. The more open canopy type was found on both north- and south-facing slopes and down to 70 m above OD near Banchory. Both types tended to occur on podzols, and were found on slopes or terraces above the floodplain rather than on alluvial soils or poorly drained areas. Pinewoods covered 12.6% of the study area (Table 1) and were greatly affected by management.

2.1.2 Conifer plantations

Apart from Scots pine, Sitka and Norway spruce were commonly dominant. Other species planted extensively were European larch, Douglas fir and western hemlock. Grand fir, noble fir, Japanese larch and lodgepole pine were less frequent, usually occurring as stands within larger plantations. Most plantations were on land that was previously heather moorland, Scots pinewood or birchwood. Plantations were rarely found on former arable ground or in areas subject to flooding. This woodland type occupied 9.9% of the study area (Table 1). It was most frequent from Banchory to Aboyne (21.8% of that area), and it was the second commonest type after arable agricultural land in the low-altitude section from Banchory to Aberdeen. Overall, conifer plantations at 5.1% were the second highest category after arable.

2.1.3 Birch

Both downy and silver birch occur in the Dee Valley, but silver birch is confined to the drier eastern section downstream from Glen Gairn. It grows on free-draining slopes, whereas downy birch in these sections requires sites with a high water table, eg flats by the river, where it grows with alder and bird cherry. Above the mouth of the *Gairn*, downy birch occurs on both wet and freely drained soils. Four types of birchwood were distinguished by their field layer: (i) birch invading heather moor (at low altitudes primarily silver birch, eg Muir of Dinnet), (ii) dense stands at high altitude, with bilberry dominant as understorey, (iii) birch over a species-rich grassland, (iv) moist birchwood (downy birch) with wood horsetail and tufted hair-grass. In the study area, birchwood was the dominant habitat from Aboyne to Ballater (25.7%), and this section contained 49.1% of all the birchwood (Table 1).

The birchwood category also included a small number of woods in which birch was mixed with other trees, but birch or birch and rowan predominated. These woods generally had a similar field layer to the herb-rich type of wood (type (iii) above). On north-facing slopes with better soils, they graded into oakwood.

2.1.4 Oak

Oakwood is scarce in the Dee catchment, with significant stands only at Drum, Crathes, Aboyne, Dinnet and Craigendarroch. Oaks grow on acid brown earths, on better brown earths as at Dinnet, and sometimes on granite rock ledges and scree. Only the stands at Craigendarroch and Dinnet came within the limits of the survey. Both were on steep slopes (generally greater than 25°) above the floodplain. Isolated oaks, including some superb specimens, grew beside the river upstream from Banchory, at Quithel Wood, and above Ballater at Coilacreich. Most of the trees were pedunculate oak and few were sessile oaks, though several had hybrid characters.

2.1.5 Alder

Alder occurred in locations characterized by the presence of moving water, ie the banks of the Dee and its tributaries, those parts of the floodplain which had a permanently high water table, and flushed slopes above the plain. Because most of the alluvial flats on which alder woodland might grow were farmed, the largest stands were found on islands or on flats below steep cliffs with difficult access (eg at Quithel). On banks with easy access, saplings were cut back to aid fishing. Woodland with a slightly lower water table had higher proportions of birch and bird cherry.

The field layer was very variable, depending on soil moisture status; sedges, great wood-rush, or brambles were sometimes dominant, but some woods had an interesting herb-rich flora. Although alder trees were often conspicuous, standing in lines beside the river, alderwood had a very limited extent in the study area (0.9%, Table 1). This total did not include important stands alongside the *Feugh* and *Gairn*, or some limited stands at the Dinnet lochs, but did include woods with a small proportion of bird cherry, birch, hazel and ash.

2.1.6 Willow

Willows had a more restricted distribution than alder and preferred wetter soils. Abandoned channels, islands and banks of the river were the main habitats. Different species were locally dominant, but goat willow and grey willow were most common. Other species present included white, eared and bay willows and osier. The field layer under willows contained more sedges than in the alderwoods, with bottle sedge, common and common yellow sedges. At Quithel wood, an interesting mixture of goat willow and silver birch was found. The total area of willows was 14.6 ha (0.2% of the study area) (Table 1). Over half occurred in the lowest section of the river, from Banchory to Aberdeen (8.7 ha).

2.1.7 Mixed broadleaved woodland

This category included woods in which ash, wych elm, sycamore or beech were predominant, either singly or in combinations. Except for beech, these species require flushed or brown earth soils to thrive, and all had been widely planted in the study area, especially in the lower half of the valley. Wych elm and probably ash are native to Deeside, but beech and sycamore are not. We did not attempt to distinguish planted woods from natural ones. The ash/wych elm/ sycamore woods tended to have a relatively herb-rich field layer with such species as dog's mercury and primrose. This woodland was common only in the lower reaches of the valley (Table 1). It was the most numerous type of semi-natural habitat between Aberdeen and Banchory, occupying 3.4% of the valley floor.

2.1.8 Hazel

Hazel occurred both as an understorey shrub in oakwoods and also in pure stands, sometimes as coppice. It may have been planted widely. It preferred well-drained situations such as the river banks and bluff slopes. Outside the study area, hazel grew abundantly between Ballater and Crathie on south-facing slopes with rich soils. Within the study area, hazel woodland was scarce (Table 1), and occurred only downstream from Crathie.

2.1.9 Aspen

Aspen was widespread but very local in the valley floor, with only occasional stands of more than a few stems; 8.7 ha were identified in the survey (ie 0.1% of the study area), all in the Ballater to Crathie section. The field layer was usually grassy with meadow-grass common.

2.2 Arable and improved grass

This category includes arable land and sown grasslands. Generally, the land was fenced. Perennial rye-grass and cock's-foot were the main introduced grasses. Rough grassland which did not appear to have been improved is described below. Arable and improved ground occupied 36.6% of the study area (Table 1), 3 times the extent of the next commonest vegetation type. Not surprisingly, none was present above the Linn of Dee, and by far the greatest area (1699 ha) occurred in the lowest section of the valley downstream from Banchory. This was equivalent to 49.6% of all arable ground in the study area, and was 78.7% of the area of the section.

2.3 Short grasslands and dwarf-herb communities

These communities are subject to grazing and occur on alluvial soils, often where the risk of flooding reduces the potential for reclamation.

2.3.1 Species-poor bent/fescue grassland

This community was characterized by the presence of brown bent, common bent, sweet vernal-grass, fine-leaved sheep's-fescue and heath bedstraw. It had the widest range of any community in the valley, forming the most important grassland at the river mouth and also at the Linn of Dee. It occurred on alluvial plains, especially where larger tributaries joined the Dee (eg at the junction of the Dee and *Quoich*). The soils tended to be base-poor thin podzols, well drained but subject to periodic flooding. Where grazing was light, invasion by trees and shrubs was common. The community was frequent (Table 1), especially in the section between Ballater and Linn of Dee; 200 ha occurred around the *Quoich* mouth.

2.3.2 Species-rich bent/fescue grassland

This community was characterized by the presence of many herbs such as selfheal, meadow buttercup and wild thyme. It covered a wide altitudinal range (30-370 m), but only fragmentary stands were found in the lowest reaches, and 60.3 ha out of 65 ha of this community were above Braemar. Species-rich grassland was generally grazed by cattle or sheep and was confined to the river bank or to meadows directly adjoining the banks on slopes of less than 20°. McVean and Ratcliffe (1962) suggest that the distribution of this community in the uplands is related to calcareous rocks. In this survey, it was found on well-drained soils with a brown earth or acid brown earth, less podzolic than the species-poor type.

2.3.3 Sheep's-fescue and meadow-grass grasslands

These grasslands differ from the 2 foregoing communities in the absence or scarcity of bent grasses. They shared 7 constant species, and were themselves differentiated mainly by the presence or absence of smooth meadow-grass and fine-leaved sheep's-fescue. They occurred mostly between Ballater and the Linn of Dee, and were of small extent (Table 1). The sheep's-fescue grassland was found in only one site at Mar Lodge, but the meadow-grass community occurred in scattered areas on the river bank on moderately fertile alluvial soils, confined, except for one site, to the north bank of the Dee. This community was often closely grazed. In the upper reaches, it was found most commonly with herb-rich heather moor, and in the lower reaches with species-poor bent/fescue grassland.

2.3.4 Dwarf-herb nodum

A dwarf-herb community dominated by thyme and clover species was found near the Linn of Dee. This community also occurred to the south of the river between Balmoral and Invercauld Bridge, as a complex with species-rich bent/fescue grassland (2.2 ha altogether). Both sites were ungrazed by domestic stock. Noteworthy plants present in the dwarf-herb nodum were sibbaldia, moss campion, and lesser clubmoss. McVean and Ratcliffe (1962) associated this community with high-altitude calcareous outcrops.

2.4 Meadow grasslands

There were 2 communities dominated by relatively tall non-woody plant species. Neither was grazed but both were found under circumstances which limited invasion by trees and shrubs.

2.4.1 Tall-grass nodum

A distinctive grassland type with tall grasses dominant occurred on the river banks, beside islands with poorly drained alluvium (particularly fine silt), in abandoned channels and at the edge of some alderwoods. Conditions were either too wet for grazing or there was protection from grazing. Some tall herbs, eg wild angelica, common valerian and meadowsweet, were associated with this community in strips beside the river. The community occupied only 0.9% of the study area (Table 1), but was widespread between the mouth of the river and 250 m above OD.

Table 2. Plant species found on the river bank at Banchory in 1976-79 (sources: J Green, P Marren, D Welch, pers. comm.)

Alnus glutinosa	Alder	**Galium boreale*	Northern bedstraw
Betula pubescens	Downy birch	*G. saxatile*	Heath bedstraw
Quercus robur	Pedunculate oak	**G. verum*	Lady's bedstraw
Rubus spp.	Bramble	*Geranium robertianum*	Herb-Robert
Sarothamnus scoparius	Broom	*G. sylvaticum*	Wood crane's-bill
Ulex europaeus	Gorse	*Geum rivale*	Water avens
		**G. urbanum*	Wood avens
Calluna vulgaris	Heather	*Helianthemum chamaecistus*	Common rock-rose
Erica cinerea	Bell heather	**Heracleum sphondylium*	Hogweed
		**Hieracium pilosella*	Mouse-ear hawkweed
Equisetum arvense	Field horsetail	*Hypericum hirsutum*	Hairy St John's-wort
E. fluviatile	Water horsetail	**H. maculatum*	Imperforate St John's-wort
E. hyemale	Rough horsetail	**H. perforatum*	Perforate St John's-wort
Polypodium vulgare	Polypody	**H. pulchrum*	Slender St John's-wort
		**Hypochoeris radicata*	Cat's-ear
**Agrostis stolonifera*	Creeping bent	*Lathyrus montanus*	Bitter vetch
Arrhenatherum elatius	False oat-grass	*L. pratensis*	Meadow vetchling
Briza media	Quaking-grass	*Lepidium heterophyllum*	Smith's pepperwort
**Cynosurus cristatus*	Crested dog's-tail	**Leucanthemum vulgare*	Oxeye daisy
**Deschampsia cespitosa*	Tufted hair-grass	*Lupinus nootkatensis*	Nootka lupin
Festuca arundinacea	Tall fescue	**Lychnis flos-cuculi*	Ragged-robin
F. ovina ssp. *ovina*	Sheep's-fescue	*Lysimachia nemorum*	Yellow pimpernel
Glyceria fluitans	Floating sweet-grass	*Mentha aquatica*	Water mint
**Helictotrichon pratense*	Meadow oat-grass	**M. spicata*	Spear mint
**Lolium perenne*	Perennial rye-grass	*Mercurialis perennis*	Dog's mercury
Phalaris arundinacea	Reed canary-grass	**Meum athamanticum*	Spignel
**Poa annua*	*Annual meadow-grass	*Mimulus guttatus*	Monkeyflower
P. pratensis	Smooth meadow-grass	*Myosotis arvensis*	Field forget-me-not
**P. nemoralis*	Wood meadow-grass	*M. palustris*	Water forget-me-not
		Myrrhis odorata	Sweet Cicely
Carex demissa	Common yellow-sedge	*Pimpinella saxifraga*	Burnet-saxifrage
C. echinata	Star sedge	**Plantago lanceolata*	Ribwort plantain
C. flacca	Glaucous sedge	*Polygonum bistorta*	Common bistort
C. ovalis	Oval sedge	**Primula vulgaris*	Primrose
Dactylorhiza purpurella	Northern marsh-orchid	**Prunella vulgaris*	Selfheal
Eleocharis palustris	Common spike-rush	*Ranunculus auricomus*	Goldilocks buttercup
Luzula sylvatica	Great wood-rush	*R. flammula*	Lesser spearwort
Sparganium spp.	Bur-reed	**R. repens*	Creeping buttercup
		Rhinanthus minor	Yellow rattle
**Achillea ptarmica*	Sneezewort	*Rumex longifolius*	Northern dock
**Ajuga reptans*	Bugle	*Scrophularia nodosa*	Common figwort
**Alchemilla glabra*	}	*Sedum telephium*	Orpine
**A. filicaulis* ssp. *vestita*	} Lady's mantle	**Senecio jacobaea*	Common ragwort
A. xanthochlora	}	*Solidago virgaurea*	Goldenrod
**Angelica sylvestris*	Wild angelica	*Stachys sylvatica*	Hedge woundwort
Caltha palustris	Marsh-marigold	**Stellaria graminea*	Lesser stitchwort
Campanula rotundifolia	Harebell	**Succisa pratensis*	Devil's-bit scabious
Cardamine amara	Large bitter-cress	**Thymus drucei*	Wild thyme
C. pratensis	Cuckooflower	*Trollius europaeus*	Globeflower
**Centaurea nigra*	Common knapweed	**Urtica dioica*	Common nettle
**Chamerion angustifolium*	Rosebay willowherb	**Valeriana officinalis*	Common valerian
**Cirsium heterophyllum*	Melancholy thistle	**Veronica chamaedrys*	Germander speedwell
**Clinopodium vulgare*	Wild basil	*V. officinalis*	Heath speedwell
Conopodium majus	Pignut	*Vicia cracca*	Tufted vetch
Dianthus deltoides	Maiden pink	*V. sepium*	Bush vetch
Digitalis purpurea	Foxglove	**Viola riviniana*	Common dog-violet
Doronicum pardalianches	Leopard's-bane		
**Euphrasia officinalis s.l.*	Eyebright	**Hylocomium splendens*	
**Filipendula ulmaria*	Meadowsweet	**Hypnum cupressiforme*	
Fragaria vesca	Wild strawberry	**Thuidium tamariscinum*	

*Species present within a 8 m^2 relevé

2.4.2 Tall-herb nodum

A tall-herb community, with globeflower and common valerian frequent, occurred on drier sites along the banks of the Dee below 250 m. Grazing by domestic stock was always absent, and the swards were usually mowed regularly by the fishing ghillies. This community was similar to the hay meadows of northern England and southern Scotland. Characteristic species included imperforate and perforate St John's-wort, melancholy thistle and spignel; a full list for one bank at Banchory is given in Table 2. The community was found most commonly where the river ran in a rocky bed and with boulders on the bankside. Some of the best occurrences were upstream from the bridge at Banchory, at Potarch, and near Abergeldie Castle. Because the tall-herb nodum was confined to the river bank, it occupied little area (35 ha in total, Table 1), despite being of considerable linear extent.

2.5 Gorse and broom scrub

Scrub communities, generally dominated by gorse and broom, have frequently developed from ungrazed grasslands. These areas occurred beside the river where management had ceased or grazing intensity was reduced. Given freedom from disturbance, such sites may develop eventually into broadleaved woodland. A total of 224 ha of gorse/broom scrub was located, most commonly between Aboyne and Ballater (Table 1).

2.6 Dwarf-shrub heath

Though heather moor was widespread within the catchment near the Dee, it was only abundant in the upper reaches of the study area (Table 1). Heather moor was generally poor in species, particularly herbs and grasses, and required burning for maintenance. On less acid soils, a species-rich variant occurred containing bitter vetch, wintergreens and many plants found in species-rich bent/fescue grassland. This variant occupied only 59.5 ha, all in the section of river between Aboyne and Invercauld Bridge. It was notable for the presence of 74 different species in 3 relevés, with an average of 35 species per relevé. Another type of heath contained much purple moor-grass; hence, it is termed Molinieto-Callunetum. It occurred on well-drained peats within drier heather moor above 370 m, and was grazed by red deer.

2.7 Marsh and swamp communities

Communities dominated by heath rush and mat-grass, together or singly, were found within the species-poor bent/fescue grassland where drainage was poor or lateral water movement occurred. Grazing was usual, preventing successions to heath. As the altitude increased, these communities became more extensive, but the total area occupied was very small (9.4 ha, Table 1). Similar vegetation occurs quite widely in the catchment on unimproved farmland.

The sedge nodum containing several *Carex* species occupied small areas characterized by the presence of a high water table. This type graded into a willow community in places. At the riverside and in backwaters, this nodum passed into fringing reedswamp (Holmes 1985). The total area was 4.4 ha (0.5%), though the type was difficult to map and this figure is probably an under-estimate.

Another type of marsh called the soft rush nodum (Sphagneto-Juncetum effusi) occupied 24 ha, with 18 ha between Ballater and Linn of Dee. It was found throughout the length of the river but rarely in patches more than a few m^2 in size. The cover of *Sphagna* reduced as the altitude decreased. It occurred in areas of poor drainage on gleyed soils.

2.8 Shingle

The bare shingle islands, of which Cults is the most notable, had a montane and ruderal flora of their own. Cults, for example, contained species washed down from high level, eg mountain sorrel and northern rock-cress, and, being tidal, there were also coastal plants such as sea campion and thrift. Other montane plants washed down the Dee and permanently established at many locations included northern bedstraw, yellow saxifrage and scurvygrass. The Nootka lupin, introduced from North America in the last century (Marren 1982), and now characteristic of major rivers in north-east Scotland, is widespread in the sections below Braemar.

3 The value, management and conservation of the vegetation

A complete description of the vegetation of the floodplain of a river has not previously been attempted in north-east Scotland. We are not aware of any standards for comparison. The Dee valley is particularly suitable for such a study as the width of the floodplain rarely exceeds 1000 m. Determining the boundaries of the study area posed some problems as the valley floor is bounded by a series of river terraces (Maizels 1985), and a decision as to which of these to take was sometimes arbitrary. In other cases where a site straddled the arbitrary limit set, eg Quithel Wood, it was also difficult to decide exactly where to site the boundary of the study area. However, only the amount of arable land would be significantly altered by changing the boundary of the area, and we think that the figures provide a good guide to the relative amounts of semi-natural vegetation on the valley floor.

The semi-natural vegetation of the floodplain of the Dee is an important resource. Permanent vegetation reduces soil erosion on the valley floor; lupins and other plants stabilize shingle; and alders protect the banks, slowing down the rate at which the river changes course. Many of the woods are used for shooting, particularly of pheasants, and some stretches of grassland and dwarf-shrub heath provide good grazing for domestic stock. In addition to its purely economic value, the vegetation is important as a reservoir of wild plant species and animals, and as a main contributor to the appearance of the landscape.

The catchment of the Dee contains nationally rare examples of pinewoods, birchwoods and heather moors with associated wildlife, and on the valley floor there are vegetation types scarce elsewhere in the Grampian Region, particularly alderwoods, mixed broadleaved woods, meadow grasslands and tall-herb communities. To a naturalist, perhaps the most interesting vegetation type is the tall-herb community, which occurs in 0.4% of the study area. This vegetation probably owes its existence to the association of rich soils (derived from outcrops of relatively base-rich rocks) with the mowing of the river banks for ease of fishermen. If the mowing were stopped, the composition of this vegetation would soon change. Despite fluctuations in income from the salmon fishery, we hope that the practice of mowing will continue. The attention of the Nature Conservancy Council is drawn to the desirability of preserving these habitats. Already, the diverse wood at Quithel is an SSSI, together with 3.5 km of bank at Potarch, whilst Ballochbuie pinewood SSSI and Dinnet oakwood and Muir of Dinnet NNRs lie partly within the Dee's floodplain.

It is paradoxical that for the maintenance of botanical and zoological interest there should be different priorities in the management of the river banks. For the conservation of otters and some invertebrates, the preservation of scrub on the banks is paramount (Jenkins 1981; Davidson *et al.* 1985). On the other hand, to maintain grassland, it is necessary to remove scrub and mow or graze. Fortunately, compromise is possible. There is plenty of river bank with acid soils for otter havens and the current recommendations to NCC for the specific management of parts of SSSIs for otters are to preserve scrub on only about 50 m in every 500 m (Jenkins pers. comm.).

Mixtures of marine and alpine vegetation on the shingle islands in the lower part of the valley are unusual but not unique. They are also found on the Rivers Tay and Spey in eastern Scotland. Nonetheless, scientifically, they are an important part of the vegetation of this river system.

Few would challenge the value of trying to maintain the semi-natural vegetation, but many threats face it. As already mentioned, grasslands, meadows and heaths below the altitude of the treeline will revert to scrub and woodland if they are not grazed, cut or burnt. Conversely, woodlands will not survive if grazing by sheep, cattle or red deer occurs at too great an intensity. Stock reductions or fencing will be needed in such cases. It may seem perverse to check successions both to and from woodland, but for many plant species entry to new habitat even little distant from present communities seems difficult. Moreover, woods often cannot regenerate beneath their own shade, and adjacent unwooded ground on which regeneration can occur should be set aside (and fenced off) to perpetuate the tree species in the wood.

More direct threats arise from changes in land use or from the introduction of more intensive forms of management. The most important threats include the following.

i. Improvement for agricultural purposes of the remaining semi-natural grasslands, by drainage, liming or re-seeding. This is particularly important on the floodplain.

ii. Conversion of low-yielding broadleaved woodlands composed of native species into higher-yielding coniferous woods.

iii. Planting riverside moors with commercial trees.

iv. Work to stabilize the river course and to reinforce banks, which leads to the destruction of shingle bars and islands and their natural vegetation.

There is one activity which seems totally unnecessary, namely the disposal of waste over the edge of steep bluffs and into abandoned channels. Some of the most notorious examples of this activity concern urban waste, but it is common for farm rubbish and stones to be dumped into abandoned channels and over the edge of beautifully wooded bluffs.

To protect the important vegetation types, more information on variation in composition between different sites is needed. Given that knowledge, the best examples of vegetation can be selected and appropriate management regimes recommended. The survey of semi-natural vegetation within the Grampian Region organized by Miss E Woodward will, when completed, help decide the scarcity value of the Dee valley communities. Some judgement must also be made about the extent of the catchment which should be retained in semi-natural vegetation if river quality is to be maintained. The need for more data must not, however, delay action on the ground to protect the best of the vegetation. There are 4 stages to such protection.

i. Agree management objectives for particular sites with conservationists and owners.

ii. Provide general information to managers, perhaps in the form of guidelines about desirable management methods.

iii. Safeguard key areas by statutory notification of areas as SSSIs to enable the protection of the Wildlife and Countryside Act to be given.

iv. Provide financial support to encourage the conservation of natural and semi-natural vegetation.

4 Conclusion

It is to be hoped that one successful achievement of this symposium will be the widespread dissemination to owners, occupiers and other land managers of knowledge of the value of the riverside land for nature conservation. In the longer term, the conservation of the vegetation cannot be considered in isolation from the conservation and management of other biological resources in the river, and it may be necessary to create an appropriate forum in which the wide range of issues involved can be discussed constructively.

5 Summary

5.1 This paper describes the vegetation of the valley floor, which is distinguished as the area where

river processes and management related to the river both operate. The vegetation on the valley floor was closely related to river processes, landform and management.

5.2 Twenty-three different vegetation types are described.

5.3 Mixed broadleaved woods, alderwoods, meadow grasslands and herb-dominant vegetation were the most significant of these vegetation types because, in the Dee catchment, they were virtually confined to the valley floor.

5.4 The survival of these vegetation types is threatened by land improvement, commercial forestry and bank engineering. To protect these types of vegetation, land managers need to be informed of their value, and appropriate systems of management need to be drawn up jointly with wildlife conservationists.

6 Acknowledgements

We thank the landowners involved for permission to visit their estates.

7 References

Birse, E. L. & Robertson, J. S. 1976. *Plant communities and soils of the lowland and southern upland regimes of Scotland.* (Soil survey of Scotland monograph.) Aberdeen: Macaulay Institute for Soil Research.

Davidson, M. B., Owen, R. P. & Young, M. R. 1985. Invertebrates of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 64-82. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Holmes, N. T. H. 1985. Vegetation of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 42-55. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Jenkins, D. 1981. Ecology of otters in northern Scotland. V. A model scheme for otter *Lutra lutra* L. conservation in a freshwater system in Aberdeenshire. *Biol. Conserv.,* **20,** 123-132.

McVean, D. & Ratcliffe, D. 1962. *The plant communities of the Scottish highlands.* London: HMSO.

Maizels, J. K. 1985. The physical background of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 7-22. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Marren, P. R. 1982. *A natural history of Aberdeen.* Finzean: Robin Callander.

Steven, H. M. & Carlisle, A. 1959. *The native pinewoods of Scotland.* London: Oliver & Boyd.

Invertebrates of the River Dee

M B DAVIDSON*, R P OWEN* and M R YOUNG[†]
*North East River Purification Board, Aberdeen
[†]Department of Zoology, University of Aberdeen

1 Introduction

This paper concentrates on the larger, bottom-living invertebrates of the River Dee. They are a vital link in the food chain, being essential food for economically important species such as the salmon, and leading ultimately to those with significance for conservation such as the otter and dipper. Furthermore, they are generally recognized as being excellent indicators of the 'health' of a river and, because they form an integral part of regional and national monitoring schemes, comparisons can be made easily with other river systems. They show the essential characteristics required by organisms which are useful as 'indicators' of the state of a river, that is they are abundant, easily caught and identified, fairly sedentary, show a wide range of tolerances, and are present throughout the year. They integrate temporal variations in river water quality in a way no other features do, and so even short episodes of pollution, which might be missed by infrequent chemical analysis, are detectable by studying them.

In this study, the invertebrate data have been looked at in 2 ways. First, the communities of animal species at each site have been compared, using association analysis, and their similarities or differences related subjectively to environmental factors. Second, certain individual species have been selected which show different distribution patterns within the catchment and the reasons for these differences have been explored. Additionally, in order to demonstrate distribution differences on a smaller scale, the environmental preferences within one site of several members of the ephemeropteran (mayfly) family, the Heptageniidae, have been investigated.

A diversity index and a biotic score system which are widely used in pollution assessment have been applied to the data to demonstrate the effects of pollution and enrichment at certain sites, and to enable comparisons to be made with other river systems.

Actual or potential threats to this special river create a particular need for this type of study. Although many of these problems are of a lowland nature, such as from agriculture, industry and urban centres, there are, in addition, upland problems such as recreation and afforestation.

This study describes the characteristic invertebrate communities of the river and its tributaries, and suggests some explanation of the reasons for their variations. It provides an essential baseline for 1983-84, against which future changes may be judged, and allows comparison with other rivers, most of which are more affected by man's activities. It also enables an assessment to be made of the effect of current problems, and suggests actions needed to prevent any deleterious changes in the future.

2 Study area and sites

Samples were taken at 30 sites for this study, 10 on the main river and 20 on various tributaries in the upper, middle and lower parts of the catchment (Figure 1).

The sites (Table 1) are situated in a variety of land use areas: for example, the upper tributaries drain the Grampian Mountains with high-altitude deer forest; the intermediate ones drain hill-farming areas, grouse moor and coniferous forest; and the lower ones drain agricultural land, industrial sites and urban areas.

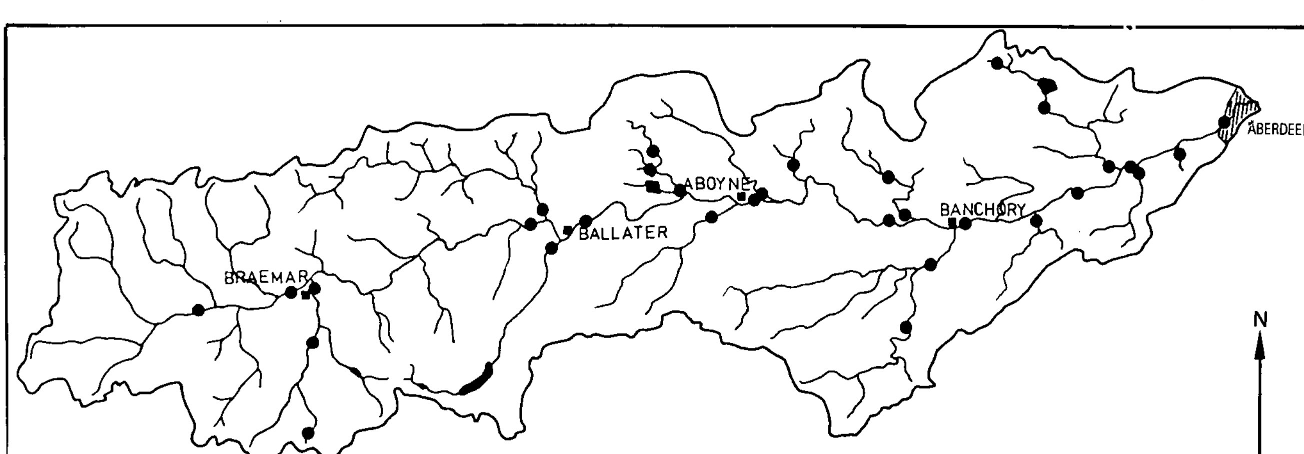


Figure 1. River Dee catchment sampling sites

Table 1. Sites sampled for invertebrates in the catchment of the Dee

Number	Watercourse	Site name	Grid reference	Altitude (m)	Distance from source of Dee (km)
1	Dee	Linn of Dee	NO 061 897	360	21
2	Dee	Braemar	NO 143 914	323	31
3	Dee	Polhollick	NO 344 966	220	57
4	Dee	Ballater	NO 386 966	190	62
5	Dee	Aboyne	NO 549 977	115	85
6	Dee	Potarch	NO 607 974	90	94
7	Dee	Silverbank	NO 716 963	46	109
8	Dee	Park Bridge	NO 797 983	30	117
9	Dee	Milltimber	NO 856 004	<15	127
10	Dee	Aberdeen	NO 928 036	—	136
					Distance to confluence of tributary (km)
11	*Clunie*	Cairnwell	NO 139 781	640	—
12	*Clunie*	Campsite	NO 152 879	470	—
13	*Clunie*	Braemar	NO 151 913	320	32
14	*Gairn*	Bridge of Gairn	NO 352 971	220	58
15	*Muick*	Bridge of Muick	NO 366 948	200	61
16	*Logie*	Galton	NJ 441 029	180	—
17	*Dinnet*	Mill of Dinnet	NO 468 992	152	76
18	*Tanar*	Bridge O'Ess	NO 504 972	150	82
19	*Tarland*	Aboyne	NO 550 980	120	87
20	*Dess*	Lumphanan	NJ 572 034	147	91
21	*Beltie*	Torphins	NJ 636 006	120	—
22	*Canny*	Invercanny	NO 668 964	75	103
23	*Feugh*	Strachan	NO 675 922	74	108
24	*Dye*	Bridge of Bogendreip	NO 663 911	90	—
25	*Sheeoch*	Durris	NO 772 961	45	114
26	*Kinnernie*	Dunecht	NJ 772 083	90	—
27	*Leuchar*	Garlogie	NJ 783 068	76	—
28	*Culter*	Kennerty Mills	NJ 839 003	20	125
29	*Crynoch*	Milton Bridge	NJ 858 001	<15	127
30	*Ardoe*	Ardoe House	NJ 893 016	<15	129

The tributaries vary in catchment area from the *Ardoe*, at a little over 4 km^2, to the *Gairn* at 148 km^2, although most are over 40 km^2. The majority of the tributary sites were located close to the main river, but some were placed for the purposes of monitoring specific pollution threats in various parts of the catchment: the upper *Clunie* is near the ski-ing areas of Glenshee, the *Logie* is downstream of a sewage works' discharge but above the Muir of Dinnet National Nature Reserve (NNR), and the *Leuchar* is the outlet stream of the highly eutrophic Loch of Skene.

The precise location of each site was carefully chosen so that the substrate types were as similar as possible, with eroding beds and turbulent water flow. However, amongst these 'riffle' sites, there were inevitable differences due in part to discharge regimes and also to geological variation. In the main river, substrates varied from well-distributed, evenly sized cobbles and gravels at Braemar, Silverbank, Milltimber and Aberdeen, to fairly heterogeneous compositions of bedrock and boulders with pockets of gravels and sands at Polhollick and Potarch. Many of the tributary sites had similar substrates of bedrock with boulders and a heterogeneous distribution of gravels. These included the large watercourses of the *Gairn* and the *Muick*, the intermediate ones such as the *Tanar*, the *Canny*, the *Feugh* and the *Dye*, but also some small ones like the *Sheeoch* and the *Ardoe*. Most of the other tributaries had mixtures of cobbles, pebbles, gravels and sands in various proportions, although the *Kinnernie*, for example, had a rather homogeneous combination of fine gravel and sand.

Some of the tributary locations were peculiar, in that they were the immediate outlet streams for areas of standing water; the *Dinnet*, the *Leuchar* and the *Ardoe* drain the Lochs Davan and Kinord, Loch of Skene and Ardoe Dam, respectively.

3 Methods

3.1 Sample collection

Samples of bottom-living invertebrates were collected using a hand-net and a standard 'heel-kick' technique (Furse *et al.* 1981). After each site visit, the animals collected were preserved and hand-sorted from the accompanying substrate material in the laboratory. Identification was taken to species level in most cases, but to genus and family in a few groups. The level of taxonomic differentiation was consistent with most other recent studies on freshwater macro-invertebrates (Jenkins *et al.* 1984; Clare & Edwards 1983; Scullion *et al.* 1982).

Apart from one site, all the locations were sampled in April, August and October 1983, and in April/May and

August 1984. These dates were taken to correspond with spring, summer and autumn seasons. The only exception was the *Sheeoch*, which was not sampled in summer 1983. The last 3 sample sets were used to derive a diversity index and, for this purpose, the invertebrates were also counted.

3.2 Classification and ordination techniques

Groups of similar sites within the river and tributaries and then groups of species with similar preferences were identified using TWINSPAN analysis. This is a polythetic, divisive hierarchical classification technique devised by Hill (1979b), which splits up the total group of sites into sub-groups based on their shared species and arranges them along a gradient depending on the degree of similarity between their species components. The dendrogram produced can be used as a 'key' for placing sites in their correct group by identifying the most characteristic 'indicator' species for each group. No exact statistical guidance is given as to the level at which division should be stopped but, generally, the earlier the division, the more information it conveys.

The next stage in the analysis was an ordination which arrayed the sites along various axes, with succeeding axes reflecting less and less of the overall variation. The technique used was Detrended Correspondence Analysis, ie DECORANA (Hill 1979a). The clusters produced by this method do not correspond exactly to the single axis TWINSPAN dendrogram groups but, if axis 1 of DECORANA reflects most of the variation (as is often the case), then correspondence is quite good.

3.3 Diversity index

Environmental stress frequently reduces community diversity (Hellawell 1978), and changes in community structure are often assessed by a diversity index. Many lotic invertebrate studies have used the Shannon-Weaver index (Shannon & Weaver 1963), so it has been used in this study in order to facilitate comparisons with other rivers.

This index relates the numbers of each individual taxon to the total numbers of animals in the community and takes the form:

$$d = -\sum (n_i/N \log^2 n_i/N)$$

where n_i = the number of individuals in the ith taxon, and N = total number of individuals in the sample.

The Shannon-Weaver diversity index was calculated for each of the counted samples, ie for each site for autumn 1983, and for spring and summer 1984.

3.4 Biotic score

Certain indices have been developed which make use of the varying tolerances of different species to pollution, and many assign 'scores' which reflect these pollution tolerances. However, not all of these indices can be applied to a wide variety of river types.

The Biological Monitoring Working Party (BMWP) score system was developed with the aim of nationwide applicability in assessing the biological condition of rivers (BMWP 1978), and has recently been tested on 41 rivers throughout the UK, including the Dee (Armitage *et al.* 1983). Because this system facilitates the placing of the Dee in a British context, it seemed logical to use it in this study. The version used is the Average Score Per Taxon (ASPT) which allows the collection of more information with less effort and reduces seasonal variation (Armitage *et al.* 1983).

The BMWP (ASPT) score has been calculated on the cumulative species list for each site over the 5 surveys. This procedure tends to maximize the scores and integrate seasonal variation and, for the purposes of this study, presents a broad view of the biological conditions pertaining during the study period.

4 Results

4.1 Species lists

The species lists for each of the 30 sites used in this study, which formed the basis of all subsequent analysis, are combined in Table 2 to give a total list for the whole catchment (the raw data are available from the North East River Purification Board). The list is not exhaustive and includes only those taxa encountered in this study; other species undoubtedly occurred at other sites.

4.2 Classification and ordination analysis

The dendrogram in Figure 2 displays the result of the TWINSPAN analysis of the sites/species matrix derived from the species lists and, at the fourth level of division, has produced 10 groups of sites associated by their similar invertebrate communities and arrayed along a similarity gradient.

The first 4 groups (A-D) included all the main river sites, and geographically adjacent sites were placed together. The exceptions were sites 6 and 10 (Potarch and Aberdeen). Most of the major tributaries such as the *Muick, Tanar* and *Feugh* were grouped with the middle main river sites, while the *Gairn* and lower *Clunie* were placed with the 2 highest main river sites.

The central part of the dendrogram (groups E-G) encompassed the richer tributaries of the middle catchment, which drain areas including agricultural land, and this description could probably include the *Crynoch* at the lower end of the catchment. The anomalous site in this group was the *Clunie* at Cairnwell (site 11), below the Glenshee ski development.

The remaining portion of the dendrogram (groups H-J) separated off the *Leuchar/Culter* sub-catchment, the *Dinnet* and the *Ardoe*, all of which are the outlet streams of lochs or impoundments. The *Kinnernie* was included in this group and is the inlet stream of the Loch of Skene, below the village of Dunecht.

A similar procedure was followed for the species associations, producing the TWINSPAN dendrogram in Figure 3 which relates to the groups listed in Table 3. Again, the analysis was terminated at level 4, and at this point there were 10 groups of associated species. The first division split the species into 2 major groupings: A-G containing 85 species, and H-L the remaining 40 species. Groups H-L can be defined, broadly, as including those species which occur at the more 'enriched' sites and, in particular, those which live in the outlet streams of lochs and ponds.

Groups A-G represent the characteristic communities of the Dee system and, because of the general uniformity of the sites used in the analysis, defining these associations in terms of environmental factors is a much more difficult proposition. However, certain general statements can be made: groups A and B include species characteristic of the smaller tributaries with slower flows and gravelly substrates; group C contains species which occur in the main river and the larger tributaries; groups F and G are associations of species which are widespread within the catchment.

Table 2. Species found at the sample areas in the Dee catchment

PLECOPTERA (STONEFLIES)

Taeniopteryx nebulosa (L.)
Brachyptera putata (Newman)
Brachyptera risi (Morton)
Protonemura praecox (Morton)
Protonemura montana (Kimmins)
Protonemura meyeri (Pictet)
Amphinemura sulcicollis (Stephens)
Nemoura cinerea (Retzius)
Nemoura avicularis (Morton)
Nemoura cambrica (Stephens)
Leuctra geniculata (Stephens)
Leuctra inermis (Kempny)
Leuctra hippopus (Kempny)
Leuctra fusca (L.)
Capnia bifrons (Newman)
Perlodes microcephala (Pictet)
Diura bicaudata (L.)
Isoperla grammatica (Poda)
Dinocras cephalotes (Curtis)
Perla bipunctata (Pictet)
Chloroperla torrentium (Pictet)
Chloroperla tripunctata (Scopoli)

EPHEMEROPTERA (MAYFLIES)

Baetis scambus Eaton
Baetis vernus/tenax Curtis/Eaton
Baetis rhodani (Pictet)
Baetis muticus (L.)
Centroptilum luteolum (Müller)
Rhithrogena semicolorata (Curtis)
Heptagenia sulphurea (Müller)
Ecdyonurus venosus (Fabricius)
Ecdyonurus torrentis Kimmins
Ecdyonurus dispar (Curtis)
Leptophlebia marginata (L.)
Paraleptophlebia submarginata (Stephens)
Ephemerella ignita (Poda)
Ephemerella notata Eaton
Ephemera danica Müller
Caenis rivulorum Eaton

TRICHOPTERA (CADDIS FLIES)

Rhyacophila dorsalis (Curtis)
Rhyacophila obliterata McLachlan
Glossosoma spp.
Agapetus spp.
Philopotamus montanus (Donovan)
Wormaldia spp.
Plectrocnemia conspersa (Curtis)
Polycentropus flavomaculatus (Pictet)
Hydropsyche pellucidula (Curtis)
Hydropsyche angustipennis (Curtis)
Hydropsyche contubernalis (McLachlan)
Hydropsyche siltalai Döhler
Hydropsyche instabilis (Curtis)
Hydroptilidae
Drusus annulatus Stephens
Ecclisopteryx guttulata (Pictet)
Limnephilus spp.
Anabolia nervosa Curtis
Potamophylax latipennis (Curtis)
Potamophylax cingulatus (Stephens)
Halesus radiatus/digitatus
Stenophylax lateralis/sequax
Allogamus auricollis (Pictet)
Odontocerum albicorne (Scopoli)
Athripsodes spp.
Goera pilosa (Fabricius)
Silo pallipes (Fabricius)
Lepidostoma hirtum (Fabricius)
Lasiocephala basalis (Kolenati)
Brachycentrus subnubilus Curtis
Sericostoma personatum (Spence)

DIPTERA (TWO-WINGED FLIES)

Tipula spp.
Hexatoma spp.
Pedicia spp.
Dicranota spp.
Elaeophila spp.
Taphrophila spp.
Psychodidae
Ceratopogonidae
Chironomidae
Simulidae
Hemerodromia spp.
Clinocera spp.
Atherix ibis (Fabricius)
Limnophora spp.

MEGALOPTERA (ALDER FLIES)

Sialis lutaria (L.)

COLEOPTERA (BEETLES)

Brychius elevatus (Panzer)
Haliplus spp.
Potamonectes depressus/elegans
Oreodytes sanmarki (Sahlberg)
Platambus maculatus (L.)
Agabus spp.
Helophorus spp.
Hydraena gracilis Germar
Elmis aenea (Müller)
Esolus parallelepipedus (Müller)
Limnius volckmari (Panzer)
Oulimnius tuberculatus (Müller)

Table 2.—continued

HEMIPTERA (WATER BUGS)

Sigara concinna (Fieber)

MOLLUSCA (WATER SNAILS)

Potamopyrgus jenkinsi (Smith)
Lymnaea peregra (Müller)
Physa fontinalis (L.)
Planorbis albus Müller
Planorbis contortus (L.)
Ancylus fluviatilis Müller
Sphaerium spp.
Pisidium spp.

HYDRACARINA (WATER MITES)

Unidentified spp.

MALACOSTRACA (WATER SLATERS & SHRIMPS)

Asellus aquaticus (L.)
Asellus meridianus Racovitza
Gammarus pulex (L.)
Gammarus zaddachi Sexton

HIRUDINEA (LEECHES)

Theromyzon tessulatum (Müller)
Glossiphonia complanata (L.)
Helobdella stagnalis (L.)
Erpobdella octoculata (L.)
Trocheta bykowskii Gedroyc

NEMATODA (ROUND WORMS)

Unidentified spp.

TRICLADIDA (FLATWORMS)

Polycelis tenuis/nigra
Polycelis felina (Dalyell)
Crenobia alpina (Dana)

OLIGOCHAETA (SEGMENTED WORMS)
Enchytraeidae
Lumbricidae
Lumbriculidae
Tubificidae
Naididae

GORDIOIDEA (HORSEHAIR WORMS)

Unidentified spp.

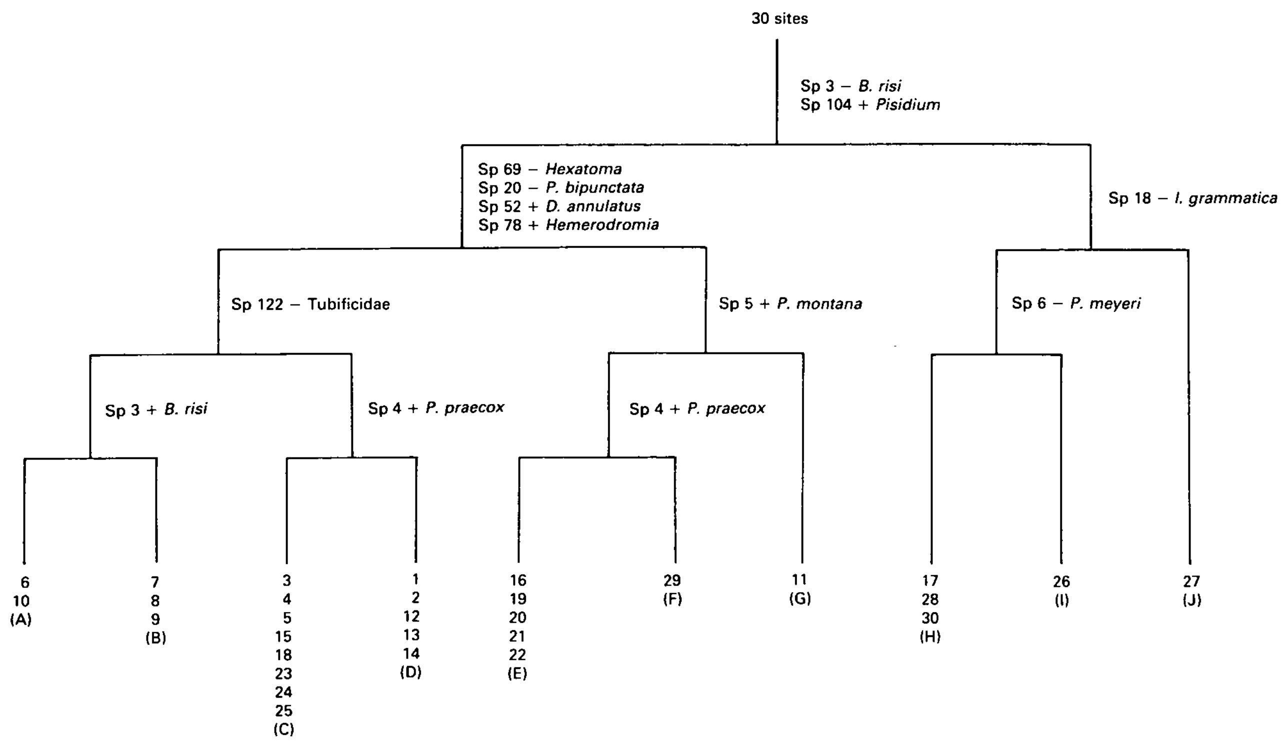


Figure 2. TWINSPAN classification of sites (cf Table 1 for site numbers)

Table 3. TWINSPAN species groups

A — *P. montana*	*E. torrentis*	*S. pallipes*	*Agabus* spp.
N. avicularis	*E. notata*	*R. obliterata*	*O. sanmarki*
C. luteolum	*E. danica*	*Haliplus* spp.	*P. maculatus*
P. submarginata	*H. instabilis*	*P. depressus/elegans*	
B — *D. cephalotes*	*B. vernus/tenax*		
C — *B. putata*	*P. montanus*	Hydroptilidae	*P. fontinalis*
C. bifrons	*Wormaldia* spp.	*A. auricollis*	*Hexatoma* spp.
P. bipunctata	*H. contubernalis*	*Athripsodes* spp.	*Taphrophila* spp.
D. bicaudata	*G. pilosa*	*L. basalis*	*Atherix ibis*
H. sulphurea	*L. hirtum*	*Limnephilus* spp.	*B. elevatus*
E. dispar	*B. subnubilus*	*G. zaddachi*	*T. bykowskii*
D — *B. risi*	*Pedicia* spp.	*C. alpina*	
C. tripunctata			
E — *P. microcephala*	*Glossosoma* spp.	*Tipula* spp.	*E. parallelepipedus*
F — *P. praecox*	*B. scambus*	*Agapetus* spp.	*H. pellucidula*
L. hippopus	*E. venosus*	*P. flavomaculatus*	*O. tuberculatus*
G — *A. sulcicollis*	*B. rhodani*	*Dicranota* spp.	Hydracarina
P. meyeri	*E. ignita*	Chironomidae	Enchytraeidae
L. inermis	*R. semicolorata*	Simulidae	Lumbricidae
L. fusca	*R. dorsalis*	*E. aenea*	Lumbriculidae
I. grammatica	*H. siltalai*	*L. volckmari*	Naididae
C. torrentium	*E. guttulata*	*H. gracilis*	
B. muticus	*S. personatum*	*L. peregra*	
H — *H. rad/digitatus*	*A. fluviatilis*	*P. felina*	Tubificidae
Clinocera spp.	Nematoda		
I — *T. nebulosa*	*P. latipennis*	*Elaeophila* spp.	*Helophorus* spp.
P. conspersa	*P. cingulatus*	*Hemerodromia* spp.	*P. jenkinsi*
D. annulatus	*O. albicorne*		
J — *A. nervosa*	*Pisidium* spp.	*G. pulex*	*G. complanata*
Limnophora spp.	*A. aquaticus*		
K — *C. rivulorum*	Ceratopogonidae	*E. octoculata*	*P. tenuis/nigra*
H. angustipennis			
L — *N. cinerea*	*S. lateralis/sequax*	*P. albus*	*A. meridianus*
L. geniculata	*S. concinna*	*P. contortus*	*T. tessulatum*
L. marginata	Psychodidae	*Sphaerium* spp.	*H. stagnalis*
S. lutaria			

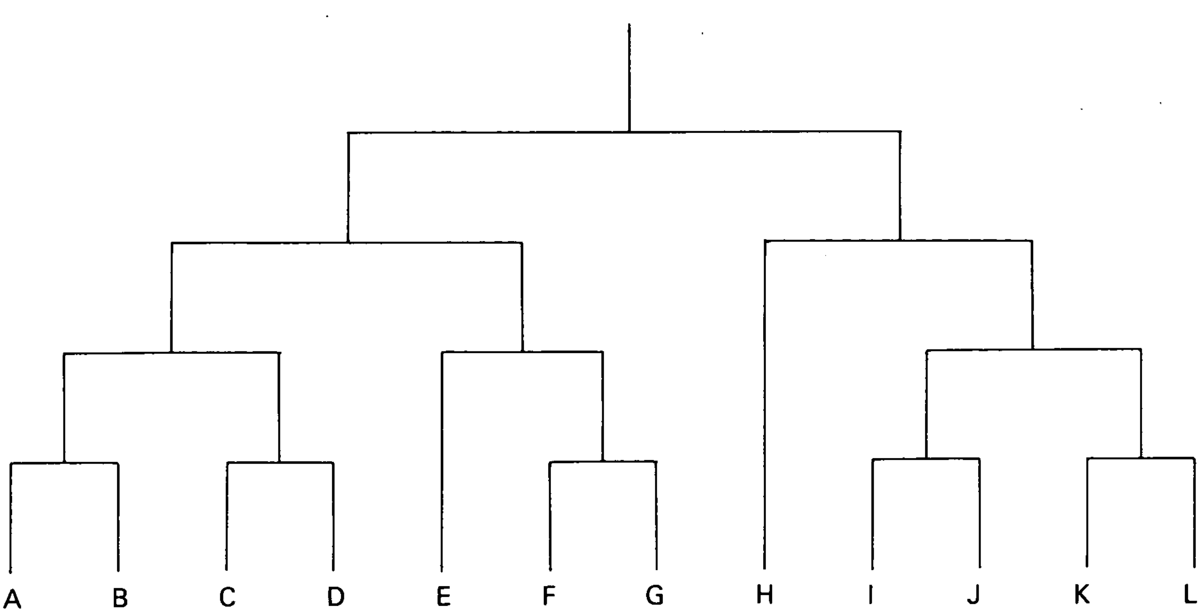


Figure 3. TWINSPAN classification of species (cf Table 3 for details of groups)

As expected, the site associations produced by DECORANA (Figure 4) were essentially the same as in the TWINSPAN dendrogram (Figure 2). Most of the main river sites were closely associated and grouped with the larger, more upland tributaries. The other main association included the middle and smaller, lower catchment tributaries which tended to be somewhat richer and less torrential.

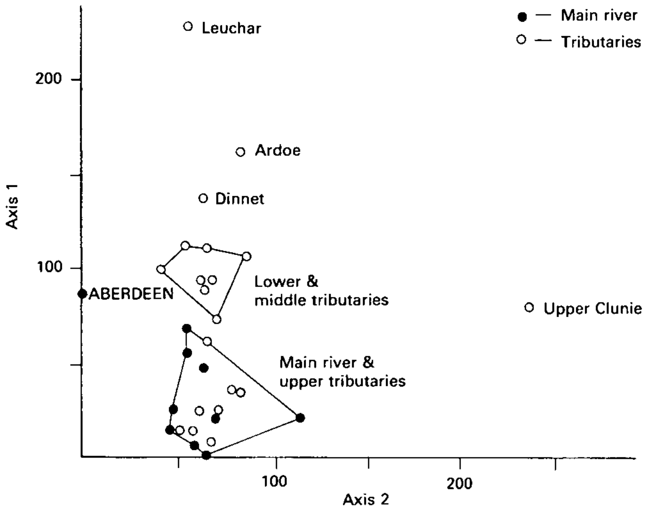


Figure 4. DECORANA ordination plot (axis 1 vs axis 2)

Five sites can be picked out from the diagram as being somewhat different on the basis of their invertebrate communities. These are the main river at Aberdeen (site 10), the *Leuchar* (site 27), the *Ardoe* (site 30), the *Dinnet* (site 17) and the *Clunie* below the ski development (site 11).

4.3 Relative abundance of Plecoptera (stoneflies) and Ephemeroptera (mayflies)

Figure 5 shows the numbers of different species of Plecoptera and of Ephemeroptera which occurred at each of the 10 main river sites in 1983 and 1984. In general, there was a tendency for the number of mayfly species to increase downstream, whereas the numbers of stonefly species remained fairly constant to the tidal limit (just upstream of site 10), with the exception of site 6 at Potarch.

4.4 Distribution of species

Figures 6i-x show a series of sample sites, indicated by open circles, along a linear river (double line) and on a number of tributaries (single lines). The positive occurrence of a particular species at a site is shown by a filled circle. The information used in plotting these diagrams came not only from the present study, but also from Davidson and Young (1980).

These maps show a range of spatial distribution patterns within the Dee catchment, from the ubiquitous species, through those more selective animals preferring tributary or main river sites, to those species with restricted distributions requiring specialized conditions.

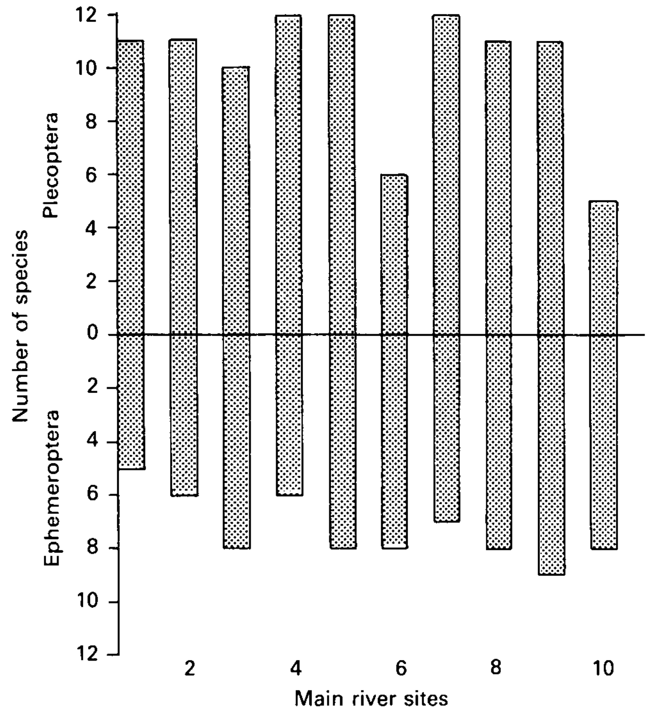


Figure 5. Relative numbers of species of Plecoptera and Ephemeroptera at main river sites

The riffle beetle *Elmis aenea* (Figure 6i) occurred at virtually all sites within the catchment, whereas the mayfly *Heptagenia sulphurea* (Figure 6ii) and the dipteran fly *Atherix ibis* (Figure 6iii), although widespread and well distributed in the main river, tended to be restricted to the longer tributaries.

The 2 common species of flatworm (Tricladida) in the catchment were *Polycelis felina* and *Crenobia alpina*. These had overlapping ranges but quite different distributions. *P. felina* (Figure 6iv) occurred throughout the main river and the smaller tributaries but not in the larger and more oligotrophic streams, such as the *Quoich*, the *Muick* and the *Tanar*. *C. alpina* (Figure 6v), on the other hand, was present in the upper part of the main river, overlapping with *P. felina* (but not necessarily at the same season), and in the more upland tributaries.

The caddis fly (Trichoptera) genus *Hydropsyche* was represented in the catchment by 5 species which had contrasting distributions and which illustrate how animals which are superficially identical share the overall habitat. *Hydropsyche siltalai* (Figure 6vi) and *H. pellucidula* (Figure 6vii) had very similar distributions, both being well spread throughout the catchment. *H. instabilis* (Figure 6viii) was completely absent from the main river, but was found in a number of tributaries, while *H. contubernalis* (Figure 6ix) was restricted to the middle and lower parts of the main river. The fifth species, *H. angustipennis* (Figure 6x), had the most restricted distribution, occurring only in the *Culter* sub-catchment at 2 sites, and in the main river at one site. All of these sites were downstream from the eutrophic Loch of Skene.

Figure 6i-x. Distribution of selected species at sample sites in the Dee catchment, 1984

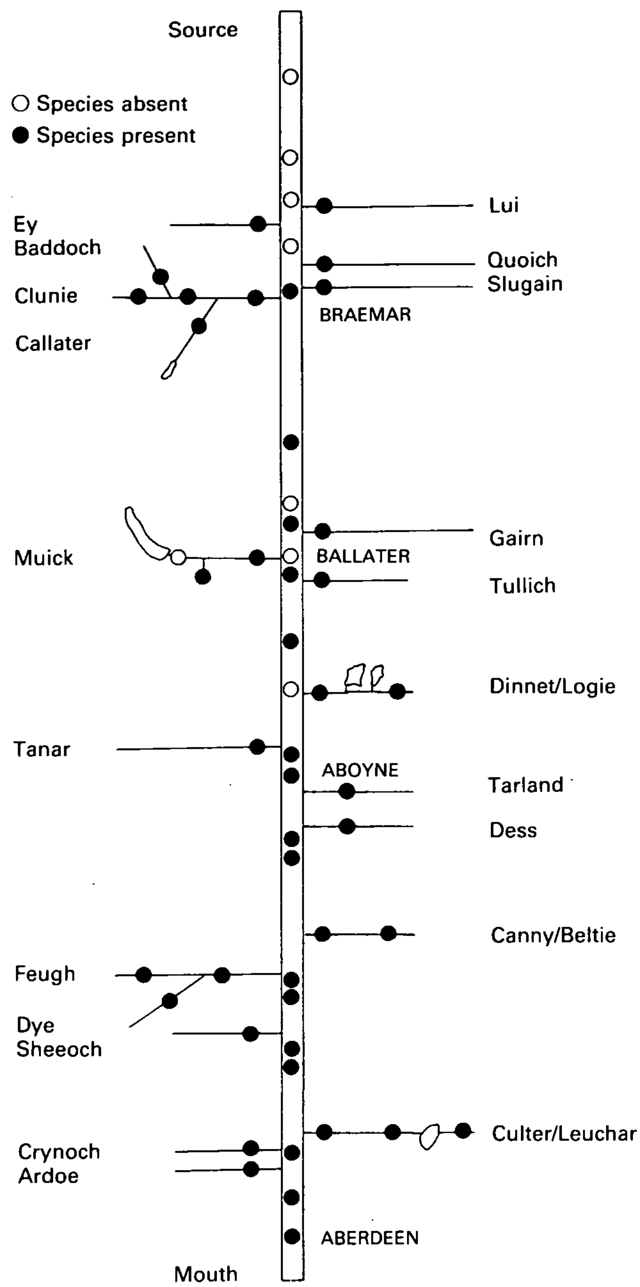


Figure 6i. Elmis aenea

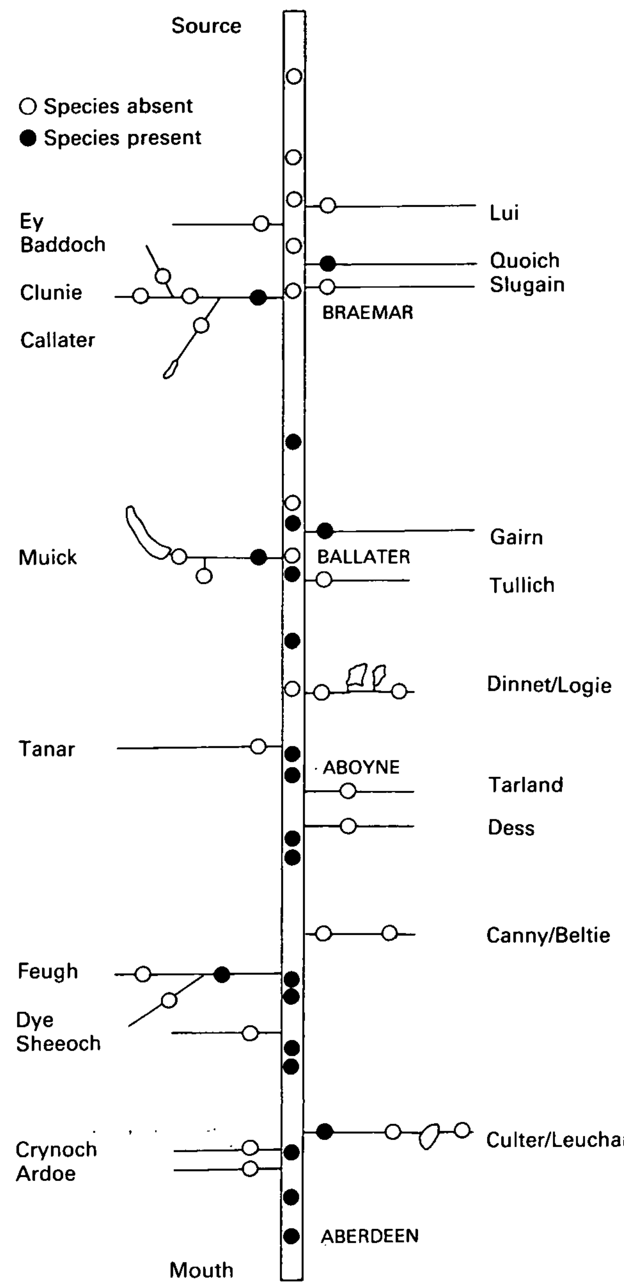


Figure 6ii. Heptagenia sulphurea

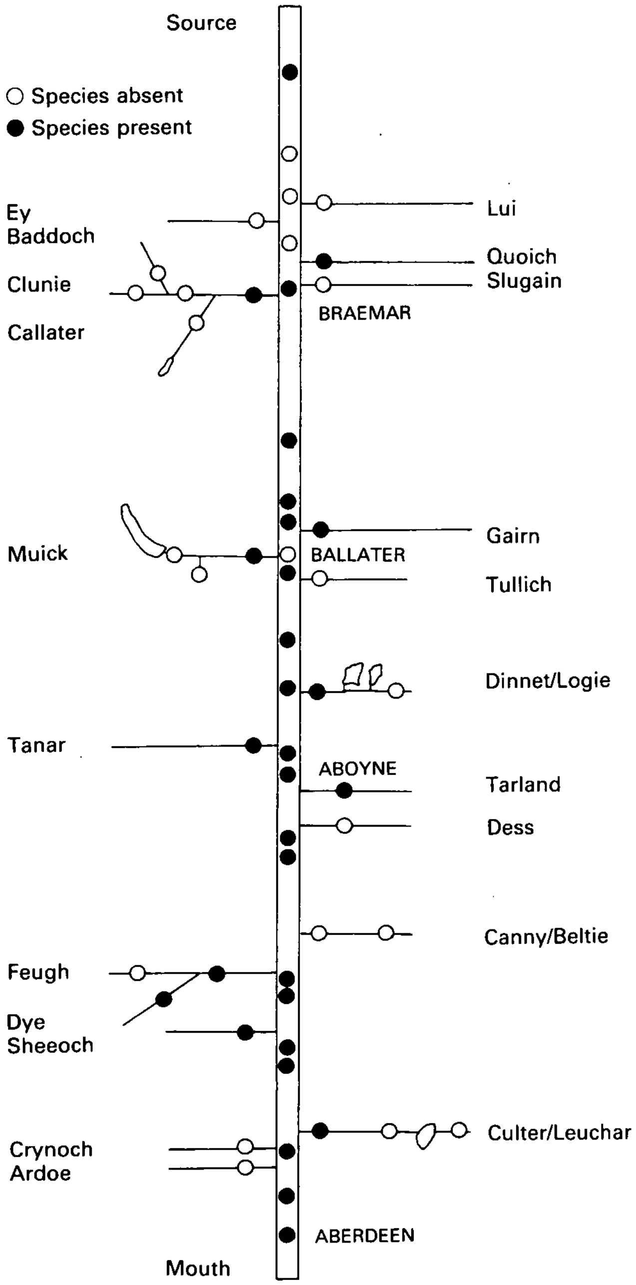


Figure 6iii. Atherix ibis

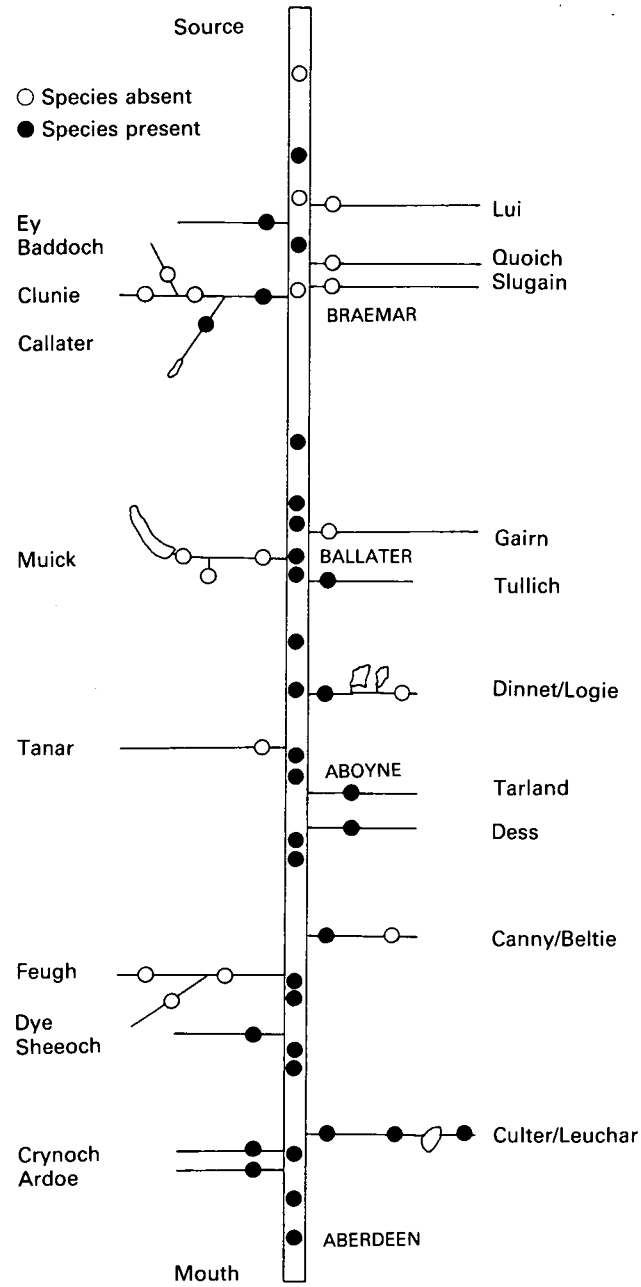


Figure 6iv. Polycelis felina

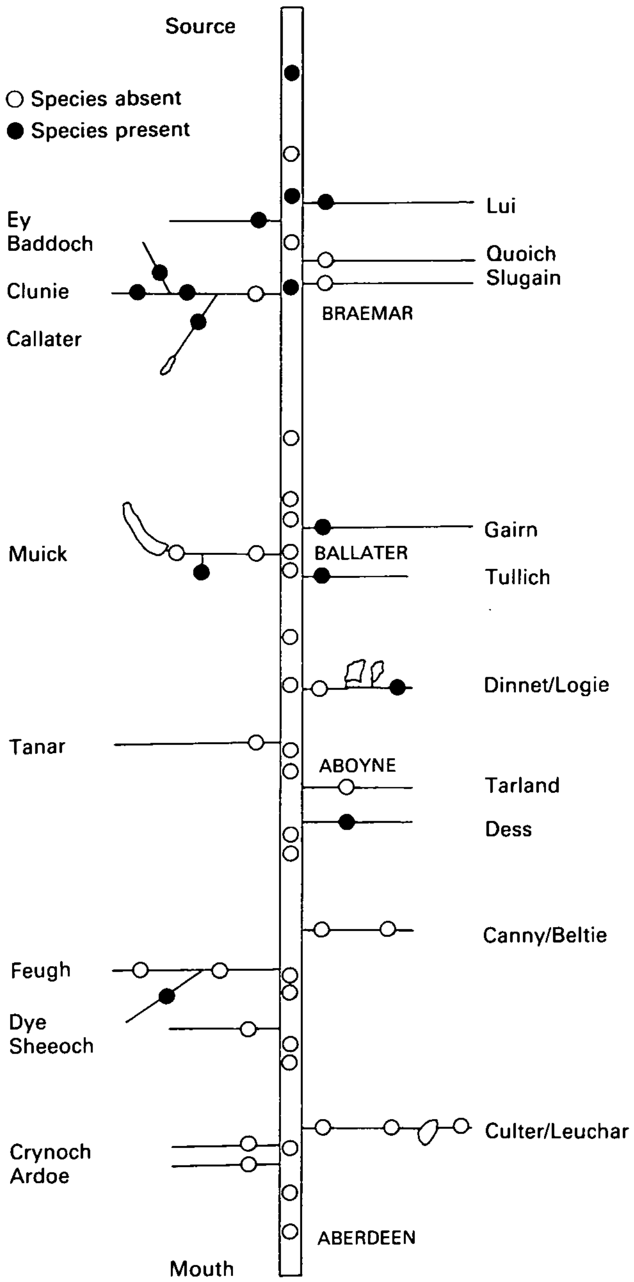


Figure 6v. Crenobia alpina

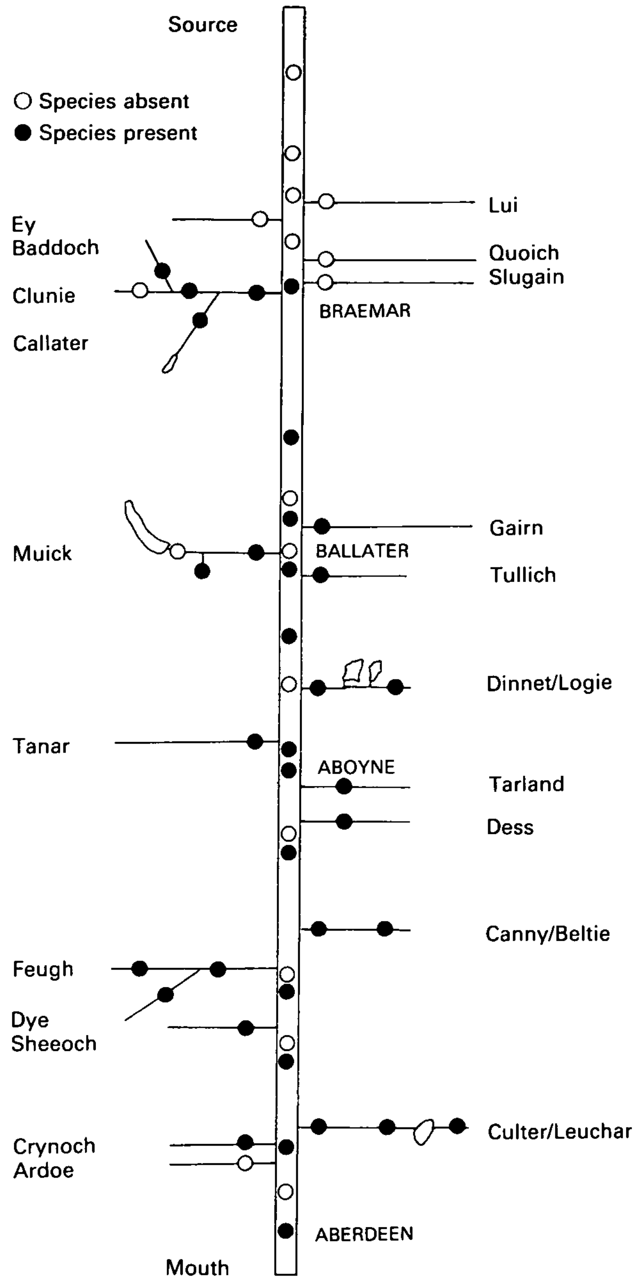


Figure 6vi. Hydropsyche siltalai

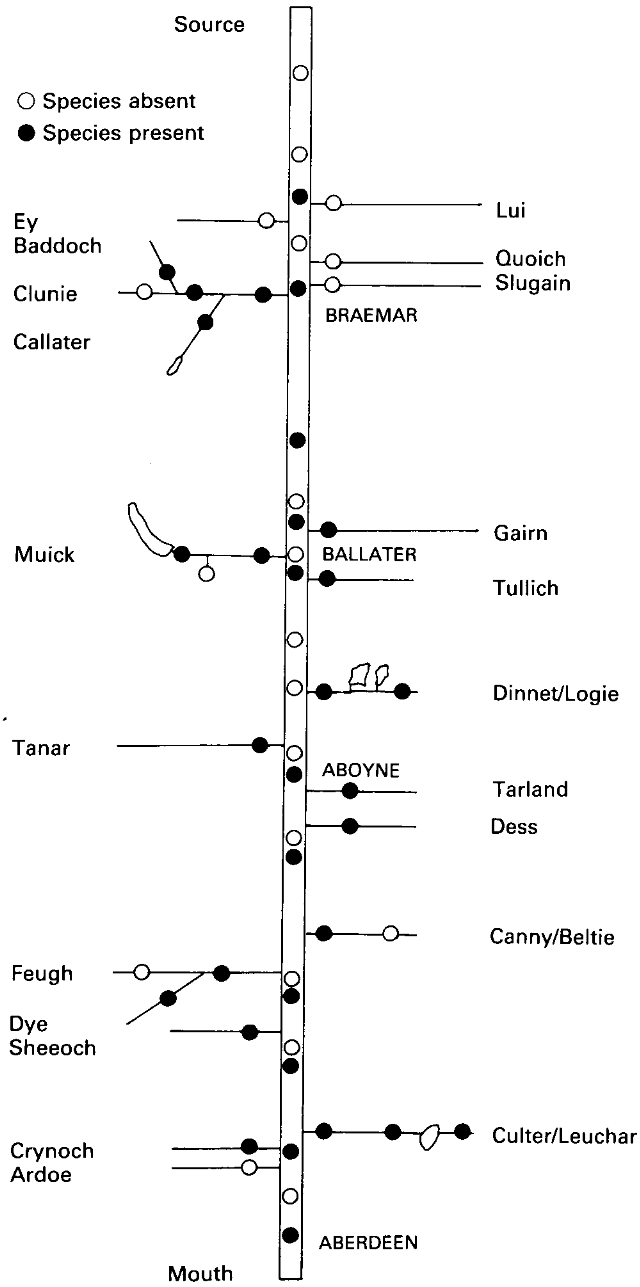


Figure 6vii. Hydropsyche pellucidula

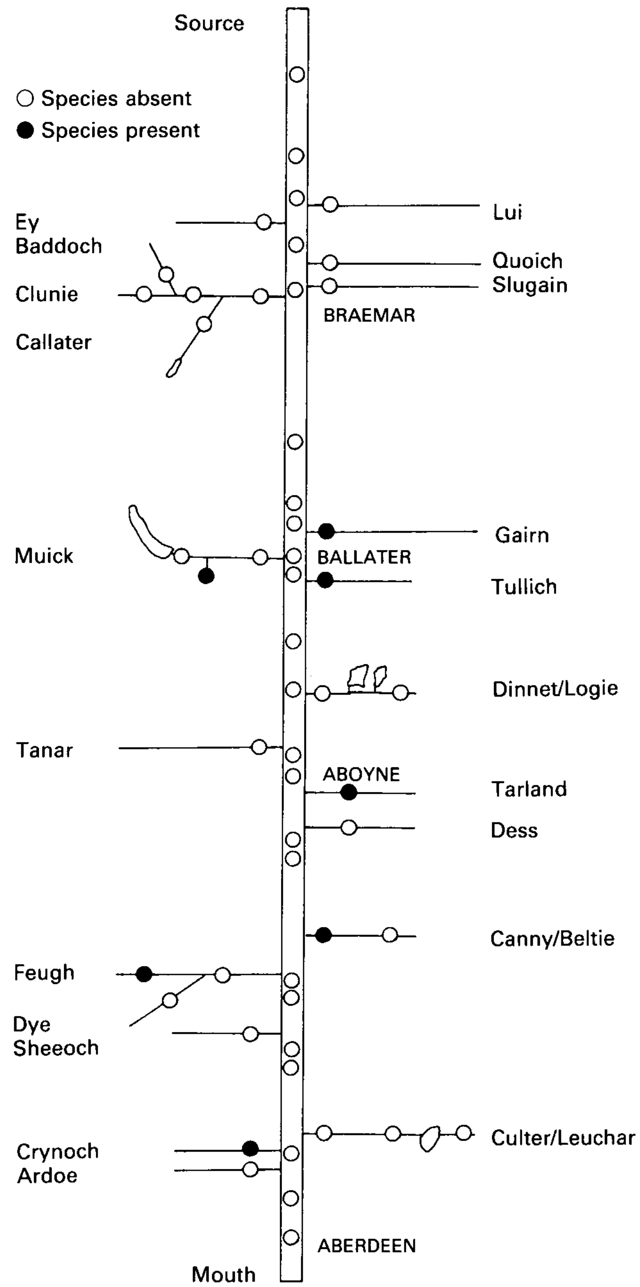


Figure 6viii. Hydropsyche instabilis

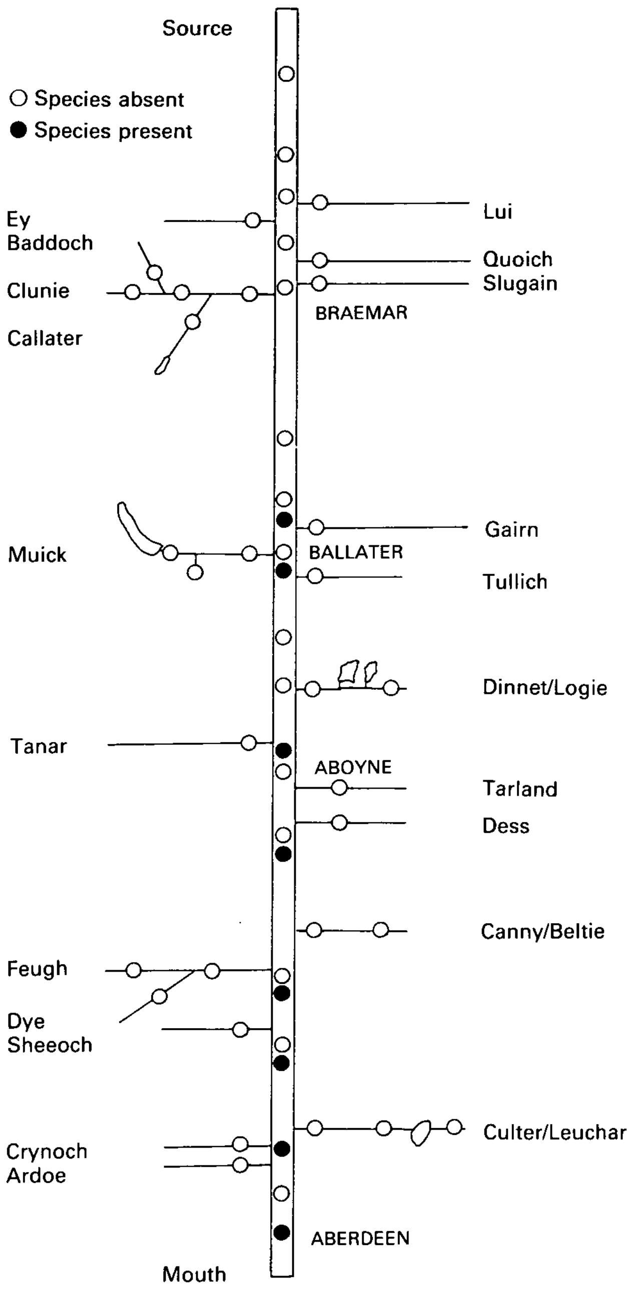


Figure 6ix. Hydropsyche contubernalis

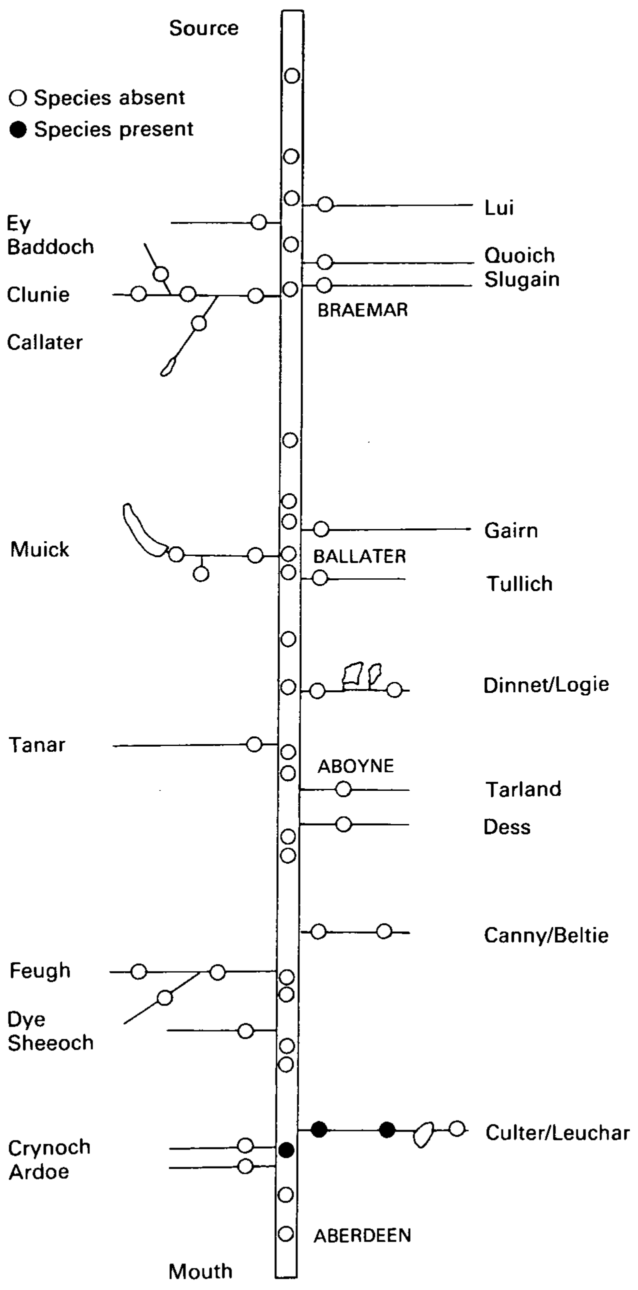


Figure 6x. Hydropsyche angustipennis

Several species had very restricted distributions, such as *Ephemera danica* (Ephemeroptera), found only in the *Tarland*, and *Gammarus zaddachi* (Crustacea) in the Dee only at Aberdeen.

4.5 Habitat preferences amongst Ephemeroptera (mayflies)

MacGowan (1978) examined the detailed habitat preferences of *Ecdyonurus venosus, E. dispar, Rhithrogena semicolorata* and *Heptagenia sulphurea* in the lower Dee at Durris and Maryculter. These species are similar morphologically, all showing strong dorso-ventral flattening, presumably to reduce resistance to the current.

Table 4. Habitat preferences of 4 species of Ephemeroptera larvae from the lower Dee in September 1977

	Habitat preferences			
Species	Depth (0-50 cm)	Stone size ($5\text{-}20\ cm^2$) (approx area)	Current speed ($0.1\text{-}1.1\ m\ s^{-1}$)	Food
Ecdyonurus venosus	All depths	Most $> 10\ cm^2$	$0.1\text{-}0.6\ m\ s^{-1}$	Algae
E. dispar	Most 0-10 cm	Most $< 5\ cm^2$	Prefers slow current*	Algae
Rhithrogena semicolorata	Most 30-50 cm	Most $< 5\ cm^2$	Dominant $> 0.7\ m\ s^{-1}$	Algae
Heptagenia sulphurea	20-40 cm	Most $> 10\ cm^2$	$0.2\text{-}0.8\ m\ s^{-1}$	Detritus

*Not quantified

Individual specimens were collected, measured and counted on stones of differing sizes, at different depths and at different current speeds. The density of each species under different conditions is recorded in Table 4, where it can be seen that each showed a characteristic set of preferences. However, although the average size range of each species differed somewhat, there was no evidence to show that there was a relationship within each species between size and any of the environmental variables.

These differing preferences suggest that there was, in general, only limited overlap between *E. dispar* and *R. semicolorata* and between them and the others, whereas *E. venosus* and *H. sulphurea*, which were usually separated, nevertheless occurred together on medium and large stones, at medium depths and at medium current speeds (Figure 7).

Stomach content identification and examination of the mouthparts show a further differentiation, in that *H. sulphurea* preferred detritus, whereas the other species used diatoms and other algae. There was slight evidence that *R. semicolorata* has mouthparts more fitted to scraping stone surfaces rather than general foraging, but this is unsubstantiated.

4.6 Diversity index

Table 5 lists the values of the Shannon-Weaver index for each site and for each of the 3 surveys that were used for this calculation. The mean diversity index is also shown for each site, and these have been plotted against site distance in Figure 8i, where open circles represent tributaries and filled circles sites on the main river. In general, the main river communities were remarkably similar in diversity, with the mean and seasonal indices at the most upstream site (Linn of Dee) being about the same as at the most downstream site (Aberdeen). There were some indications of increased diversity at Braemar and at Milltimber, and a decrease at Silverbank.

The tributaries varied rather more in diversity, with the lowest mean index values being on the *Clunie* near the Glenshee ski-ing area and on the *Ardoe*, close to Aberdeen. The highest mean diversity indices were found on the *Gairn* and *Culter*. In many cases, the tributary sites had similar mean diversities to the adjacent main river, even at the unusually high

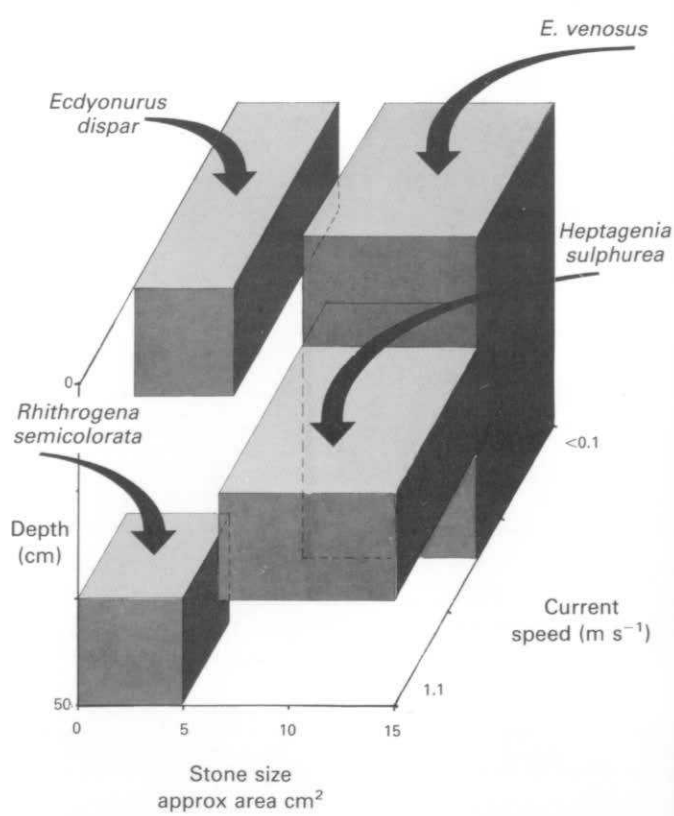


Figure 7. Habitat preferences of 4 species of Ephemeroptera larvae from the lower Dee in September 1977

Table 5. Shannon-Weaver diversity index and Biological Monitoring Working Party score (average score per taxon) for sites in the catchment of the Dee

Site	Diversity index Date October 1983	April 1984	August 1984	Mean	BMWP (ASPT) Cumulative species list 1983-84
Main river					
1 Linn of Dee	2.99	3.13	2.55	2.89	6.9
2 Braemar	3.82	3.76	3.41	3.66	7.1
3 Polhollick	2.53	3.01	3.33	2.96	7.2
4 Ballater	2.42	3.83	3.20	3.15	7.2
5 Aboyne	2.42	3.44	3.36	3.07	7.1
6 Potarch	2.66	3.49	3.07	3.07	6.9
7 Silverbank	2.29	2.57	3.08	2.65	6.5
8 Park Bridge	2.19	3.53	3.39	3.04	7.0
9 Milltimber	3.80	4.26	2.95	3.67	6.6
10 Aberdeen	3.23	2.65	2.60	2.83	6.3
Tributaries					
11 *Clunie* (Cairnwell)	2.25	2.40	1.63	2.09	6.2
12 *Clunie* (Campsite)	3.14	2.56	4.01	2.90	6.7
13 *Clunie* (Braemar)	3.08	3.10	2.96	3.05	7.1
14 *Gairn*	4.14	3.95	4.24	4.11	7.0
15 *Muick*	3.30	2.45	2.93	2.89	7.4
16 *Logie*	3.35	3.11	3.42	3.29	6.5
17 *Dinnet*	1.92	4.21	3.32	3.15	6.2
18 *Tanar*	2.73	3.79	2.92	3.15	7.2
19 *Tarland*	2.98	2.99	3.54	3.17	6.4
20 *Dess*	3.73	4.29	3.01	3.68	6.7
21 *Beltie*	3.55	3.82	3.20	3.52	6.3
22 *Canny*	3.70	4.04	2.53	3.42	6.7
23 *Feugh*	3.09	4.01	2.80	3.30	7.1
24 *Dye*	1.80	3.54	2.49	2.58	7.0
25 *Sheeoch*	3.51	3.51	2.53	3.18	6.3
26 *Kinnernie*	1.66	3.43	0.46	1.85	5.9
27 *Leuchar*	3.06	2.95	1.96	2.66	4.9
28 *Culter*	3.37	3.91	3.29	3.52	6.3
29 *Crynoch*	4.28	3.89	3.17	3.78	6.4
30 *Ardoe*	2.53	2.85	1.95	2.44	5.2

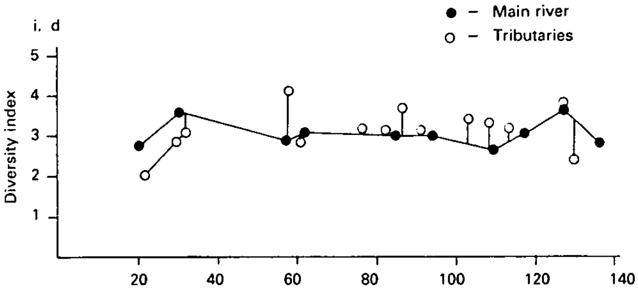


Figure 8i. Shannon-Weaver diversity index (d)

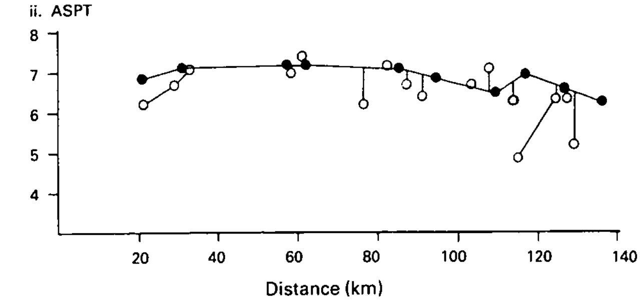


Figure 8ii. Biological Monitoring Working Party score (average score per taxon—ASPT)

diversity site at Milltimber, just above which both the *Culter* and *Crynoch* are confluent with the Dee. At Silverbank, the mean diversity index was somewhat depressed but the *Canny, Feugh* and *Sheeoch*, which join the Dee in this vicinity, remained significantly more diverse.

Seasonally, the diversity indices varied to some extent, although on the main river sites the differences were neither large nor consistent between the 3 surveys. Amongst the tributaries, the diversities appeared, in most cases, to be greatest in the spring and in some streams, notably the *Dinnet, Dye, Kinnernie, Leuchar* and *Ardoe*, there were quite large seasonal variations.

4.7 Biotic scores

The scores for the main Dee sites (Table 5, Figure 8ii) remained consistent through most of the river's length, except for a slight dip at Silverbank, and then a gradual decline was evident at the last 2 sites. Some of the tributary sites had much lower BMWP scores than was normal for the catchment. These included the upper *Clunie*, the *Dinnet*, the *Leuchar* and the *Ardoe*.

5 Discussion

5.1 Historical modifications to the Dee catchment

Although the Dee is relatively unaffected by man's activities compared with other British rivers, the catchment has changed with the destruction of some upland pine forest and deciduous woodland along the valleys. Extensive drainage, especially in the last 150 years, has resulted in the loss of large areas of wetland and of lochs, such as the Loch of Auchlossan, near Lumphanan, which were important for wildfowl.

These historical changes must have altered the pattern and composition of the invertebrate communities in the Dee catchment, probably with a reduction in habitat diversity and restriction of the ranges of certain species.

However, the Dee has probably retained a greater proportion of natural communities in comparison to other British rivers, especially in the lower reaches, which are usually the parts most influenced by man.

5.2 Comparisons with other British rivers

The importance of the Dee has been put in a national context by the Freshwater Biological Association in their River Typing Project. Wright *et al.* (1984) produced an ordination of 41 British rivers (with 268 sites in total) and concluded that axis 1 of their ordination (with a total score range of 0-275) distinguished best between river types. Most rivers appeared to have a limited range of axis 1 score and, in general, rivers which had all sites with scores of less than 100 occurred in Scotland and northern England, whereas rivers with axis 1 scores greater than 100 occurred in East Anglia, the midlands, east and south-east England. The Dee was placed at one extreme of this analysis with all sites having scores of 50 or less, and all the Dee sites were described as typical of upland rivers.

The Don, rising only a few km from the headwaters of the Dee and also entering the sea at Aberdeen, has a more agricultural catchment and this is reflected in its invertebrate communities. Although the lowest section of the Don is as torrential as the Dee and should support an interesting and diverse invertebrate community to its estuary, it is, unfortunately, adulterated by industrial and domestic effluents, leaving a restricted pollution-tolerant fauna.

5.3 Groups of sites and anomalous sites

In this study, TWINSPAN and DECORANA demonstrated that there were clear geographical factors operating to produce a gradient of community types. The catchment can be divided up conveniently, using these techniques, to produce 2 main groups of sites. These are: (i) the main river along with the larger upland tributaries; (ii) the smaller, mid- and lower catchment tributaries.

Within these groups (Figures 2 & 4), there was a distinct gradient along which the sites were arrayed, reflecting the major physical and chemical characteristics of the catchment. In general, there was a tendency for a slight increase in the concentration of nutrients down the catchment, along with a reduction in current speed and an increase in temperature. The invertebrates responded to these changes and the communities became slightly more diverse downstream at the richer, less torrential and warmer sites.

This general pattern was over-printed by other factors related to land use. For example, most of the streams in the second group drain some agricultural land and the invertebrate communities showed signs of further enrichment.

Outside these 2 main groups were other sites which appeared to have unusual invertebrate communities compared to geographically adjacent locations. The *Leuchar* (site 27) is only a short distance below the Loch of Skene, a large 'lowland' loch, surrounded by agricultural land and receiving drainage from a number of small settlements. As a result, the loch is eutrophic, with annual blooms of the cyanobacterium *Aphanizomenon* (Owen 1983). The discharge from the loch was rich in nutrients and suspended matter, as reflected by the invertebrate community which included many detritus- and filter-feeding organisms such as the caddis *Hydropsyche angustipennis* and the mollusc *Sphaerium corneum*. The *Leuchar* becomes the *Culter* near the confluence with the Dee, and it had a similar species association but better water quality, due to self-purification in the intervening 9 km and dilution by other tributaries. The *Ardoe* and the *Dinnet* drain a small pond and 2 lochs (one slightly mesotrophic) respectively, and they showed intermediate positions between the *Leuchar* and the main group of mid-catchment tributaries (Figure 4).

The upper *Clunie* at Cairnwell (site 11) was well removed from the main body of sites in the ordination plot (Figure 4). In the TWINSPAN dendrogram (Figure 2), it was separated off in group G, away from the other *Clunie* sample sites in group D. As it is the highest sampling point in the catchment, it might be expected to be a little unusual. However, the situation is complicated and, although the burn flows off relatively calcium-rich rock, it also receives drainage from the expanding ski-ing development at the *Clunie* watershed, including oils from vehicles and machinery and also septic tank discharges. The species list for this site included upland stoneflies such as *Protonemura praecox* and *P. montana*, but had only 24 taxa in all. The mean diversity index was the lowest of all the sites studied and the biotic score was also much lower than for the other upland sites, being similar instead to the enriched sites of the middle tributaries. Unofficial camping in this valley is a potential problem, especially during low flow periods, with large numbers of people using the bankside areas of the *Clunie*. With no facilities for waste disposal, there is a strong possibility of pollution although, as yet, the invertebrates below this area have shown no signs of stress.

The main river at Aberdeen (site 10) was somewhat unusual relative to the other main river sites because of its tidal nature and the occurrence of species confined to this site, such as the essentially estuarine shrimp *Gammarus zaddachi*, and the snail *Physa fontinalis*, which was also found in the lower Don. Nevertheless, the site also had a good selection of stoneflies, mayflies and caddis, all characteristic of large upland rivers.

5.4 Diversity indices and biotic scores

A measure of the diversity of a community may be useful where it is highly stressed and a small number of pollution-tolerant species become dominant. However, where mild pollution causes enrichment of an oligotrophic watercourse, any loss of species intolerant to enrichment is, in general, more than counterbalanced by an influx of species that are unable to survive in oligotrophic waters and are, instead, favoured by extra nutrients. This increased diversity is not necessarily a desirable feature as it indicates a departure from more natural conditions. An oligotrophic river such as the Dee should show low diversity indices. The diversity index is, therefore, not a very useful tool in assessing the potential threats to the Dee catchment.

The biotic score relies on the presence or absence of pollution-tolerant or pollution-intolerant animals to assess the pollution stress at a site. However, biotic scores are often too crude in differentiating between the tolerances of species to mild enrichment in oligotrophic systems (eg amongst the genus *Hydropsyche*). It is, perhaps, more useful than the diversity index, and, indeed, BMWP detected pollution stress on the *Clunie, Dinnet, Leuchar* and *Ardoe*, but again had fairly restricted application in the catchment as a whole.

5.5 Species distributions

5.5.1 Variation between sites

The various analyses showed that the most important feature of the Dee system was the general uniformity of the invertebrate communities with characteristic upland and oligotrophic species remaining even in the lowest areas.

Although it was possible to demonstrate a change in the relative numbers of species of stoneflies and mayflies from source to mouth, both groups were still well represented at the tidal limit (Figure 5). These groups are characteristic of torrential stream faunas, with the stoneflies preferring colder and better oxygenated water and, therefore, being dominant in the upper catchment.

The distributions of particular species within the catchment help to illustrate the various environmental factors which act on freshwater invertebrates and which are important from the river management point of view.

Most species appeared to have fairly wide tolerances and could be accommodated in an appropriate niche at most sites in the Dee catchment. However, certain species were more restricted in distribution; for example, the mayfly *Heptagenia sulphurea* and the dipteran *Atherix ibis* preferred sites on the main river and large tributaries and probably require a relatively constant temperature regime and are adapted to withstand fairly strong currents.

The 2 common flatworms in the catchment, *Polycelis felina* and *Crenobia alpina*, showed contrasting distributions (Figures 6iv & 6v) controlled by temperature (Hynes 1970). They provide a classic example of interspecific competition and zonation. *C. alpina* was restricted to the upper main river and larger tributaries. It requires colder water to complete its life cycle than *P. felina*, which was well distributed in the main river and smaller tributaries. Both species migrate up- and downstream (Kaushik & Hynes 1971) to feed and breed, and consequently there is an overlap in their ranges but probably with a fair amount of temporal separation.

The breeding range of *C. alpina* has probably been reduced with the removal of bankside shading trees which keep down the summer maximum temperature. This change may also have affected other species.

In recent years, it has become possible to identify reliably various species of the caddis genus *Hydropsyche*. It is interesting to consider how such a group of superficially identical animals share habitats and exhibit different environmental requirements, especially as they are often lumped together in one category in pollution indices, such as the BMWP score system.

H. siltalai and *H. pellucidula* had similarly widespread distributions, extending to the tidal limit. These species, however, occupied different niches because of a slight temporal stagger in their life cycles, resulting in *H. pellucidula* over-wintering at a larger size (instar 5) than *H. siltalai* (instar 3) (Macan 1981). Consequently, the larvae of *H. siltalai* can live in smaller crevices; they spin finer nets for filter feeding and so catch a different range of food.

H. instabilis was restricted to certain tributaries, probably related to a requirement for low temperatures and high dissolved oxygen concentrations. In contrast, *H. contubernalis* was confined to the middle and lower sections of the main river where the temperature was higher and less variable.

The fifth species in the catchment, *H. angustipennis*, was restricted to 2 sites on the *Leuchar/Culter* sub-catchment and one main river site below its confluence with the Dee, presumably responding to the rich discharge from the eutrophic Loch of Skene.

H. angustipennis is known to occur below lakes and ponds and to be tolerant of low oxygen concentrations and high temperatures. One could speculate that *H. angustipennis* was restricted, originally, to a short stretch below the loch outlet and, as eutrophication proceeded, it was able to extend its range downstream. In 1983-84, it was found regularly in the main river at Milltimber, probably because of larvae drifting downstream from the Culter Burn.

5.5.2 Variation within sites

Mayfly larvae of the family Heptageniidae are common inhabitants of oligotrophic rivers and more than one species often occur together in the same area. They are similar morphologically both in general body shape (flattened to avoid the current) and, for most species, in mouthparts (suggesting a similar diet). This similarity leads inevitably to the question of whether they compete for resources or have some means of avoiding such competition. The 4 species which inhabit the Dee at Durris have different preferences for depth, stone size and current speed (MacGowan 1978). Their separation is not complete but is substantial, and suggests that to a large extent they avoid competition. The fact that some overlap remains is not too surprising, especially in the light of such studies as Reynoldson's (1975), and, in any case, the rather crude assessment of habitat variables and the restriction of the data to one season may have masked their exact preferences, and so under-estimated their separation. One species, *Heptagenia sulphurea,* appeared to include more detritus in its diet than the others which concentrated on algae, but a more substantial study would be needed to confirm this hypothesis.

These varied micro-habitat preferences were established in an area which would generally be regarded as uniform, compared with the normal range of river variation, and emphasize the fact that generally accepted characterization of lotic habitat types is rather crude. Our general conclusion in 1983-84 that the Dee was largely homogeneous must be tempered by this observation.

5.6 Threats from human activities

Aquatic and terrestrial vegetation is important in the ecology of temperate river systems (Dawson 1978; Peterson & Cummins 1974). Water weeds increase the diversity of a stream, providing additional habitats and food, either directly or, more usually, as a substrate for epiphytic algae. The Dee, however, has little aquatic vegetation other than mosses, which makes the role of the bankside trees all the more important for the conservation and management of this important and delicately balanced river system; their removal from river banks may cause changes in the distribution of aquatic invertebrates. Bankside trees provide shade, probably reducing the amount of epilithic algae, but also reduce the temperature and so favour upland invertebrates. Broadleaved trees also provide much allochthonous material in the form of leaves and terrestrial invertebrates dropping into the river, and so shift the community balance from the algal scrapers and grazers (especially mayflies) to the shredders and detritivores (such as certain of the caddis). Fish also benefit directly from the extra insect food dropping from the trees.

A good mix of bankside vegetation helps to maintain a diverse and balanced clean-water invertebrate community, better able to cope with mild pollution.

Perhaps the most obvious symptom of man's influence on the Dee catchment in 1983-84 was the annual algal bloom on the Loch of Skene. This was probably the result of nutrient enrichment from agricultural and domestic discharges, and it is important that a similar fate does not befall the lochs on the Muir of Dinnet NNR or in other parts of the catchment.

Other types of human activity pose a variety of threats to the invertebrates of different parts of the catchment and even the high-altitude animals could suffer from developments such as the ski complex on the *Clunie* and potential problems from large-scale camping on areas with no sewerage.

In 1983-84, the upland areas were largely managed as open moorland for deer or grouse but a change in use of plantable land to commercial forestry might cause changes in the flow regimes of local streams. Runoff from commercial forests would probably be less than from moorland or more open native pinewoods (Calder 1985) and this water might be more acidic. Any increased acidity would reduce the numbers and diversity of the local invertebrate communities with the diminution of many species of stonefly, mayfly and caddis. Subsequent felling of the trees could then increase runoff, with the possibility of soil erosion and increased sediment load in the receiving streams.

Another upland problem (but extending to other parts of the catchment) is the use of pesticides for sheep dipping (Bowen *et al.* 1978; Doughty 1984). Many sheep dips are located in remote areas with unsatisfactory methods of disposal, often to poorly constructed soakaways. Spillages to watercourses undoubtedly occur, sometimes resulting in the elimination of invertebrates and with the possibility of accumulation of toxic chemicals in the substrate and food chain.

Lower down the catchment, especially around towns, domestic refuse disposal has recently become a serious problem, resulting in the use of quite unsuitable sites close to, and in one case (near Aboyne) over, streams. This situation can result in severe contamination of the watercourse by a leachate rich in organic substances, nutrients and metals such as zinc and iron, producing growths of sewage fungus and deposits of iron and causing major changes in the fauna.

Plate 1. Source of the River Dee at 1220 m (4000′) in the alpine environment of the Braeriach plateau (Photograph J B Hepburn)

Plate 2. The upper stretches of the River Dee, here flowing out of the Cairngorm mountains through the Lairig Ghru pass, have seldom been studied by biologists (Photograph I Strachan)

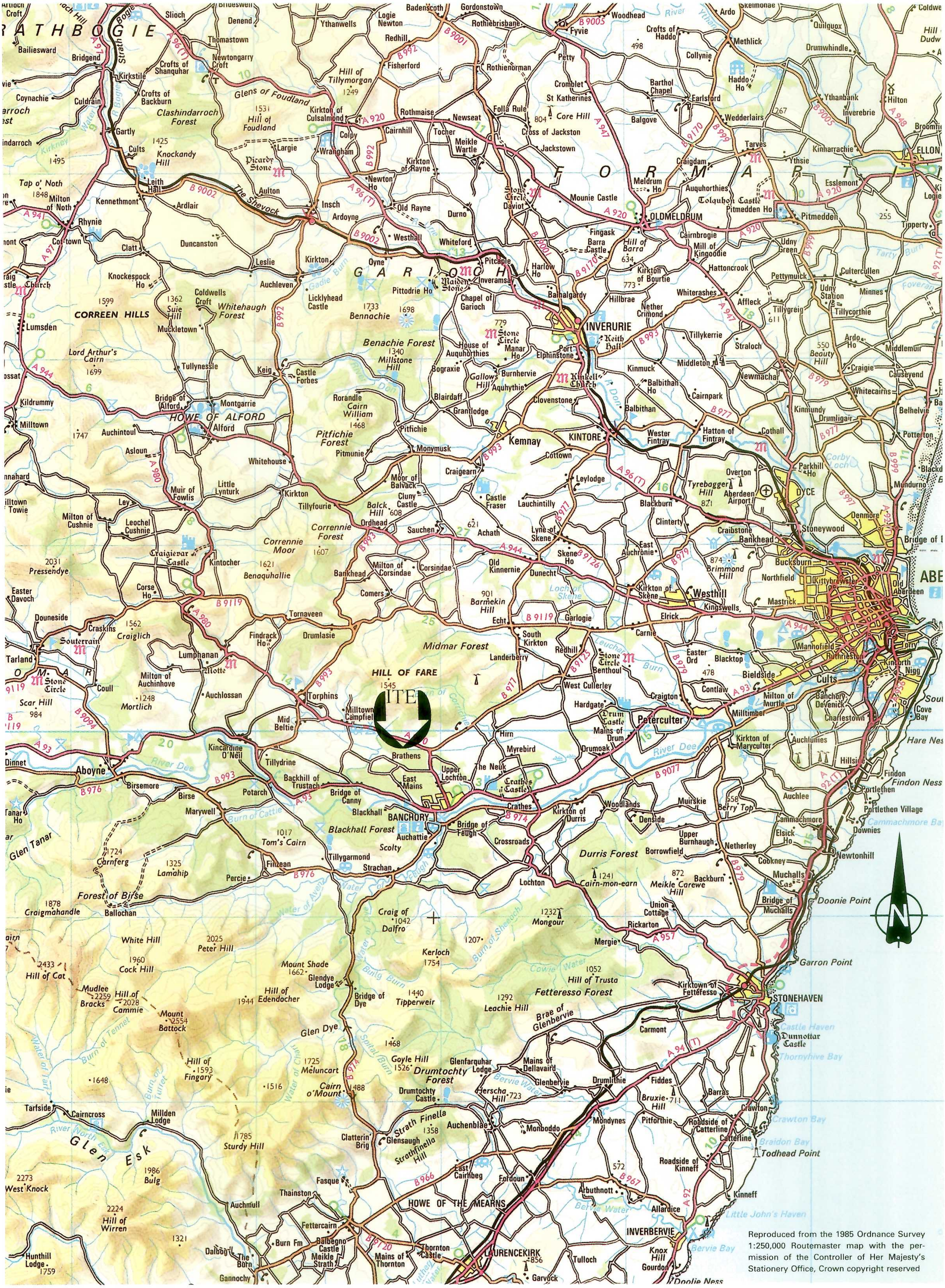
Plate 3. In January and February, the river is often reduced to a narrow channel for much of its length. Temperatures as low as −27.2°C (10 January 1982) have been recorded at Braemar (Photograph J B Hepburn)

Plate 4. Panoramic views like this of the valley are often obscured by regeneration and afforestation at the roadside. The autumn tints show birch to be fairly widespread on the valley floor here west of Coilacriech, with larch/pine mixtures in the middle distance (Photograph N Picozzi)

Plate 5. Lochs Davan and Kinord (the lower loch) form the central part of the Muir of Dinnet NNR. These lochs are one of the main rearing areas for otters in Deeside, and an important roosting area for greylag geese in autumn (Photograph D Jenkins)

Plate 6. Floodplain deposits overlying coarse cobble beds of fluvioglacial origin. Floodplain deposits comprise both fine sandy alluvium and coarse pebble beds deposited during large flood events (Photograph J K Maizels)

GRAMPIAN MOUNTAINS
STRATHSPEY
CAIRNGORM MOUNTAINS
BRAEMAR
GLEN AVON
FOREST OF MAR
HILLS OF CROMDALE
LADDER HILLS
BEN RINNES
CAIRNGORM NATURE RESERVE
Hill of Aitnoch
Lochindorb Lodge
Carn Ruigh Chorrach
Carn na Loine
Scootmore Forest
Marypark
Bellehiglash
Advie
Bridge of Avon
Cairnacay
Beatshach
Meikle Conval
Auchindoun Castle
The Scalp
Haugh of Glass
Favillar
Glen Rinnes
Achnastank
Glenfiddich Lodge
Glen Fiddich
Glenfiddich Forest
Tomnaven
Bridgend
Inverharroch
Upper Derraid
Auchnagallin
Lettoch
Creag Liath
Camerory
Cottartown
Dellefure
Mains of Dalvey
Drumin
Glenlivet
Shenval
Corryhabbie Hill
Cairn Muldonich
Carn an t-Suidhe
Blackwater Forest
Round Hill
Aldunie
Cabrach
Mount of Haddoch
Beinn Mhòr
Glenbeg
GRANTOWN-ON-SPEY
Achnahannet
Cromdale
Haughs of Cromdale
Craggan
Dulnain Bridge
Speybridge
Duthil
Skye of Curr
Strath Avon
Carn Liath
Carn Daimh
Tomnavoulin
Knockandhu
Cairnbrallan
Hill of Three Stones
The Buck
Creagan a'Chaise
Sgòr Gaoithe
Bridge of Brown
Fodderletter
Clashnoir
Braes of Glenlivet
Chapeltown
Drumuillie
Cullachie
Nethy Bridge
Sliemore
Lettoch
Tomintoul
Milton
East Croftmore
Boat of Garten
Loch Garten
Abernethy Forest
Dell Lodge
Baddoch
Tom an t-Suidhe Mhòir
Carn Meadhonach
Carn Mòr
Glenbuchat Lodge
Moss Hill
Badenyon
Creag an Eunan
Aundorach
Tore Hill
Tulloch
Forest Lodge
Dorback Lodge
Braes of Abernethy
Auchgourish
Carn na Farraidh
Blairnamarrow
Carn Liath
Ladylea Hill
Belnacraig
Rinmore
Kirkton of Glenbuchat
Castle
Bridge of Buchat
The Socach
Lecht Road
Breagach Hill
Bellabeg
Strathdon
Glenkindie
Meall a'Bhuachaille
Carn Bheadhair
Geal Charn
Craig Veann
Carn Ealasaid
Glen Ernan
Geal Charn
Inverernan Ho.
Candacraig Ho.
Heugh-head
Boultenstone
The Queen's Forest
Glenmore Lodge
Loch Morlich
Glen More
Stac na h-Iolaire
Cnap Chaochan Aitinn
Big Garvoun
Carn na Feannaige
Cock Bridge
Delnadamph Lodge
Castle
Corgarff
Colnabaichin
Tornahaish
Tornashean Forest
Craig of Bunzeach
Hillockhead
Bynack More
Castle Hill
Carn Eilrig
The Bruach
Forest of Glenavon
Carn Leac Saighdeir
Cairn Mona Gowan
Morven
Logie Coldstone
CAIRN GORM
Lairig Ghru
Shelter Stone
Loch Avon
Beinn a'Chaorainn
Stob an t-Sluichd
Loch Builg
Brown Cow Hill
River Gairn
Gairnshiel Lodge
Glen Fenzie
Peter's Hill
Culblean Hill
BRAERIACH
BEN MACDUI (BEINN MACDUIBH)
Derry Cairngorm
BEN AVON
Càrn Eas
Culardoch
Glen Gairn
Lary
Geallaig Hill
Milton of Tullich
CAIRN TOUL (CARN AN T-SABHAIL)
BEINN A'BHUIRD
Dubh-Ghleann
Beinn Bhreac
Creag an Dail Bheag
Bush Crathie
Coilacriech
Culsh
Bridge of Gairn
Ballater
Glascorrie
The Devil's Point
Carn a'Mhaim
Glen Dee
Meall Gorm
Carn na Drochaide
Balmoral Castle
Crathie
Abergeldie Castle
Easter Balmoral
House of Glenmuick
Pannanich Hill
Beinn Bhrotain
Glen Lui
Sgòr Mòr
Creag Bhalg
Allanaquoich
Invercauld Ho
Inver
Birkhall
Creag nan Gall
The Coyles of Muick
Aucholzie
Cairn Leuchan
Claybokie
Braemar
Castle
Tomintoul
Ballochbuie Forest
Glen Gelder
Muir
Inverey
Linn of Dee
Cairn Geldie
Falls of Garbh Allt
Auchallater
The Colonel's Bed
Balmoral Forest
Conachcraig
Glen Muick
Mount Keen
Carn Liath
Glen Ey
Geldie Burn
LOCHNAGAR
Spittal of Glenmuick
Fasheilach
Glen Mark
Creag nan Gabhar
Glen Callater
Loch Callater
White Mouth
Dubh Loch
Loch Muick
Carn Bhac
Baddoch
Sgòr Mòr
Cairn Bannoch
Broad Cairn
Glas-allt-Shiel
Glen Lee
Black Hill of Mark
Easter Balloch
Monawee
Invermark Lodge
AN SOCACH
Carn an Tuirc
Tolmount
Loch Esk
Inchgrundle
Beinn Iutharn Mhòr
Loch Vrotachan
Carn an Righ
Gleann Mòr
Glas Tulaichean
Carn a'Gheoidh
The Cairnwell
Devil's Elbow
GLAS MAOL
Caenlochan Forest
Glen Doll
Glendoll Forest
Glendoll Lodge
Braedownie
Lair of Aldararie
Muckle Cairn
Cruys
Creag Leacach
Finalty Hill
Mayar
Driesh
Loch Brandy
Ben Tirran
Beinn a' Ghlò
Glen Loch
Ben Gulabin
Dalmunzie Hotel
Carn an Daimh
Monamenach
Cairn Inks
Clova
Glen Clova
White Hill
Meall a' Choire Bhuidhe
Cairn Baddoch
Cairn of Barns
Wheen


STRATHBOGIE
FORMARTINE
GARIOCH
HOWE OF ALFORD
CORREEN HILLS
HILL OF FARE
HOWE OF THE MEARNS
Glen Tanar
Glen Esk
Forest of Birse
ITE
INVERURIE
OLDMELDRUM
ELLON
Kemnay
KINTORE
DYCE
Aberdeen Airport
Westhill
Peterculter
Cults
Bieldside
Milltimber
Stoneywood
Bucksburn
Kingswells
ABERDEEN
Banchory
Aboyne
Torphins
Alford
Insch
Rhynie
Tarland
Lumphanan
Kincardine O'Neil
STONEHAVEN
INVERBERVIE
LAURENCEKIRK
Fettercairn
Auchenblae
Drumlithie
Newtonhill
Portlethen
Muchalls
Bennachie
Benachie Forest
Pitfichie Forest
Corrennie Forest
Midmar Forest
Blackhall Forest
Durris Forest
Fetteresso Forest
Drumtochty Forest
Clashindarroch Forest
Whitehaugh Forest
Cairn-mon-earn
Mount Battock
Hill of Cat
Cairn o'Mount
Clachnaben
Kerloch
Craig of Dalfro
Tap o' Noth
River Dee
River Don
River Ythan
Doonie Point
Garron Point
Findon Ness
Hare Ness
Todhead Point
Dunnottar Castle
Crathes Castle
Drum Castle
Castle Fraser
Craigievar Castle
Stonehaven Bay
Bervie Bay
N

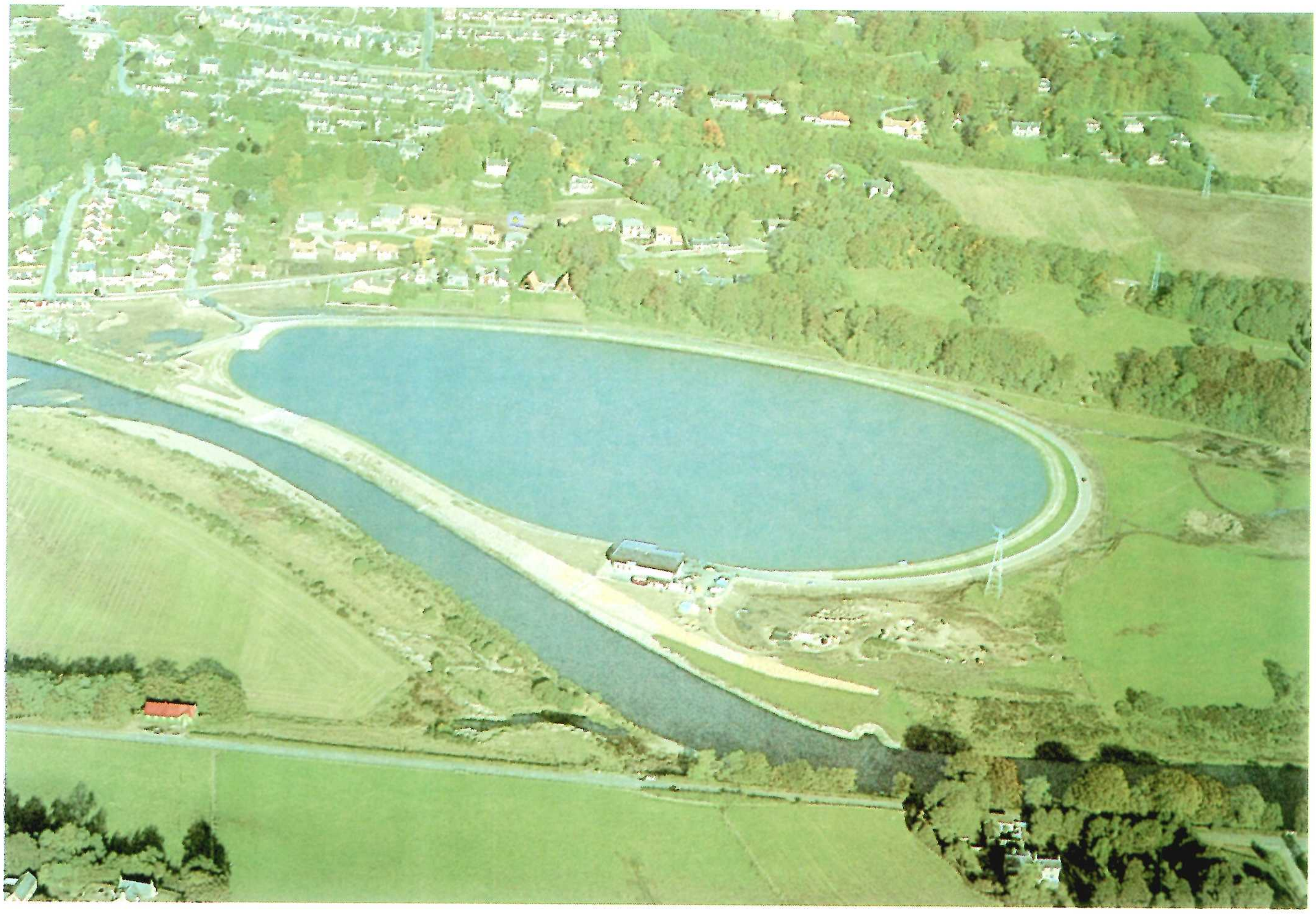


Plate 7. The new raw water Inchgarth Reservoir at Cults also has an important potential for recreation near Aberdeen (Photograph D Glennie)

Plate 8. The harbour at Aberdeen retains its importance as a fishing port. In recent years it has attained major status as a centre for vessels servicing the oil industry (Photograph N Picozzi)

1946

1956

1968

Plate 9. River Dee at Morrison's Bridge, Cults; geometric changes from 1946-68 (Crown copyright reserved)

Plate 10. Constricted bedrock channel near Invercanny water works (Photograph Grampian Regional Council)

Plate 11. Large meander in the Maryculter–Murtle reach which has developed since the mid-19th century. Point bar deposits have been dissected by chute channels (Photograph Grampian Regional Council)

Domestic sewage, on the other hand, causes few problems in the main river because of high dilution. Below Banchory (at Silverbank, site 7), however, there was some evidence of a change in water quality caused by the sewage discharge, possibly reflected by the biotic score (Figure 8). Aberdeen does not discharge its sewage to the Dee but disposes of it to the adjacent sea. The expansion of the city has seen the movement of some industry to rural areas, resulting in the contamination of small watercourses with a wide variety of substances, because of inadequate drainage or treatment provisions.

In order to meet the increased demands for domestic and industrial water supplies, the water abstraction capacity has recently been increased in the lower part of the river, and during periods of low flow will remove a significant proportion of the river's volume. It is not clear how this will affect the invertebrates, but lower river levels in the summer may leave sedentary animals, like the pearl mussel, stranded.

5.7 Recommendations for conservation

The many threats to the invertebrates, and to the river system in general, are all potentially serious, but a change in the trophic status of the catchment by nutrient enrichment from agricultural and forestry fertilizers and domestic or farm wastes is possibly the most important and immediate. The current low nutrient status and the relative lack of disturbance of the Dee catchment must be preserved in order to retain its unique series of invertebrate communities and to protect the present ecological balance. To do so, the following actions are necessary.

i. Retention and extension of the deciduous tree fringe along the river banks, especially in upland areas. This would particularly benefit the invertebrates, but would also provide habitats for birds and terrestrial insects, shade and feeding for fish, and cover for otters.

ii. Rural commercial developments such as the small industrial estates and the ski-ing complexes should be subject to stringent planning controls and these should be enforced. Unofficial developments must also be controlled. The quality of water, especially in the headwaters, must be protected.

iii. The effects of water abstraction, especially at low flows, must be monitored and further river volume reduction resisted if this would seem to be deleterious.

iv. An integrated land use policy should be developed for the catchment to harmonize man's activities and to prevent sudden unsympathetic changes which could be harmful to invertebrates and to other interests, such as fishing, conservation and tourism.

6 Summary

6.1 Thirty sites, distributed along the River Dee and its major tributaries, were sampled for invertebrates, using a standard 'heel-kick' technique, on 5 occasions in spring, summer and autumn 1983 and in spring and summer 1984.

6.2 In total, 125 taxa of invertebrates were identified and the resulting site species matrix was then analysed.

6.3 Two-way Species Analysis (TWINSPAN) and Detrended Correspondence Analysis (DECORANA) identified groups of similar sites and species. Generally, those sites subject to enrichment, either natural or associated with man, were separated from the majority of sites, which were more oligotrophic, and these latter then split into a group containing lowland tributaries and one including the main river areas and the major, middle and upland tributaries. The analysis identified anomalies, including one upland tributary site which is known to be stressed artificially and one which was associated with a polluted lowland tributary.

6.4 Some species groups reflected identifiable habitat preferences, such as those requiring nutrient enrichment or a gravel substrate, but others seemed to be generally associated with the stony substrate usual throughout the Dee catchment.

6.5 As expected, Plecoptera (stoneflies) and Ephemeroptera (mayflies) predominated at all except the enriched sites; but it was found, at least amongst the mayfly family Heptageniidae, that each species has its own characteristic micro-habitat preferences.

6.6 The analysis showed examples of species with a range of distribution patterns. Some were found generally throughout the catchment, others were restricted to either upland tributaries, enriched lowland sites, the main river or other such sub-sections.

6.7 Diversity and biotic indices indicated a general uniformity within the catchment, except for a few tributary sites as a result of enrichment or stress.

6.8 It is clear that the Dee catchment is generally uniform and apparently unmodified; however, certain areas are different and for each of these it is possible to assign a cause. In 2 cases, this is the presence of a loch upstream of the sample site, but in most others the effect is due to man's influence, either in the form of agricultural or domestic effluents or as a result of recreational activities.

6.9 Rivers as unmodified as the Dee are rare and worthy of conservation. To achieve this, man's influence must be monitored and controlled as necessary. Invertebrates are ideal as monitors and the current study provides a baseline for future studies on this river and for comparison with other, more modified, rivers.

7 Acknowledgements

The authors wish to thank Donald Paterson of the Department of Plant Science at Aberdeen University for his assistance with data analysis. We are also grateful to Ian MacGowan for the use of his data on habitat preferences in Ephemeroptera.

The opinions expressed in this paper are those of the authors and are not necessarily those of the North East River Purification Board.

8 References

Armitage, P. D., Moss, D., Wright, J. F. & Furse, M. T. 1983. The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. *Wat. Res.*, **17,** 333-347.

Biological Monitoring Working Party. 1978. *Final report: assessment and presentation of the biological quality of rivers in Great Britain, December 1978.* London: Department of the Environment, Water Data Unit.

Bowen, H. M., Cutler, J. R. & Craigie, I. 1978. *A survey of sheep-dip usage in Scotland.* Edinburgh: Department of Agriculture and Fisheries for Scotland.

Calder, I. R. 1985. Influence of woodlands on water quantity. In: *Woodlands, weather and water.* Proceedings of the Environment Division symposium, Edinburgh, 1984, edited by D. J. L. Harding & J. K. Fawell. London: Institute of Biology.

Calder, I. R. 1985. Influence of woodlands on water quantity. In: *Woodlands, weather and water.* Proceedings of the Environment Division symposium, Edinburgh, 1984. London: Institute of Biology.

Clare, P. & Edwards, R. W. 1983. The macroinvertebrate fauna of the drainage channels of the Gwent Levels, South Wales. *Freshwater Biol.,* **13,** 205-225.

Davidson, M. B. & Young, M. R. 1980. *A seasonal invertebrate survey of the River Dee (Aberdeenshire) and its main tributaries.* Banbury: Nature Conservancy Council. (Unpublished.)

Dawson, F. H. 1978. Aquatic plant management in semi-natural streams: the role of marginal vegetation. *J. environ. Manage.,* **6,** 213-221.

Doughty, R. 1984. *Water pollution resulting from sheep-dipping in Scotland, 1979-83.* Association of Directors and River Inspectors for Scotland (Biology Section). (Unpublished.)

Furse, M. T., Wright, J. F., Armitage, P. D. & Moss, D. 1981. An appraisal of pond-net samples for biological monitoring of lotic macroinvertebrates. *Wat. Res.,* **15,** 679-689.

Hellawell, J. M. 1978. *Biological surveillance of rivers.* Stevenage: Water Research Centre.

Hill, M. O. 1979a. *DECORANA—a FORTRAN program for detrended correspondence analysis and reciprocal averaging.* Ithaca, N.Y.: Section of Ecology and Systematics, Cornell University.

Hill, M. O. 1979b. *TWINSPAN—a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Ithaca: N.Y.: Section of Ecology and Systematics, Cornell University.

Hynes, H. B. N. 1970. *The ecology of running waters.* Liverpool: Liverpool University Press.

Jenkins, R. A., Wade, K. R. & Pugh, E. 1984. Macroinvertebrate-habitat relationships in the River Teifi catchment and the significance to conservation. *Freshwater Biol.,* **14,** 23-42.

Kaushik, N. K. & Hynes, H. B. N. 1971. The fate of the dead leaves that fall into streams. *Arch. Hydrobiol.,* **68,** 465-515.

Macan, T. T. 1981. Modifications of populations of aquatic invertebrates and the quality of the water. In: *Dynamique de populations et qualité de l'eau,* edited by H. Hoestlandt, 161-192. Paris: Gauthier-Villars.

MacGowan, I. 1978. *The microdistribution of four species of mayfly nymphs in the River Dee.* BSc thesis, Aberdeen University.

Owen, R. P. 1983. *Causes and effects of nuisance populations of phytoplankton in the Loch of Skene, Aberdeenshire.* Aberdeen: North East River Purification Board.

Peterson, R. C. & Cummins, K. W. 1974. Leaf processing in a woodland stream. *Freshwater Biol.,* **4,** 343-368.

Ratcliffe, D. A. 1977. *A nature conservation review: the selection of biological sites of national importance to nature conservation in Britain.* Vol. 1. Cambridge: Cambridge University Press.

Reynoldson, T. B. 1975. Food overlap of lake dwelling triclads in the field. *J. Anim. Ecol.,* **44,** 245-250.

Scullion, J., Parish, C. A., Morgan, N. & Edwards, R. W. 1982. Comparison of benthic macroinvertebrate and substratum composition in riffles and pools in the impounded River Elan and the unregulated River Wye, mid-Wales. *Freshwater Biol.,* **12,** 579-595.

Shannon, C. & Weaver, W. 1963. *The mathematical theory of communications.* Urbana: University of Illinois Press.

Wright, J. F., Moss, D., Armitage, P. D. & Furse, M. T. 1984. A preliminary classification of running-water sites in Great Britain based on macroinvertebrate species and the prediction of community type using environmental data. *Freshwater Biol.,* **14,** 221-256.

Vertebrates, except salmon and trout, associated with the River Dee

D JENKINS* & M V BELL[†]
*Institute of Terrestrial Ecology, Banchory
[†]Institute of Marine Biochemistry, Aberdeen

1 Introduction

This paper gives an exploratory account of the wild vertebrates of the River Dee, its tributaries, lochs and associated marshes and other wetlands. We do not attempt a comprehensive survey as no such survey has been done, and most information is qualitative. More survey work would be useful, and the paper draws attention to some obvious gaps in knowledge. We also emphasize some of the requirements of the vertebrates, and indicate potential conflicts between their conservation and other interests.

2 Fauna

As mammals and birds, especially, are mobile, it is difficult to define those species clearly associated with the Dee and those not. In the case of waders and gulls, some of which nest on river shingles and nearby marshes, we also mention groups on nearby hills as these birds are part of the Dee populations. In general, the vertebrates associated with the Dee are not unusual or important. The main exceptions are the otter and the long-eared bat.

2.1 Fish

Small numbers of sea lampreys occur in the Dee. Adults migrating from the sea to spawning grounds in the lower reaches of the river are obvious in June and July. Sea lampreys are unlikely to occur in the tributaries but, although they have never been recorded, the young must occur in silty areas in the lower river. The river lamprey probably occurs in the Dee in small numbers, with a small run each autumn and spring. Adults run into both the Don to the north and the North Esk to the south.

In contrast, the brook lamprey appears to be common in the Dee, especially in the lower and middle reaches but also in many tributaries, including the *Girnock* and *Dinnet* Burns. In the *Dinnet*, W Irvine collected approximately one lamprey every 10 m when electro-fishing in 1967.

As in many other parts of Scotland, rainbow trout have been introduced to several lochs within the Dee catchment for sport fishing. No stocks became established and any fish occurring in the Dee can only be strays.

Pike are common in several Deeside lochs (eg Davan and Kinord (Treasurer 1983)), and occur in small numbers in slow-flowing parts of the lower reaches of the main river. They also occur in some smaller tributaries of the Dee. In 1967, W Irvine found about one specimen every 120 m during electro-fishing.

Minnows are common, occasionally abundant, in the lower and middle reaches of the Dee and in many of its tributaries. Spawning occurs in May and June, and fry can be seen in large numbers along the edges of pools later in the year.

Because of its bottom-living habit, the stone loach is believed to be less abundant than it actually is. In fact, it is quite common in the lower and middle reaches of the main river and in some of its tributaries.

Eels are common in most parts of the Dee system which are accessible from the sea. Electro-fishing in the *Dinnet* in 1967 (W Irvine) revealed about one eel every 5 m. Jenkins and Harper (1980) showed that eels were a major item of the diet of otters in the area. Three-spined sticklebacks are found in some of the more slow-flowing parts of the Dee and its tributaries and in some lochs. Several lochs in the Dee valley contain populations of perch (see Treasurer 1983). This species also occurs in some numbers in the slow-flowing parts of the lower reaches of the River Dee.

Young flounders ascend from the sea to the lower and middle reaches of the Dee and may spend some time there before returning to the sea as young adults. However, flounders were uncommon in the Dee near Banchory in 1925-30 (W J M Menzies).

2.2 Amphibia and reptiles

Frogs and toads are widespread. At high altitudes, some tadpoles still occur in autumn and are unlikely to develop further over winter (A Watson), so either they metamorphose in their second year, or die. Large numbers of frogs and toads spawn at some ponds and lochs, eg at Glen Tanar and Loch Kinord. At Kinord, at least 18 common buzzards were counted preying on spawning amphibia in April 1983 (J Parkin).

Slow worms, viviparous lizards and adders are well distributed along the Dee in the valleys, glens, and lower moors, as well as on river banks (Taylor 1963). Taylor records the smooth newt from Braemar in 1950 and Morrone in 1956, but recent records, when checked, have turned out to be palmate newts (M Young). Taylor had no records of the great crested newt in Deeside. However, it is apparently not uncommon in the Moray basin, and it would be worthwhile to look for it in deep ponds over better soils in Deeside. The palmate newt is common in pools and wet places along the Dee.

2.3 Birds

2.3.1 Waterfowl in mid-Deeside

The largest concentration of waterfowl in mid-Deeside occurs on Lochs Davan and Kinord at Dinnet. Data are available for 2 series of winters, 1955/56-1962/63 and 1981/82-1983/84 (Table 1). Apart from mallard, the numbers of which have remained roughly constant, all other species have increased. Mean monthly counts of wigeon, for example, in 1981-84 were 82-223 compared with 6-162 in 1955-63. Mean March numbers of tufted duck and goldeneye, in addition, are now over 60, compared with 15-20 only 21 years ago. Teal, pochard and goosander also now occur regularly in small numbers. These larger numbers in recent years following protection give encouragement to the efforts of wildlife conservation. In some years, whooper swans occur in large numbers for several days or weeks (over 110 in 1971 and 260 in 1972 (J A Forster)) and up to 87 were present in autumn 1983. Other duck species recorded at the Dinnet lochs include gadwall, pintail, shoveler, shelduck, scaup, long-tailed duck, common scoter, red-breasted merganser and smew. A few species nest each year, including mallard, teal, wigeon, tufted duck, and also coot and moorhen. Few young are reared, however, perhaps because of predation by pike. This predation has often been seen but its effect on the duck populations is unknown.

'Thriving breeding populations' of waterfowl were found till recently at the Loch of Aboyne (Nethersole-Thompson & Watson 1981), but, unlike the situation at protected Davan and Kinord, this is no longer the case at Aboyne, probably because of disturbance by recreation (see below).

Greylag geese started roosting at the Dinnet lochs in the early to mid-1970s and numbers have increased rapidly since. Numbers appeared to have stabilized at around 4000 by 1979, but in the last 2 winters peaks of 10 000 and over 11 000 have been recorded. Up to 1500 can be seen at Auchlossan throughout the winter, but in autumn most feed on arable fields towards Donside as far as Muir of Fowlis and Glenkindie, if not further. They usually leave when the stubbles are snow-covered or frozen in late November-December and only small numbers occur in spring, favouring areas at Auchlossan/Ballogie, Torphins and the Howe of Tarland. Up to 1500 sometimes roost on river shingle at Ballogie in winter when the area is undisturbed.

Small numbers of pink-footed geese occur at these lochs and elsewhere, mainly in spring (eg 76 on 5 February 1977), and there is an exceptional record of 780 at Tarland in April 1979. Up to 6 barnacle geese, 4 Canada geese, 3 snow geese and 12 bean geese have been seen at Davan. Bean geese have also been recorded at Aboyne, and a white-fronted goose at least once at Auchlossan (1982) and once at Birse (1985).

Loch Davan is one of the northernmost sites for breeding great crested grebes in Britain. They successfully fledged young here in some years up to 1976 when 3 pairs were present, but there has been only one pair each summer since 1977. Nesting was attempted in some of the later years (not 1983 and 1984), but no young have fledged. They formerly bred at Auchlossan (per J Parkin) and Aboyne, and were regular at Kinord up to the early 1970s; however, nesting has not been recorded at Kinord since the 1940s (see Nethersole-Thompson & Watson 1981).

The Dinnet lochs are the centre for wigeon on Deeside; about 30 pairs breed between Ballater, Glen Tanar and Aboyne up to at least 220 m on the hills. Mute swans breed on both Davan (up to 4 pairs) and Kinord (up to 3 pairs, but none in the last 3 years). The only other sites with mute swans are the small lochs at Braeroddach and Aboyne. None breeds on the Dee compared with many pairs on lower Donside, probably because the Dee is too shallow, fast flowing and nutrient-poor to allow the growth of aquatic plants on which they depend.

The Dinnet lochs and the surrounding marshes also support a few pairs of water rails; the only other sites in Grampian to do so are Loch of Leys and Loch of Strathbeg. There are several sedge warblers at both lochs, and occasional grasshopper warblers. Waders include redshank, now scarce in Deeside due to drainage of wet places; dunlin sang at Kinord up to the early 1970s.

Table 1. Mean mid-monthly wildfowl counts at Lochs Davan and Kinord for the winters from 1955/56-1962/63 (in brackets) and 1981/82-1983/84, plus the maximum count for each species within each period. Coots were not counted in the earlier period

	Sept		Oct		Nov		Dec		Jan		Feb		March		Max	
Mallard	301	(153)	309	(305)	318	(420)	425	(638)	130	(279)	317	(178)	66	(126)	680	(1870)
Teal	6	(0)	25	(0)	37	(0)	9	(0)	0	(0)	6	(0)	38	(0)	110	
Wigeon	121	(6)	213	(85)	193	(162)	223	(141)	101	(103)	82	(57)	171	(38)	600	(650)
Tufted duck	53	(2)	88	(7)	67	(18)	39	(22)	6	(8)	47	(6)	69	(20)	116	(130)
Pochard	7	(0)	25	(0)	13	(0)	9	(0)	0	(0)	5	(0)	12	(0)	37	
Goldeneye	1	(0)	25	(0)	30	(0)	20	(0)	6	(6)	25	(4)	67	(15)	78	(40)
Goosander	1	(2)	16	(0)	11	(2)	7	(2)	2	(2)	13	(4)	18	(2)	47	(15)
Mute swan	17	(4)	22	(5)	24	(4)	23	(3)	13	(1)	12	(2)	15	(2)	27	(16)
Coot	116		150		187		217		30		38		68		350	

2.3.2 Gulls associated with the Dee

Colonies of black-headed gulls and common gulls associated with the Dee are shown in Figure 1. Most black-headed gulls are found on the agriculturally richer ground of middle and lower Deeside. They nest in marshes or marshy loch margins and their numbers may be limited by lack of suitable nesting habitat. The total Deeside population numbers about 3000 pairs, of which by far the largest colonies are at Dinnet (1000-1500 pairs) and at Leys (about 1000 pairs). Most of the population of 150-300 pairs of common gulls are found in upper Deeside where they nest on river shingle and nearby vegetation. There are 3 small hill colonies lower down the valley at Morven, Kerloch and Durris, and a few scattered pairs elsewhere. In recent years, there has been a large increase in common gulls and black-headed gulls in the Braemar area, which is associated with an increase in tourists, as many gulls now feed in roadside lay-bys during the summer. In spring, there is a large roost of up to 10000 black-headed gulls on Loch Kinord. The herring gulls from the Aboyne rubbish tip and elsewhere roost on Kinord.

2.3.3 Birds of the hill streams and lochs

Loch Muick is little used by wildfowl. A few goosanders may be seen there, and there are common sandpipers and grey wagtails round the shore. Loch Callater has a small black-headed gull colony of about 50 pairs and a few common gulls and common sandpipers. Besides gulls, one can find mallard, teal, goosanders, common sandpipers, dippers and grey wagtails up tributary rivers, streams and lochans high into the hills. Dippers have been recorded at Loch Etchachan (900 m) on several occasions. Herons can also be found fishing in places like Glen Derry and Chest of Dee. Scattered pairs of greenshanks breed on the upper Dee or in association with small upper tributaries. Above Braemar, there were 4-7 pairs in 7-12 sites checked in 1969 and 1971-73. On the Dee, greenshanks are on the edge of their range, and not all known breeding sites were used in every year. In about 40 breeding attempts, only 7 pairs produced one or 2 flying young and, overall, the average breeding success was about 0.6 young per pair per year (R Moss, in Nethersole-Thompson & Nethersole-Thompson 1979). In mid-Deeside, at least one pair reared young in some years in the period 1978-82.

2.3.4 Birds of the middle and lower Dee

Oystercatchers are confined to the river when they first come to Deeside in February and March, and at this time they roost on river shingles (over 2000 birds counted between Ballater and Peterculter), but most do not nest there. Other waders, including curlew, lapwing, redshank and greenshank, use the river as a migration route. In late autumn and winter, great black-backed and other gulls, herons and occasionally buzzards eat dead salmon (there may be as many as 5000 dead kelts on the river (W Irvine)), and many gulls follow the line of the river, flighting to and from their roosts on the lochs. In autumn and winter, a variety of birds use the reed beds and marshes as roosts, the most notable being up to 14 hen harriers (including a bird wing-tagged in Orkney). Swallows, sand martins, pied wagtails and starlings also roost there at various times. Marsh harriers have been recorded at the Dinnet lochs and at Braeroddach.

Apart from about 5 nests near Braemar, known heronries are below Ballater. Herons frequently move their nesting sites if disturbed, but counts between 1971 and 1981 showed 10 colonies with 4-10 (average 6.4) nests per colony along the Dee. For some of these colonies, there are data for only 1-2 years, but the pattern (Figure 2) shows a relatively large number of small colonies, closely spaced below Durris and progressively further apart upstream to Braemar. Two colonies in mid-Deeside had most nests (on average 10 each), but there was no obvious trend in average colony size in relation to the course of the main river. The birds feed mostly in tributaries and ditches, presumably mainly on eels and small salmonids (M Marquiss).

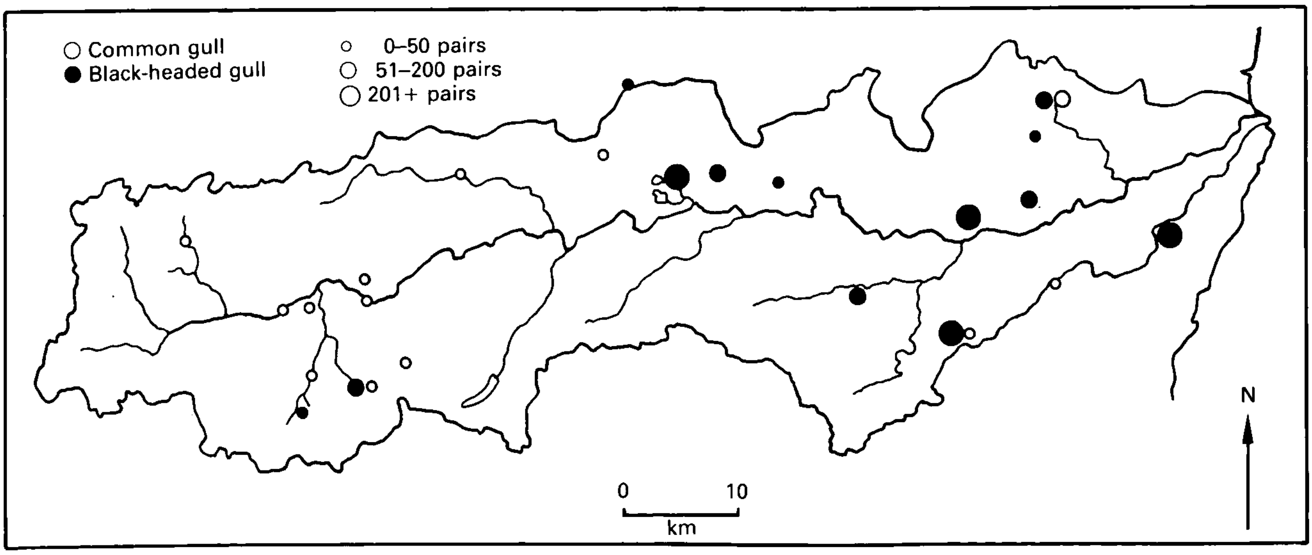


Figure 1. Gulleries associated with the River Dee in 1984

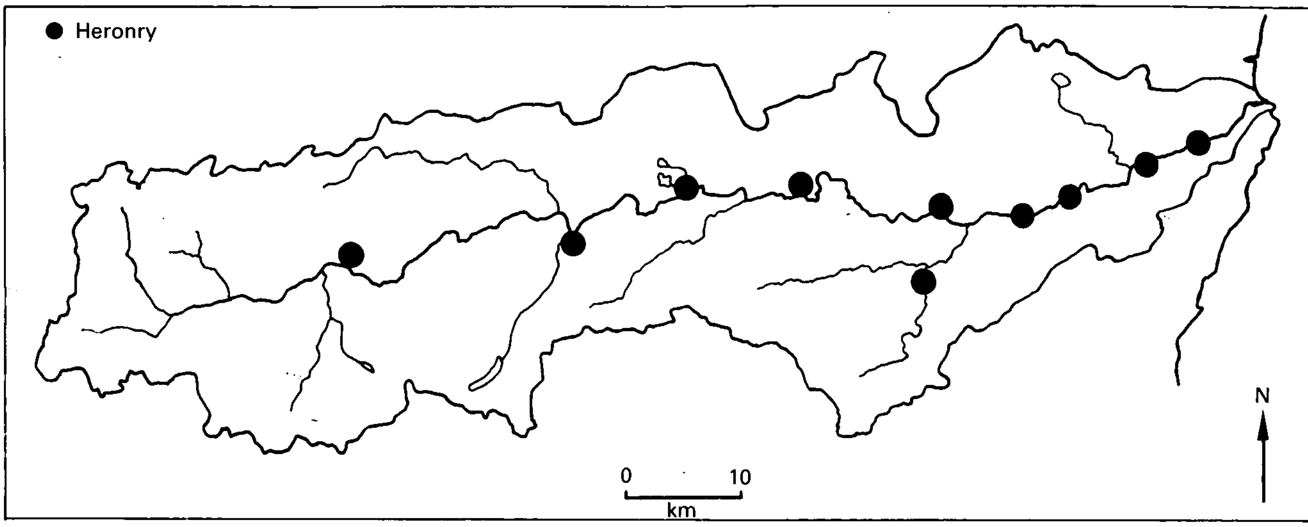


Figure 2. Heronries associated with the River Dee in 1980-84

Goosanders on the river were counted on 25 March 1984. Results were: Aberdeen-Banchory (*c* 29 km), 18 drakes, 16 ducks; Banchory-Chest of Dee (*c* 81 km), 20 drakes, 16 ducks, plus one unsexed. On the lower stretch, the density was 1.2 goosanders km^{-1}, compared with 0.46 birds km^{-1} on the upper stretch. One red-breasted merganser drake was seen between Aberdeen and Banchory. Individuals of this species, perhaps more commonly single drakes beyond Banchory, are seen throughout the length of the river, and nests have been recorded.

Special walks were done to count birds on the middle Dee between Invercauld and Banchory, and on the *Tanar, Muick* and *Gairn*, in late June-early July 1984 (Tables 2 & 3). Spring 1984 was unusually dry and the low water level in the river exposed more shingle than usual. The main feature of the data is the low density of birds. Even the most numerous, the common sandpiper, reached a maximum density of only 4.4 birds km^{-1} and averaged 1.8 over nearly 70 km. Common gull was next most numerous, averaging 1.1 km^{-1}, and the other species ranged between 0.2 km^{-1} and 0.9 km^{-1}. The highest densities of common sandpiper and pied wagtail were at Balmoral-Dalraddie, of common gulls at Polhollick-Ballater, and of grey wagtail at Balmoral-Polhollick. Overall, densities were similar on the short stretches walked on the tributaries, with common sandpiper and grey wagtail most numerous (0.8 km^{-1} and 1.0 km^{-1}). More dippers are seen on the Dee in winter than in summer, often singing on ice. Presumably they move down from the tributaries when these freeze in winter.

Table 2. Densities of breeding birds 10 km^{-1} of the River Dee, Aberdeenshire, in June-July 1984

	Invercauld to Balmoral	Balmoral to Dalraddie	Dalraddie to Polhollick	Polhollick to Ballater	Ballater to Cambus	Cambus to Dinnet	Dinnet to Aboyne	Aboyne to Potarch	Potarch to Banchory	Totals: Distance	Totals: Adult birds seen	Totals: Birds 10 km^{-1}
Distance (km)	10.2	5.5	5.0	3.0	6.0	6.2	8.7	13.0	11.2	68.8		
Mallard ♀♀	0	0	0	3	0	0	1	0	1		11	1.6
Goosander ♀♀	2	0	0	3	2	5	3	3	2		17	2.5
Common sandpiper	6	44	18	23	27	19	19	21	5		125	18.2
Common gull	18	0	2	33	2	0	11	14	13		73	10.6
Common tern	0	0	0	0	0	0	2	7	1		12	1.7
Grey wagtail	5	20	24	7	10	10	3	5	11		64	9.3
Pied wagtail	1	13	4	0	3	6	0	1	7		25	3.6
Dipper												
February 1977	—	—	—	—	—	13	5	—	6*			
April 1977	—	—	—	0	—	—	5	—	—			
June	—	—	0	—	—	—	2	—	—			
June-July 1984	0	4	4	0	3	5	1	1	2		13	1.8

*5 km only

Table 3. Habitats occupied by birds on 3 tributaries of the River Dee in June 1984: *Tanar* (7.5 km), *Gairn* (9.5 km) and *Muick* (8.5 km)

	Open: Shingle	Open: Rapids	Wooded
Mallard	6	0	1
Goosander	0	0	2
Common sandpiper	19	1	0
Grey wagtail	22	3	0
Pied wagtail	5	0	1
Dipper	3	6	0

Table 4. Adult birds (%) seen in different habitats on 68.8 km of River Dee in June-July 1984, and trends* in preference or avoidance of these habitats

i. Habitats classified by vegetation on bank

		Open	Open/wooded	Wooded
Percentage of total		25	35	40
Species	n[†]			
Mallard	9	(0) ↓↓↓	(89) ↑↑	(11) ↓↓
Goosander	19	(21) NS	(42) NS	(37) NS
Common sandpiper	122	(57) ↑↑↑	(29) NS	(14) ↓↓↓
Common gull	9	(67) ↑	(22) NS	(11) ↓
Common tern	4	(75) (marginal)	(25) NS	(0) NS
Grey wagtail	58	(38) ↑↑↑	(43) ↑ (marginal)	(19) ↓↓
Pied wagtail	25	(40) ↑	(40) NS (marginal)	(20) ↓
Dipper	13	(54) ↑↑	(15) ↓	(31) NS

ii. Habitats classified by river characteristics

		Rocks/rapids	Extensive shingle	Open water from bank to bank
Percentage of total		10	65	25
Species	n[†]			
Mallard	9	(11) NS	(0) ↓↓↓	(89) ↑↑↑
Goosander	19	(10) NS	(21) ↓↓↓	(68) ↑↑↑
Common sandpiper	122	(7) NS	(57) NS	(36) NS
Common gull	9	(0) NS	(22) ↓↓↓	(78) ↑↑↑
Common tern	4	(0) NS	(0) ↓	(100) ↑↑
Grey wagtail	58	(10) NS	(29) ↓↓↓	(60) ↑↑↑
Pied wagtail	25	(8) NS	(20) ↓↓↓	(72) ↑↑↑
Dipper	13	(54) ↑↑↑	(15) ↓↓	(31) NS

* ↓ Trend towards avoidance, ↑ Trends towards preference } cumulative binomial probabilities
↓↓↓, ↑↑↑ P <0.001; ↓↓, ↑↑ P <0.01; ↓, ↑ P <0.05; NS = Not significant

[†]The units for analysis are individual birds; in the case of common tern and common gulls, there were loose flocks of 9 (tern) and 5, 10, 3, 15, 3, 10, 2, 5 (gull), each of which is treated here as 1.

In the walks done in June-July 1984, the river bank habitats were broadly classified as open (moor or fields), wooded, or half-open (ie one bank open, one bank wooded), with regard to the main habitat features at the point where each bird was seen. The proportions of these different habitats were measured over the whole stretch. The character of the river was further classified according to rate of flow as 'extensive shingle' or 'open water from bank to bank' or as 'rapids with large boulders in the bed of the river'. Some trends for preference or avoidance shown in Table 4 are statistically significant.

Common sandpipers, grey wagtails, dippers, common gulls, pied wagtails and probably common terns preferred open habitats; and common sandpipers, common terns, mallards, grey wagtails, common gulls and pied wagtails avoided wooded banks. Except for the dipper and common sandpiper, all species preferred stretches where there was open water from bank to bank, and all, except perhaps common sandpipers, avoided extensive shingle. Dippers preferred rapids. Common sandpipers showed no significant trends. Grey wagtails and pied wagtails were similar in their occupation of habitats, but grey wagtails showed a stronger trend than pied towards preference for open or half-open habitats and towards avoidance of woods. Twice as many grey wagtails were seen as pied, and it is interesting to speculate whether these 2 species may compete for the same riverine habitats, with the grey wagtail predominating. These preliminary data suggest that a detailed comparison of the 2 wagtail species might be worthwhile.

The proportions of the different habitats on the tributaries (Table 3) were not recorded. However, the 2 most numerous species, common sandpiper and grey wagtail, were found more often in habitats registered as shingle than elsewhere; this apparent difference from Table 4 should be checked in a wetter spring when there may be less shingle on the tributaries. Dippers were again more numerous on the rapids than other species. On these tributaries, grey wagtails were nearly 5 times as common as pied wagtails.

No kingfisher was recorded in 1984, but they do occur rarely. Ospreys have been recorded regularly in the Dee river system since the mid-1970s and occasionally earlier, with at least 2 nesting attempts, both unsuccessful. Single birds have been seen from Crathes to Ballater, most frequently within a few km of Dinnet. The contrast between the Dee and Spey is notable. In Speyside, there are several successful nests each year, but none in Deeside.

Small numbers of goldeneyes and goosanders are regular inland on the Dee in winter. On the Dee in Aberdeen, the winter population of wildfowl includes 100-150 mallard, up to 25 goldeneyes and 10-20 goosanders. Small numbers of mute swans occur, together with occasional tufted ducks, pochards, long-tailed ducks, smew, mergansers and eiders. In hard weather when the lochs freeze over, the unfrozen river at Aberdeen can be important for waterfowl, and in January 1979 it held up to 200 tufted ducks, 4 scaup, 88 pochards and 100 goldeneyes for a few weeks. Goosanders occasionally moult there in summer; it is unusual to find this shy species so close to people.

2.4 Mammals

Besides seals at the river mouth (excluded here), and bats (see below), only 4 species can properly be regarded as riparian, let alone aquatic. We exclude roe deer, which are often seen in reed beds, hares and rabbits. The 4 main species are water shrew, water vole, mink and otter.

2.4.1 Insectivores and rodents

The status of water shrew and water vole is uncertain. There are 4 records of water shrews for Deeside for 1964-69 at the Biological Records Centre, ITE, Monks Wood Experimental Station (H R Arnold). In addition, R Hewson and T Healing trapped a water shrew in 1976 at Blackhall, Banchory; R J Harper saw one at a marsh at Loch Davan in 1976 and 1977; and M P Harris saw one near the *Canny* in 1981. Corbet and Southern's (1977) description of the habitat used by water shrews is 'by clear, unpolluted streams wherever there is cover', and trapping by the Dee and its tributaries would probably show that the water shrew is more widespread than these few records suggest.

Sim (1903) stated that water voles were abundant in most streams in Deeside. The Biological Records Centre has 3 records for the middle Dee and another 2 from above Braemar. They are local but widespread along streams in the hills, though numbers fluctuate. J Oswald reports that water voles occur on the Tanar beat of Dee wherever there are patches of rushes, but no signs were found on the Dee by Jenkins' team in 1974-79 during work on otters. However, they were found on the *Dinnet* near its source in Loch Davan, and were also trapped there in 1977 by R Balharry. H Kolb trapped water voles in 1972-73 at Moss-side, Strachan. The distribution of water voles may be patchy, in dense vegetation and, perhaps especially, in places with over-hanging cover, small deep pools and areas with good grass on stream banks or ditches, rather than along rivers (R Hewson). Although widespread, signs of brown rats on stream banks in 1974-79 were mostly found near farms and houses.

2.4.2 Carnivores

The first records of wild mink breeding in Aberdeenshire were in the early 1960s (Cuthbert 1973). They are now widespread in north-east Scotland (Corbet & Southern 1977), occurring throughout the Dee valley up to at least 300 m, and have therefore become an integral, naturalized part of the fauna. Mink mainly frequent good cover on stream and loch banks, but they also use stone dykes and may be seen one km or more away from water.

On the Glen Tanar estate bank of the Dee (36 km), 39 were killed in 1971-83. J Oswald considered that there were no more than 1-2 families of mink on this stretch. Elsewhere, they have not been systematically trapped, presumably because numbers are low. Few signs of mink were found during walks of the river and its tributaries in 1976-78 during research on otters (Jenkins 1980). Indeed, places with mink signs were often several km apart. In 1977, no trace of mink was found on 9.5 km of the *Gairn* in January-June or on the upper *Gairn* in May-July, or on 7.5 km of the *Tanar* in March-November; only scattered signs were found on occasional visits to the *Feugh*, but they occurred up to at least 8 km from the Dee. However, on 5-6 km of river banks at Park, 54 mink were trapped in 1981-84, and 60 at the mouth of the *Dinnet* in 1972-75.

In April-November 1975, 23 mink were live-trapped, marked and released in the 8 km banks of the Dinnet lochs. Seven marked mink were recaptured (one 5 times) 1-31 days later, near where they were first caught. Adult males were caught in 8 different places, and there were at least 6 family parties. These observations suggest that, at least in 1975, mink may have been more numerous on these lochs than on much of the nearby main river and other tributaries. Few have been killed on the National Nature Reserve (NNR) at Muir of Dinnet subsequently (14 in 1982-84), not because they are scarcer than in 1975 so much as because less manpower is available for trapping them.

In 1969-70, mink scats from the *Sheeoch*, east of Banchory (Figure 1), contained mainly salmonid fish and eels, with no remains of game birds (Cuthbert 1979). In 1975-78, the main items in mink scats from mid-Deeside were mammalian, mainly rabbits, throughout the year (Jenkins & Harper 1980). In neither of these studies was there any suggestion that mink predation was important to human interests, and trapping them on an NNR may cause more disturbance than the animals' predation warrants. The main conclusion is that mink are probably widespread but relatively scarce on most parts of the middle Dee and its tributaries and, though a potential nuisance, are unlikely to be a major problem to landowners or nature conservationists.

Jenkins (1980) and his colleagues studied the distribution of otter families in 1974-79 on the Dee above Aboyne. About 9 otter families were thought to have been reared in 1977-78 on 26 km of river plus 124 ha of lochs near Dinnet. In 1974-79, 1.4 young were reared, on average, per successful family, so that about 13 otters may have been reared on this stretch in 1977-78. Otter families were also seen on the *Tanar* and *Feugh*, and Jenkins was told of otter families on 4 other tributaries. Most signs of otters were found where the bankside vegetation provided good cover (Jenkins & Burrows 1980; Bas *et al.* 1984); and the national decline in otters is attributed partly to loss of such cover, partly to increased disturbance due to increased riverside recreation, including angling and pleasure boating, and partly to the greater use of agro- and other chemicals which later get into river systems (O'Connor *et al.* 1977). Aboyne-Polhollick may be the best stretch of the Dee for otters. Signs of them were scarcer further upriver, and the agricultural and populated stretches of the lower river would not be expected to provide suitable habitat for them.

The Dinnet lochs were important rearing areas for otters, with up to 2-3 families at once, staying for 7-12 months. The young then moved to the nearby river. In 1984, otters should probably be regarded as the most important wild vertebrates on the Dee, with the Dinnet area vital for their conservation.

Their main food was eels in the Dinnet lochs, and eels and salmonids in the rivers (Jenkins & Harper 1980). Most eels and salmonids taken were small (eels mostly 23-32 cm, salmonids mostly <13 cm). On the tributaries, more spraints in autumn were associated with a higher proportion of undigested remains of salmonids. Presumably more otters were in the tributaries in autumn than at other seasons, perhaps because they followed spawning fish. However, otters occurred in the *Feugh* in January 1982, when one killed a moorhen. Care should be taken when interpreting evidence from numbers of faeces because otters may use spraints for marking their ranges, and may vary this practice seasonally, so a reduction in the number of spraints found may not necessarily indicate a change in the number of otters present.

One to 3 otters were found dead in Deeside each year from 1978-84, in addition to the families of young which disappeared (see Jenkins 1980). Eight of 11 known deaths were due to road accidents, though at least one animal was ill beforehand. Most deaths were in January-June. Otters are not now known to be deliberately killed by man on the Dee.

2.4.3 Bats

The pipistrelle bat, Daubenton's bat and brown long-eared bat are common north of Perth in the summer (Racey & Swift 1982), the noctule and parti-coloured bat are rare vagrants, and Natterer's bat occurs occasionally. The 3 common species are frequently found roosting close to rivers or standing water, where they can easily find food. Long-eared bats may be unusually common in the mid-Dee valley because of the abundance of Lepidoptera which are gleaned from riverside trees by hovering bats (Swift & Racey 1983). Daubenton's bats, which hunt over rivers and open water (Swift & Racey 1983), were found in a single roost near the Dinnet lochs; they depend on chironomids, caddis flies and other insect fauna associated with these areas of water.

Most (>95%) reported bat roosts in Deeside are in occupied dwelling houses within 4 km of the river system (Figure 3). Few roosts have been reported upstream of Ballater, but, of 21 nursery roosts reported downstream in summer 1984, 13 were of long-eared bats, one of Daubenton's bats, and 7 of pipistrelle bats. No roosts of long-eared bats have been recorded downstream of Banchory. Above Banchory, roosts of this species outnumber all others (Figure 3). Numbers of roost occupants fluctuate in summer but no movement of bats between roosts has been recorded, so that the proportion of known roosts may be low. A single instance of long-eared bats roosting in a tree has been reported in Deeside (B Mitchell).

It is conservatively estimated that in summer the Dee valley (downstream of Ballater) contains 1000-10 000 adult female pipistrelle bats, 100-1000 adult female long-eared bats, and 10-100 adult female Daubenton's bats. Solitary adult males are encountered only infrequently and are impossible to census. Without the river and its associated trees, the density of bats would probably be much lower.

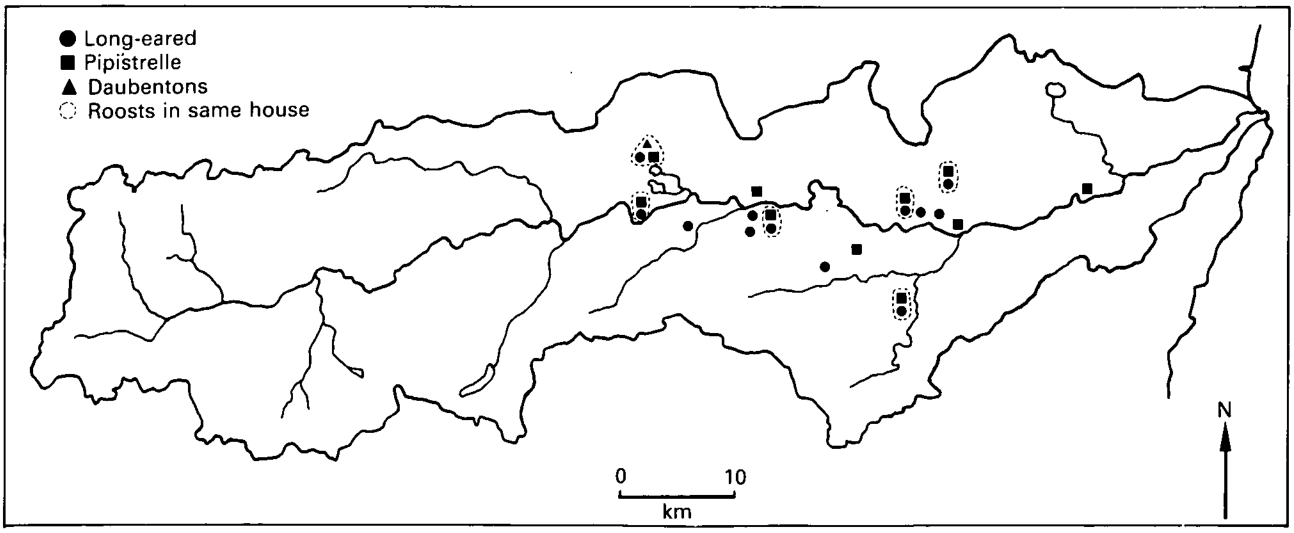


Figure 3. Known roosts of bats in Deeside in 1984

The pipistrelle bat is evenly distributed along the valley, where it forages among riparian trees. These bats may travel up to 5 km from the roost each night (Racey & Swift 1985), and eat mainly caddis flies and Nematocera (Swift *et al.* 1985).

Virtually nothing is known of the wintering populations of these bats, mainly because of their reduced activity. Most Scottish bats may migrate south in winter (Racey & Swift 1982).

3 Conservation of the vertebrates

Few if any of the species described here are at risk at the moment. However, a species which is apparently secure now may become vulnerable to potential threats (eg from recreation) in the future. The security of the vertebrates of the river depends partly on the interest, tolerance and goodwill of the landowners, and partly on active voluntary and statutory conservation.

The continuing increase of wintering and moulting waterfowl at Muir of Dinnet NNR following protection is associated with a new freedom from disturbance. This protection has led to increased opportunities for local bird-watchers.

Other recreational uses of the Dee system include angling, canoeing, water ski-ing, walking and picknicking on the river bank, and casual and organized camping on stream bank and lochside. Wind-surfing has recently begun on the Loch of Loirston, which is near the Dee though hardly a part of the river system. It is nonetheless a good example of a potential threat; the regular winter duck population of this loch includes not only mallards, wigeon and tufted ducks, but also a roost of up to 100 goldeneyes and 20 goosanders, and a flock of up to 41 whooper swans. In 1982/83 and 1983/84, these swans were driven off by wind-surfers.

The present wildlife of the Dee has co-existed with angling, agriculture and forestry for a long time. However, trends are changing with the income from angling now setting off losses from other game, and with perhaps less money available for the maintenance of river banks. This maintenance sometimes involves powerful machinery, including not only bulldozers which quickly convert drains into canals but also power-saws and a risk of the removal of whole trees, instead of branches as previously with a hand-saw. On some tributaries especially, river bank fences are decaying and not always being replaced, and this leads to grazing on the tributary bank and fewer trees regenerating. This situation may be offset on the Dee by a decrease in the number of smallholders, resulting in less intensive grazing on the river bank (J Oswald). Our problem is not only that few of these changes have been measured, but that different conservation interests require different land uses.

For wildlife, the Dee is of prime importance for otters which should feature prominently in any plans for wildlife conservation. Otters require good cover for shelter on river banks, especially near pools with muddy bottoms where there are eels. These pools may be good for angling, requiring some tree clearances to make room for casting. Grassy banks may be also preferred by botanists because short cover may favour flowers. A new suggestion is that conifer trees should not be planted up to the river's edge because of accentuating problems of acidity in the river from acid rain, yet one of the best places for seeing young otters above Aboyne is where the trees come right to the river's edge with the path set well back into the forest. This place is interesting because, despite the trees, it is good for angling, with small areas cleared of trees so that casting is easy in the best places for catching fish. There is little shingle, so there is no conflict between the needs of otters and riverside birds, and it is a good example of the development of forestry, angling and otter conservation to the benefit of all three. Other places could be developed actively to foster several interests, perhaps, for example, angling, picnic sites, access for canoeists and drinking places for domestic stock.

Apart from the loss of riverside trees on which the food of long-eared bats in particular depends, the most immediate threats to bats near the Dee valley are incidental destruction of bat roosts during house improvements, remedial timber treatments to kill wood-boring beetles, and deliberate attempts by householders to remove bats. A more long-term threat to bats would be greater use of agricultural insecticides on new farm crops, which would reduce their insect prey as well as resulting in the accumulation of such insecticides by the bats. Insecticides have been inferred as important in reducing bat populations in western Europe (Stebbings 1982), and it is important to recognize this potential area of conflict between agriculture and wildlife conservation. Because such insecticides are seldom used in north-east Scotland and the local bat populations are apparently healthy, Scottish river valleys such as the Dee with large areas of riverside trees may represent sites of national importance for bats, and Deeside farmers should be aware of this fact.

In addition to the situation at the Loch of Loirston, recreation and wildlife on the Dee are also in conflict at the Loch of Aboyne. In the case of the Loch of Loirston, it is to be hoped that wind-surfers could be diverted elsewhere. Water ski-ing at the Loch of Aboyne has led to the loss there of most breeding ducks and coots, though mute swans still breed, and an otter was seen there at night in August 1984. At Aboyne, recreation would seem to be a reasonable priority, and the loss of the waterfowl presumably has to be tolerated by bird-watchers. On the river, canoeing at present mostly occurs near bridges, where other disturbance is likely anyway. As canoeists extend their activities, however, it is to be hoped that they will not land on islands or in otter havens (see below), and agreement is desirable on the optimum use of each section of the river system.

Despite the apparent lack of serious conflict so far, there is still a need for conscious management for wildlife conservation as a major use of the river system. The main threats to all wildlife are likely to arise from loss of habitat, and the dangers of disturbance, if cover is removed, should not be underestimated. Wildlife conservation at the Dinnet lochs is ensured by a statutory NNR, managed jointly by the Nature Conservancy Council and the landowner. This NNR includes both lochs but very little of their associated waterways and none of the Dee itself. Only a small part of the watershed of the lochs and none of their outlets are included in the protected area. Marren (1984) describes the importance of the purity of the water of Loch Kinord, thereby emphasizing the desirability of careful control of the management of the whole watershed.

Other Sites of Special Scientific Interest (SSSIs) in the Dee system include parts of streams in Glen Tanar, within the conserved forest system, but with neither the source nor much length of the streams formally protected. Quithel Wood at Ballogie and Crathie Wood near Braemar are other SSSIs on the main river bank, together with the drained Loch of Park nearby. The Loch of Skene is also an SSSI.

However, apart from the montane Cairngorms NNR, which includes the source of the river, and 3800 m of both banks at Potarch, mostly treeless and chosen for its interesting flora, no part of the Dee is included within an SSSI for its intrinsic interest as part of the river system.

The Department of Planning in Grampian Regional Council has gone to much trouble in defining 'Sites of Interest to Natural Sciences'; these SINS carry a pre-emption for natural history use in planning, but have no statutory weight if there is a conflict. Another recent development is an otter haven of 7.25 km of one bank of the middle Dee. This is an important initiative between the landowner and the Scottish Wildlife Trust, embodying a formal commitment to maintain existing bankside vegetation, to fence off other areas at present without trees, and to plant native species in order to help preserve or increase habitat suitable for the Dee's most important wild animal. A similar agreement on a tributary between another landowner and the Friends of the Earth seems to be in abeyance, though the landowner has erected a new fence to exclude stock from a stretch of river bank. These initiatives are much to be encouraged, and it is hoped they will be followed elsewhere.

4 Discussion

The relatively sparse fauna of the Dee might be regarded as typical of a nutrient-poor, short, fast-flowing, shallow river rising in granite mountains. In its upper reaches, it runs mostly over acid rocks, and, though it sometimes flows slowly with a lesser fall, it is inhospitable because it often freezes in winter. It flows over richer rocks in the Dinnet stretch and is further enriched by nutrient runoff from agricultural land below Banchory. A poorer fauna above Ballater might be expected to become progressively richer or more numerous towards the sea, but this simple picture is complicated by loss of natural habitats, by disturbance, and perhaps by the effects of sewage pollution and eutrophication, fortunately slight at present.

In view of the importance of the Dee as a salmonid fishery and in scientific terms, it is surprising that so little is known about its fish. Other than salmon and trout, basic knowledge on the status and distribution of fish in most parts of the system is almost entirely absent. It is possible, for instance, that several species may occur in the area but have not been mentioned here. The arctic charr is known to occur in lochs to the west, north and south of the Dee catchment, and several lochs in the upper Dee valley (eg Loch Etchachan, Lochan Uaine) would seem suitable for this species. One of the urgent scientific requirements, therefore, is a thorough survey of fish populations in the area, as is equally true of several other important river systems in Scotland (Maitland 1972). The gap in knowledge is also relevant to some important applied areas, as well as preventing further scientific understanding of the river system. It has been shown (Maitland 1977) that several fish species (some of them previously absent from Scotland) are gradually moving northward in distribution (eg dace and ruffe). Some of these may cause problems in salmonid nursery streams in the future, but it will be impossible to make any assessment of their impact there or to develop control measures, unless we have basic information on the fish communities which are present now.

Acid precipitation is a topical and relatively new form of pollution which appears to be affecting fish populations in some Scottish lochs. Because of the extensive areas of granite within the Dee catchment, and the fact that much of the rainfall there is fairly acid, it is likely that some sensitive fish (eg arctic charr) have already been affected. However, because of our ignorance of the status of this and other species, we may never know if this has been the case.

For other wild vertebrates, most conservation interest focuses on the otter and on bats, both of which are rare in most agricultural habitats but which still occur in natural or semi-natural habitats on the Dee, and for which the main requirements are absence of disturbance and the preservation of riverside vegetation. In the case of birds, the main conflicts arise from the destruction of habitats through drainage (eg one of the hen harrier roosts at Dinnet is at risk), or disturbance, including actual killing by gamekeepers (eg shooting goosanders or poisoning birds of prey), and by bird-watchers. There is a risk that publicity for rare birds can result in over-exposure; this risk must usually be faced openly as one of the grounds for wildlife conservation is for people to enjoy seeing wildlife.

An aim of this conference is to identify areas of actual or potential conflict. Naturalists, anglers and canoeists, for example, should discuss whether there are parts of the Dee where bankside vegetation should be preserved and recreation limited, and other parts where wildlife is less at risk, where other interests should have priority, and where recreational activities can flourish. In principle, the middle section of the Dee may be the best for the wildlife at present, at least in comparison with places where the Dee flows through farmland. However, if riverside woods of birch, willow and alder could be re-established on the upper Dee, the vertebrate fauna there would probably be richer than it is now, especially on the flatter stretches where carr might develop and encourage more waterfowl to stay in summer.

The need for safeguards in management of the river system as a whole has apparently not registered strongly in the NCC's scientific appraisal of the wildlife resource of Grampian Region, which is surprising in view of the loss of the Lochs of Auchlossan, Leys and Park. Even on the NNR at Dinnet, both eastern and western parts of the Muir have recently been drained, and it is surprising that such a small part of the habitats known to be used by otters has official protection. The Dee is important nationally for the conservation of otters. Organized camping on the edge of Loch Kinord in the middle of the NNR also seems incongruous to conservationists. It is a potential cause of disturbance and should be stopped. Other possible active steps by the NCC include the consideration of parts of the river as SSSIs.

The symposium highlights the desirability not only of an agreed code of conduct between users of the river and its banks, but also of a re-assessment of aspects of the conservation of vertebrates of the Dee and their habitats, and of the responsibilities of the Nature Conservancy Council.

5 Summary
This paper describes some wild vertebrates which are associated with the river system of the Dee, including not only the main river but also its tributaries, lochs and associated marshes.

Little is known about the non-salmonid fish of the Dee, and it will be impossible to assess their impact without basic information on the fish communities which are there now.

Vertebrates sensitive to environmental pressures include otters and bats. The Dee is an important river for the conservation of otters, while long-eared bats are especially characteristic of the middle Dee. Birds nesting on the Dee characteristically occur at low densities, reflecting the low productivity and fast rate of flow of the river. The most numerous of the breeding river birds are common sandpipers and grey wagtails, reaching densities of about 2-4 km^{-1} but mostly less. Non-breeding waterfowl are much more abundant, with lochs and river shingles important as roosts for geese and oystercatchers. Most duck species wintering at the Dinnet lochs are increasing.

The main features identified as affecting vertebrates in the Dee include: (i) the low productivity and fast flow of the upper river (poor for wildlife); (ii) bare banks, especially on the upper stretches of both main river and tributaries (often in association with heavy grazing) and in the richer agricultural stretches (poor for wildlife); (iii) conifer woods above Aboyne and deciduous woods and fringes between Banchory and Ballater, providing shelter on the river bank, with the birches and alders probably good for Lepidoptera as food for bats; (iv) the pure Loch Kinord and rather richer Loch Davan, and their important outlets and associated marshland. The middle parts of the river system are richest for vertebrates at present. This situation could change with management aimed specifically to improve habitats for vertebrates. There is also a need to integrate wildlife conservation with pressures from recreation (water ski-ing, canoeists, wind-surfers, campers, picknickers) on lochs and elsewhere, and to integrate the requirements of fishermen and of farmers with the scientific aims of wildlife conservation and with satisfying the pleasure that people get from watching wild animals in semi-natural habitats.

There are at present few conflicts on the Dee, and this may make it especially easy to have discussions on a code of conduct for river users, including farmers, foresters, anglers, and naturalists, as well as those seeking recreation. Formal conservation of the river by the Nature Conservancy Council is minimal, and we suggest that a scientific appraisal of conservation needs for the whole river system would be timely in order to identify sensitive areas and avoid conflict in the future.

6 Acknowledgements
We thank many friends for help, especially Peter Maitland, John Speakman and Paul Racey for the sections on fish and bats, Dan McCowan and Rosemary Harper for work on mink and otters, Andrea van der Berg, Anneke Stolte and Addy de Jongh who counted the birds in June-July 1984, and others, including those named in the text, for the use of their notes. We are grateful to the Deeside landowners and to the Nature Conservancy Council for permission to visit their lands, and to several colleagues, particularly Adam Watson and Don French, for comments on the manuscript and help with statistics.

7 References

Bas, N., Jenkins, D. & Rothery, P. 1984. Ecology of otters in northern Scotland. V. The distribution of otter (*Lutra lutra*) faeces in relation to bankside vegetation on the River Dee in summer 1981. *J. appl. Ecol.*, **21**, 507-513.

Corbet, G. B. & Southern, H. N. 1977. *Handbook of British mammals.* Oxford: Blackwell Scientific.

Cuthbert, J. H. 1973. The origin and distribution of feral mink in Scotland. *Mammal Rev.*, **3**, 97-103.

Cuthbert, J. H. 1979. Food studies of feral mink (*Mustela vison*) in Scotland. *Fish Manage.*, **10**, 17-25.

Jenkins, D. 1980. Ecology of otters in northern Scotland. I. Otter (*Lutra lutra*) breeding and dispersion in mid-Deeside, Aberdeenshire in 1974-79. *J. Anim. Ecol.*, **49**, 713-735.

Jenkins, D. & Burrows, G. O. 1980. Ecology of otters in northern Scotland. II. Analyses of otter (*Lutra lutra*) and mink (*Mustela vison*) faeces from Deeside, NE Scotland in 1977-78. *J. Anim. Ecol.*, **49**, 737-754.

Jenkins, D. & Harper, R. J. 1980. Ecology of otters in northern Scotland. II. Analyses of otter (*Lutra lutra*) and mink (*Mustela vison*) faeces from Deeside, N.E. Scotland, in 1977-78. *J. Anim. Ecol.*, **49**, 737-754.

Maitland, P. S. 1972. *A key to the freshwater fisheries of the British Isles, with notes on their distribution and ecology.* (Scientific publications no. 27.) Windermere: Freshwater Biological Association.

Maitland, P. S. 1977. Freshwater fish in Scotland in the 18th, 19th and 20th centuries. *Biol. Conserv.*, **12**, 265-278.

Marren, P. 1984. The natural history of Loch Kinord. *Deeside Field*, 1983, 11-16.

Nethersole-Thompson, D. & Nethersole-Thompson, M. 1979. *Greenshanks.* Berkhamsted: Poyser.

Nethersole-Thompson, D. & Watson, A. 1981. *The Cairngorms: their natural history and scenery.* Perth: Melven.

O'Connor, F. B., Sands, T. S., Barwick, D., Chanin, P., Frazer, J. F. D., Jefferies, D. J., Jenkins, D. & Neal, E. G. 1977. *Report of the joint NCC/SPNC Otter Group.* London: Nature Conservancy Council/Society for the Promotion of Nature Conservation.

Racey, P. A. & Stebbings, R. E. 1972. Bats in Britain — a status report. *Oryx*, **113**, 19-27.

Racey, P. A. & Swift, S. M. 1982. Bats in Scotland. *Scott. Wildl.*, **18**, 11-18.

Racey, P. A. & Swift, S. M. 1985. Feeding ecology of *Pipistrellus pipistrellus* (Chiroptera Vespertilionidae) during pregnancy and lactation. 1. Foraging behaviour. *J. Anim. Ecol.*, **54**, 205-215.

Sim, G. 1903. *The vertebrate fauna of Dee.* Aberdeen: Wyllie.

Snow, D. W., ed. 1971. *The status of birds in Britain and Ireland.* Oxford: Blackwell Scientific.

Stebbings, R. E. 1982. *Distribution and status of bats in Europe.* Natural Environment Research Council contract report to the Commission of the European Communities. Abbots Ripton: Institute of Terrestrial Ecology. (Unpublished.)

Swift, S. M. & Racey, P. A. 1983. Resource partitioning in two species of vespertilionid bats (Chiroptera) occupying the same roost. *J. Zool.*, **200**, 249-259.

Swift, S. M., Racey, P. A. & Avery, M. I. 1985. Feeding ecology of *Pipistrellus pipistrellus* (Chiroptera Vespertilionidae) during pregnancy and lactation. II. Diet. *J. Anim. Ecol.*, **54**, 217-225.

Taylor, R. H. R. 1963. *The distribution of reptiles and amphibians in England and Wales, Scotland, Ireland and the Channel Isles, with notes on species recently introduced.* Edinburgh & Aberdeen: Nature Conservancy Council. (Unpublished.)

Treasurer, J. 1983. Estimates of egg and viable embryo production in a lacustrine perch, *Perca fluviatilis. Environ. Biol. Fishes*, **8**, 3-16.

Agricultural land use beside the River Dee

H L BLACK
North of Scotland College of Agriculture, Aberdeen

1 Introduction
This paper is presented by an agriculturist who is concerned with land improvement, crop and animal production, and the well-being of the farming community. It deals with the parishes listed in Table 1. The area of agricultural holdings and in crops and grass is given in Table 2.

Previous papers have described this pleasant land, some of it quite flat, running beside a wide, fast-flowing river. There are many species of tree which provide excellent shelter for livestock. Certain areas are particularly impressive and characteristic, like the birch scrub near Dinnet. Many people travelling along this beautiful valley would not classify it as an outstanding agricultural area, but, nevertheless, it still has an extremely important and traditional function in supplying livestock to the nearby lowlands. One tends to think of the Dee as starting at Braemar, yet at that stage it is already 42 km from its source at the Pools of Dee, nearly 900 m above OD in the Cairngorms.

Table 1. List of parishes used in statistical survey, 1972-83

Aberdeen	Durris
Aboyne	Glenmuick
Banchory Devenick	Kincardine O'Neil
Banchory Ternan	Maryculter
Birse	Peterculter
Crathie/Braemar	Strachan
Drumoak	

This paper considers the following 4 questions in relation to agricultural land use beside the Dee.

i. What is the land used for today?
ii. What determines this particular land use?
iii. Has time changed this use?
iv. What effect has this land use change had upon the valley?

2 The principal uses of the land
The valley of the Dee is relatively narrow, at its widest no more than 11 km and often only one field deep.

Table 2. Statistics for Deeside parishes (areas in ha) (source: derived from DAFS annual censuses, unpublished)

	1972	1976	1981	1983	1984
Number of holdings	631	541	504	494	412
Area of land rented	46 807	47 888	45 857	45 723	—
" " " owner/occupied	81 335	81 774	87 089	87 370	—
" " " wheat	133	49	42	164	154
" " " barley	3 551	4 762	5 602	6 092	5 471
" " " oats	2 959	1 830	1 217	589	508
" " " potatoes — seed	134	143	168	166	295
" " " " " ware	188	173	172	129	
" " " turnips	1 650	1 591	1 239	1 143	1 066
Total area of crops and grass	25 087	24 896	25 401	25 261	24 391
Area of rough grazing	101 988	103 691	105 930	105 000	104 000
Mean area of crops and grass per holding	39.8	46	50.4	51.3	59.2
Mean output at £500 ha^{-1} £	19 879	23 009	25 200	25 671	29 600
Mean income per holding at 15% output £	2 981	3 451	3 780	3 850	4 440
Number of breeding ewes	18 787	17 620	20 313	21 414	19 729
" " " lambs	23 100	21 544	25 737	25 429	25 737
" " " beef cows	9 145	10 267	9 265	8 800	7 883
" " " total beef animals	39 201	41 339	35 960	32 849	33 000
" " " dairy cows	2 414	2 472	1 991	1 631	1 028
" " " pigs	6 179	4 480	1 953	2 030	2 022
" " " poultry	192 424	231 478	247 408	222 114	224 000
Labour (people directly employed in agriculture)	782	622	609	697	510

There is, however, a surprising number of types of land use, including private and commissioned forestry, sport, including stalking red and roe deer, shooting red and black grouse, capercaillies, pheasants, partridges and brown and mountain hares, and fishing for salmon, sea trout and brown trout. The catalogue of country pursuits includes hill walking, general sight-seeing of the area or specific buildings of importance, bird-watching, canoeing, water ski-ing and pearl fishing. When people are attracted to an area by these activities, associated infrastructures are required (eg play areas for children in association with chalet development and caravan sites, golf-courses, craft and amenity centres and, most of all, hotels and tourist facilities).

It is surprising that a river the size of the Dee does not support much industry until the last few km from Peterculter to the sea, where the remains of the paper-mills and other mills dependent upon water can be seen. Small isolated sawmills and estate nurseries occur occasionally along the valley. Because of this lack of heavy industry, the Dee is a very clean river and great attention is paid to the well-kept sewage farms servicing the villages on the upper and middle reaches. The river is so clean that water is abstracted at Invercannie as the main source of water for Aberdeen.

Agriculturally, the existing wide range of activities is increasing. Until the last 20 years, Deeside was solely dependent on quality livestock production, mainly sheep and beef cattle which were produced in the uplands for finishing on the better ground further down the valley (Figure 1).

For agriculture, land is divided into the following 4 categories:

i. hill land;
ii. upland;
iii. lowland;
iv. the best quality suitable for all crops, including horticulture.

Hill land predominantly supports animals such as hill sheep or red deer, which require a minimum of labour. Upland areas can produce a limited amount of crop, but permanent and improved pasture predominates. This pasture can support hill cows, suckling one beef calf per annum. On the same land, sheep are also important and tend to be Blackface, Cheviot or occasionally 'crossed' animals such as Greyface. The crops normally grown in uplands are those required to feed the livestock, eg oats, barley, turnips, and grass for conservation either as hay or silage. The weaned calves or weaned lambs from these areas move through local markets to be purchased by low-ground farmers for finishing on the better land before slaughter to supply townspeople.

Additionally, the low-ground farmers may introduce a low-ground sheep flock lambing in January and February, for the early market in May and June. These are sold before store lambs from the uplands are bought in the autumn. Store cattle purchased from the uplands may either be finished in winter in courts or, alternatively, fattened off grass in summer.

Table 2 shows numbers of livestock in Deeside parishes from 1972-84 and the area of land currently

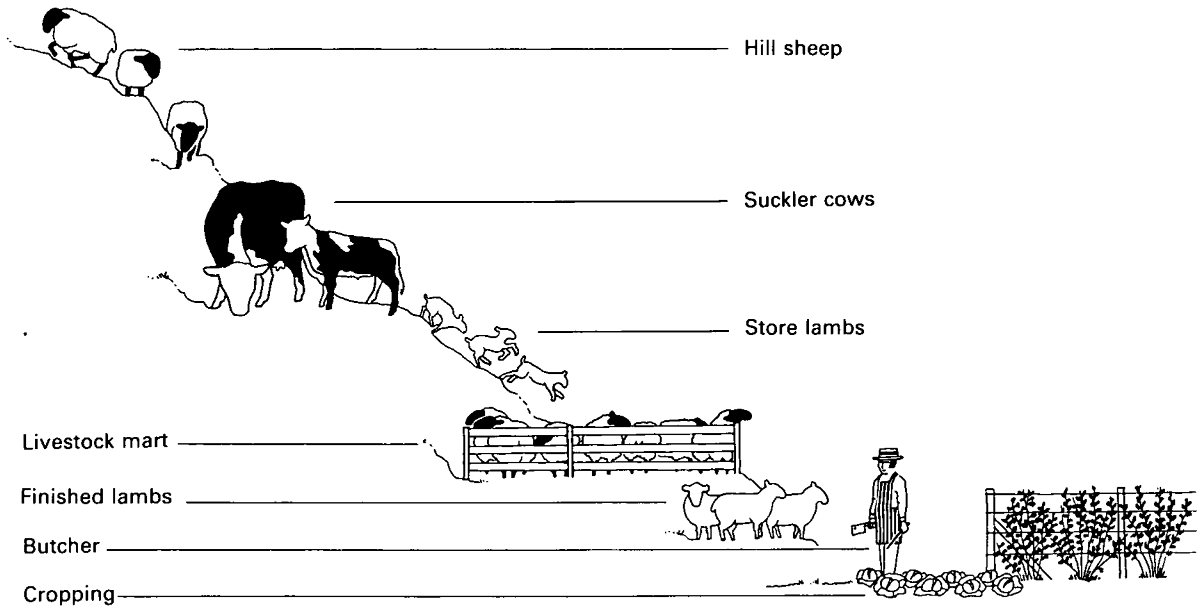


Figure 1. Movement of livestock in marginal farming

used for traditional crops. There is considerable additional scope for new crops such as oilseed rape and protein peas, as well as for growing barley for malting. The richer grassland on the better land near centres of population supports a few dairy herds. The Dee valley has little of the very best land, but occasional pockets, as far upstream as Dinnet, can support horticulture in the form of nurseries or fruit.

3 What determines these land uses?
Obviously the agricultural enterprises are not clear-cut. Many factors affect a farmer's particular choice of farming system. Traditionally, much of Deeside has been tenanted with certain restrictions placed upon the type of farming allowed. It has tended to be an area of family farms with the son following in his father's footsteps, often following his father's system of farming. Other important factors include altitude, soil type and associated deficiencies, length of winter and depth of frost, proximity to both market and town, the needs of the population for dairying or horticulture and, specifically to Deeside, the lack of moisture in a rain-shadow area.

There is a great diversity of soils in Scotland. There are, for example, more than 700 categories on a recently published 1:250 000 soil map of Scotland. The 5 main factors affecting soil formation are parent material, topography, climate, time, and soil fauna and flora; and these factors have produced considerable diversity in Deeside, as elsewhere.

The main characteristics of Deeside soils are that they are fairly young (10 000 years since the last glaciation), are often shallow, have an indurated or hard sub-soil, are frequently stony, and show great variation over short distances.

The main types in Deeside are the following:

i. Alluvial — low-lying in river channel areas
ii. Countesswells — stony till, from granite and granite gneiss
iii. Boyndie/Corby — formed from fluvioglacial sand and gravel
iv. Tarves — till derived from acid and basic igneous rock
v. Peat — originating in wet climates in areas of poor drainage; often blanketing the hills and ground in wet hollows.

This list is not exclusive and a variety of individual soils is found up the valley. Within each group, differences in slope, natural drainage, depth and other factors add to the complexity, giving rise to a multicoloured soil map (Bibby 1982).

4 Land use capability beside the Dee
The agricultural potential of the land is determined by soil, climate and topography. Most of the best land (Appendix 1) is in low-lying areas between Aberdeen and Banchory (classes 3_1 and 3_2), but, inland and therefore upslope, soils deteriorate rapidly. The last remnant of 3_2 disappears at Ballater, and even alluvial soil is mapped as 4_2 thereafter. Upslope, the land is classed as 5, 6 or 7, depending upon severity of slope and climate, which have an over-riding influence. In general, these soils are not suitable for intensive agriculture, and mixed farming predominates. The good agriculture practised here depends on physical factors (cultivation, drainage and levelling), and chemical factors (addition of lime and nutrients for improved productivity). The main features of land improvement have included drainage, fertilizer applications, and correction of trace element deficiencies.

5 Has time changed this land use?
Although the soil has not changed specifically, farmers have learned to work it better using more powerful tractors and implements able to deal with difficult, stony soil. Mechanization has helped because the season is short and timeous sowing and harvesting of crops are vital. The move away from hand and horse work to the binder, the tractor, and eventually the combine harvester have all contributed to a major reduction in farm labour. This reduction in numbers of people employed on the land has been accelerated by a more lucrative living not only further south but in the nearby cities. The greatest single effect on Deeside farming, however, appears to have been the recent change in the economic situation which has affected all agriculture. It has become more profitable to concentrate on crop production. Many farmers have changed from producing weaned calves out of a beef cow valued at between £500-£700 to growing barley. The capital required to produce barley is approximately £250 ha^{-1}, whereas suckled calf production would require £1,000 ha^{-1}. Spring cereal production only requires capital from sowing in March to harvesting in September, whereas for beef production capital is required for the full 12-month cycle. The financial return on the capital investment is greater in cropping than with livestock. We have reached a situation in which beef is a luxury product, yet it was a staple food only a few years ago.

Because of improved varieties, particularly of barley (eg Golden Promise), it has been possible to grow crops which not only mature very early but are also suitable for malting, and can therefore be sold readily in north-east Scotland. Barley is now grown at 300 m above OD. The recent introduction of hardy winter barley varieties, such as Gerbel and Igri, has allowed winter barley to be grown as far up Deeside as Braemar, giving more than double the amount one would have expected from spring barley only 10 years ago.

After the UK joined the European Economic Community in 1972, government policy encouraged the amalgamation of smaller farms to make larger farming units. This involved either 2 or more of the 20-40 ha farms which were common on Deeside combining to form one 60-80 ha unit, or an existing large unit absorbing a small neighbouring farm. The incentive to amalgamate was 2-fold in that the in-goer received a grant for the amalgamation and the out-goer received either a capital sum or a pension for giving up farming. Many landlords encouraged amalgamation because it usually involved a reduced upkeep of steadings.

There has also been a trend over recent years for landlords to take in hand any tenanted farm which becomes available. This was because of a taxation incentive and, as importantly, because of the increased value of freehold land as opposed to tenanted land. These in-hand estates often range over great distances along the river and require considerable expertise in managing a multidisciplinary unit involving sporting, agriculture, forestry, tourism, and the remaining tenanted holdings.

Subsidy support used to be a major factor influencing farmers to produce one particular type of livestock. In relative terms, prior to 1972, when the UK joined the EEC and came under the Common Agricultural Policy (CAP), the Hill Cow Subsidy and the Calf Subsidy were considered a necessity to give the upland farmer a reasonable standard of living while working in difficult conditions and on demanding soil. Nowadays, although support is still given, it is a much lower proportion of the enterprise output and hardly enough to persuade a farmer to continue with a livestock production enterprise which demands a high level of capital and gives a low level of return.

On the other hand, the sheep regime under the CAP has had a major influence in encouraging increased production of sheep meat. This regime raised the returns from sheep dramatically compared to 5 years ago and has encouraged the expansion of many flocks of hill and upland sheep. It has also stimulated a renewed interest from the low-ground farmer in the purchase of store sheep for final finishing in spring. Indeed, the renewed interest in sheep has also encouraged the upland farmer to consider selling more of his own lambs to local abattoirs than in the past. As a result, sheep numbers have increased by 15%, while numbers of beef cattle have dropped by 9%. While the introduction of winter barley varieties has not greatly reduced grassland areas, some marginal land has been improved to carry more livestock and to release some of the better grassland for cropping. Dairying has almost disappeared from the middle and upper reaches of the Dee.

6 What effects have these changes in land use had upon the valley?

Family-type farming was typical on Deeside but there has been a decrease in the population involved in agriculture (Table 2), and sons and daughters have tended to move away. Some have been absorbed into the tourist industry, working, for example, in hotels and caravan sites. Very few have been taken on to the sporting side of estates which are now tending to lose clients and to decline. Similarly, forestry has been unable to support many more employees. Therefore, the population of Deeside is falling.

When an area's major industry, such as agriculture, declines, support industries such as blacksmiths, garages, agricultural merchants and machinery distributors also go into decline. As a result, many farmers no longer do business at the local towns of Aboyne, Ballater and Banchory, but by telephone or when visiting Aberdeen. In Aboyne, although the livestock mart is not in immediate danger of closing, reduced numbers of livestock are being sold. Livestock from the west end of the valley tend to be sold in Perth and from the east end in Aberdeen. The expansion in residential housing along Deeside, especially at Banchory, but also Aboyne and even Ballater, although not directly related to agriculture, is using arable land for houses, many of good quality. Some of the people required to service these towns will presumably come from farms which may be run on a part-time basis on a more extensive type of agriculture, but at least the total population of the valley should no longer continue to decline.

The main changes in agricultural land use beside the River Dee in the period 1972-83 are that the number of holdings has dropped by 20% and there has been a slight rise in owner-occupation. There has been a big rise in the barley area of 58% which has mainly come from the fall in oats of 80%. There has been an increase in the amount of grass conserved as silage, which is reflected in the fall in the turnip area of 25%. Although the area of grass has increased slightly, the total area under crops remains unchanged. The area of crops and grass per holding has risen, because there are fewer holdings, but not many are sufficiently large to give a reasonable output and therefore a reasonable income (Table 2).

There has been a decrease in hired labour, especially of full-time hired men, from 549 to 371, a drop of 32%. Other categories of labour are fairly constant, indicating that part-time casual staff have been retained. Statistics for total land in production show an increase, due to a small amount of land being improved as rough grazing but mainly due to farmers re-designating grouse moor as rough grazing and to DAFS reclassifying land; 80% of the farmed land is rough. Although there has been a recent fall in numbers of both dairy and beef herds, the total number of beef animals has only fallen slightly (Table 2). The shortfall in suckled calves is being made up by importing artificially reared calves from dairy herds in England. The drop in intensity of Deeside farming is confirmed by the disappearance of pigs and the survival of only a few poultry.

7 Discussion

Although the agricultural land runs very close to the river bank, it is unusual for the livestock to gain access directly to the river. There are exceptions, however, mainly on the upper reaches where cattle can be seen standing in the river to get away from flies. It is usual for the river bank to be fenced off, primarily as a safety feature, as thaws and heavy precipitation can cause the river to rise very quickly and animals could be washed away. Second, there is the need to allow fishermen access to the river along this fenced right-of-way.

Because most of the Deeside soils are freely drained and with a low rainfall, it is perhaps surprising that irrigation is not more common. It is suggested that the value of crops is not high enough to justify the capital cost of an irrigation plant, but it is also likely that, if cropping continues, farmers will consider the benefits of irrigation. An area for discussion, therefore, will be the ability to draw water from the river.

Agriculture, as practised in the catchment area, is unlikely to have any adverse effects on the biology of the river. Modern agriculture utilizes many agrochemicals which are important to optimize crop and livestock output. Because the valley is narrow, the amount of runoff and natural drainage transporting any of these chemicals from agricultural land is small in relation to the volume of water in the river. The Advisory Service is aware of the potential risk of pollution, but the continuing vigilance of farmers ensures that this will not happen. The manner of farming along the river bank poses no threat to any of the other interests previously described. Agriculture lives happily with its neighbours, whether they are sporting interests of fishers needing access to the river banks, or tourists sight-seeing and travelling over the rough ground.

8 Summary

8.1 Traditionally, the main agricultural land use beside the Dee has been stock raising, breeding animals in the uplands and finishing them on the richer ground further down the valley.

8.2 This land use is changing due to economic pressures which favour crop production, instead of breeding or fattening cattle. However, sheep numbers are increasing because the CAP has encouraged more production of sheep meat.

8.3 The main changes in cropping are the substitution of oats with barley, an increase in grassland conserved for silage, and a few alternative crops. New varieties of early-maturing spring barley suitable for malting, and hardy winter barley which can be grown up to 300 m above OD are suitable for Deeside.

8.4 The amalgamation of agricultural holdings and reduction in the number of people working the land are continuing, but the average size of holding is still not enough to maintain a reasonable 'financial output'.

8.5 Agriculturists do not envisage that changes in mechanization, tillage, and the use of fertilizer and agrochemicals will affect runoff from the land or pollute the river. Outside agriculture, the period of highest pollution is likely to take place after a heavy precipitation or snowmelt when the river is in spate and brings down its own debris.

8.6 As cropping increases, a demand for irrigation for new crops beside the Dee should be anticipated. This is a potential source of conflict with those people who think that enough water is already abstracted.

9 Acknowledgements

I am grateful to several colleagues in the North of Scotland College of Agriculture for their help in preparing this paper, especially Mr C I Lumsden, Regional Director, Dr G Dalton, Economics Division, Dr E Farr, Chemistry Division, Mr P Leat, Economics Division, and Mrs M Wilson, Visual Aids.

10 Reference

Bibby, J. S., ed. 1982. *Land capability classification for agriculture.* (Soil Survey of Scotland monograph.) Aberdeen: Macaulay Institute for Soil Research.

APPENDIX 1. Summary of guidelines extracted from the *Land capability classification for agriculture* (Bibby 1982)

Land suited to arable cropping

Class 1

Land capable of producing a very wide range of crops.

Cropping is highly flexible and includes the most exacting crops such as winter-harvested vegetables. The level of yield is consistently high. Soils are usually well drained, deep with good reserves of moisture. There are no or only very minor physical limitations† affecting agriculture use.

Class 2

Land capable of producing a wide range of crops.

Cropping is flexible and a wide range of crops can be grown. The level of yield is high but less consistently obtained than on class 1 land, due to the effects of minor limitations affecting cultivation, crop growth or harvesting.

Class 3

Land capable of producing a moderate range of crops.

Land in this class is capable of producing good yields of a narrow range of crops, principally cereals and

†The limitation types. Soil, site and climate are involved in complex interactions which affect land use. The 5 principal kinds of limitation are recognized as climatic, gradient, soil, wetness and erosion.

grass, and moderate yields of a wider range including potatoes, vegetables and oilseed rape. The degree of variation in yield will be greater than is the case for classes 1 and 2. The moderate limitations require careful management and include wetness and slope.

Division 1

Land in this division is capable of producing consistently high yields of a narrow range of crops (principally cereals and grass) and moderate yields of a wider range including potatoes and root crops.

Division 2

This land is capable of average production, but high yields of grass, barley and oats are often obtained. Grass leys are more common and reflect the increasing growth limitations for arable crops.

Class 4

Land capable of producing a narrow range of crops.

This land is suitable for enterprises based primarily on grassland with short arable breaks (eg barley, oats, forage crops). Yields of arable crops are variable due to soil type, wetness or climatic factors. Although yields of grass are often high, difficulties of production or utilization may be encountered. The limitations may include severe wetness, shallow or very stony soils, moderately steep gradients or moderately severe climate.

Division 1

Land in this division is suited to rotations which, although primarily based on long ley grassland, include forage crops and cereals for stock feed.

Division 2

This land is primarily grassland with some limited potential for other crops.

Land suited only to improved grassland and rough grazing

Class 5

Land capable of use as improved grassland.

The agricultural use of land in class 5 is restricted to grass production, but such land frequently plays an important role in the economy of hill land. Mechanized surface treatments to improve the grassland are all possible.

Division 1

This land is well suited to reclamation and is used as improved grassland. The establishment of a grass sward and its maintenance present few problems and potential yields are high.

Division 2

The land is moderately suited to reclamation and is used as an improved grassland. Sward establishment presents no difficulties but limitations may cause maintenance problems.

Division 3

This land is marginally suited to reclamation and is used as improved grassland. The land in this division has properties which lead to serious difficulties in sward establishment and, although establishment may be possible, deterioration in quality is often rapid.

Class 6

Land capable of use only as rough grazing.

This land has very severe site, soil or wetness limitations which generally prevent the use of tractor-operated machinery for improvement.

Division 1

The grazing value is determined by the dominant plant communities which may contain a high proportion of palatable herbage.

Division 2

The moderate grazing value is dominated by poorer grass strains.

Division 3

The low grazing value is dominated by plant communities with low grazing values, such as heather.

Class 7

Land of very limited agricultural value. It has extremely severe limitations that cannot be rectified.

Forestry beside the River Dee

H G MILLER* and G TULEY[†]
*Department of Forestry, University of Aberdeen
[†]Forestry Commission, Durris, Banchory

Except it be for fish or tree
Ae yard o' Don's worth twa' o' Dee

1 Introduction

The 2 well-known lines of doggerel that dismiss Deeside as being good for little but trees seem to encapsulate the frustration of generations of farmers in this valley. Although deep, well-draining soils can be found on the frequent river terraces, the granitic parent material of the region contributes few bases, and productivity must have been low until artificial fertilizers became widely available. Beyond the terraces, slopes are steep and soils thin and stony. Here, extensive forests of oak, Scots pine and birch remained long after the clearings that had transformed most of the British landscape. Problems of transport and distance from markets continued to protect this resource and, paradoxically, the very size of individual trees may have saved Deeside forests from the iron smelters who ravaged vast areas on the west coast.

By the mid-18th century, however, wars on the continent and problems in the North American colonies encouraged the emerging industrialists to look to the forests of the Dee, Tay and Spey as a new source of timber for high-value uses, including ship-building. Then started a period of blatant 'timber mining' that was to be the forerunner of the better known exploitation of the forests of Quebec, Ontario, British Columbia, the western US states and Tasmania. As in these later cases, rivers were the prime mode of transport. Floating on the Dee continued until the coincidence of the building of the Potarch bridge and an Act of Parliament which made loggers responsible for damage to bridges and river banks. Now, however, there was an infrastructure of roads and extraction continued by horse and ox cart. Then came the fellings of the 2 World Wars, damage during the first being particularly severe, and, finally, the great gale of 1953.

Despite this record of destruction, forestry has survived. Some remnants of the ancient forest remain, generally because of problems of access as at Glen Tanar, but also, in the particular case of Ballochbuie, because of royal protection. Unlike the situation in the rest of Britain, the areas felled largely returned to forest. In part, this was due to a relatively low sheep population, but also it was in no small measure due to an indigenous and growing tradition of active forest management. This tradition was born on the local estates and survived because of their stability and continuity of ownership. It is a proud tradition, a pride that is justified by the resource that we have inherited.

2 Distribution and nature of the resource

As watersheds seldom coincide with political boundaries, details of the forest resource for the Dee catchment *per se* are not readily available. To a certain extent, it can be assumed to represent much of the resource in the Grampian Region. However, because this political entity is new, an indication of the pattern of development with time can only be obtained from the figures for the East Scotland Conservancy of the Forestry Commission. This area includes, in addition to Grampian Region, small parts of Central, Tayside and Fife. Certainly, in 1980, the proportion of land area under forest in Grampian Region was very similar to that for East Scotland (Table 1) and, indeed, to that of Scotland as a whole, although afforestation in the rest of Scotland had only now brought the overall proportion up to the relatively stable value in the east. East Scotland, including Deeside, therefore, has a relatively high and long-established forest area that is expanding only slowly. However, a particular shift since the war has been that from private to public ownership, although private ownership remains dominant.

Table 1. Area of woodland and pattern of ownership (source: Forestry Commission census of woodlands and trees 1979-82)

Region and date	Area ('000 ha)	% of land surface	% in private ownership
Scotland			
1947	530	7.2	81
1965	657	9.0	54
1980	920	12.6	46
East Scotland*			
1947	191	11.2	83
1965	213	12.4	63
1980	218	12.2	56
Grampian Region			
1980	131	*c* 12.5	55

**The East Conservancy of the Forestry Commission*

Immediately after the War, many of Britain's forests were in ruins, to the extent that in 1947 less than half of Scotland's forest area could be classified as high forest (Table 2). Over the following years, there has been a great increase in the proportion of coniferous forest, an increase that has occurred without a decrease in the proportion of broadleaved high forest. Indeed, it is perhaps somewhat surprising that, even in such an intensely coniferous area as eastern Scotland, broadleaved species cover about a tenth of the forest

Table 2. Distribution of forest types by regions

Region and date	Coniferous high forest (% of total forest area)	Broadleaved high forest (% of total forest area)	Other* (% of total forest area)
Scotland			
1947	36	9	55
1965	69	6	25
1980	83	8	9
East Scotland			
1947	36	8	56
1965	67	7	26
1980	81	11	8
Grampian Region			
1980	84	9	7

*'Other' includes felled or regenerating forest and scrub

area and represent about one sixth of the standing volume in high forests (Table 3). Increasing interest in this broadleaved resource, primarily from an amenity point of view but also as a means of ensuring a width and diversity at the base of the forest industry, bodes well for its maintenance and continued management.

amenity arguments for planting Scots pine, and the economic arguments against, are as great as those for planting broadleaved species in other more favoured areas. The credit, therefore, must largely go to the sensitivity of the many forest owners in the region.

By the start of this decade, the Grampian Region contained nearly one fifth of the standing volume of timber in Scotland (Table 4). In the Region, as in Scotland as a whole, this is a rapidly increasing resource to the extent that the supply of timber from our own forests will double before the end of the century. As round timber is an expensive commodity to transport, sawmilling must be carried out relatively close to the forests. Already in Deeside there are a number of well-established sawmills, and almost without exception the managements of these are laying plans for expansion in response to the projected increase in supply. This development will have a significant impact on both the economy and employment opportunities in the locality. The prospects are exciting and a great vindication of the planning and foresight of the foresters and landowners of the first half of the century.

Table 3. Allocation of high forest among species groups by regions in 1980

	Pines	Spruces	Larches	Other conifers	Broadleaves
Percentage of land area					
Scotland	30	50	8	3	9
East Scotland	44	30	11	3	12
Grampian Region	50	27	10	3	10
Percentage of standing volume					
Scotland	28	36	11	4	21
East Scotland	42	24	12	3	19
Grampian Region	46	25	10	3	16

Among the coniferous species, the spruces, and in particular Sitka spruce, dominate the forests of Scotland (Table 3). Sitka spruce is an astonishingly successful species in our maritime climate, being able to grow rapidly on a wide range of soils even under very adverse conditions. As it is also relatively easy to establish, is amenable to management dictates, and produces readily saleable material, it is little wonder that it has come to dominate so much of our forest landscape. Deeside, however, is quintessentially the land of the Scots pine and, despite the attraction of the rival spruces, has remained so. In part, this reflects grant inducements to plant native pine close to the origin of the seed. It might be argued alternatively that the available inducement is somewhat parsimonious, for it excludes large areas of Deeside. Here, the

Table 4. Standing volumes in 1980 by Regions

	Over-bark ('000 m^3) Conifers	Over-bark ('000 m^3) Broadleaves
Scotland	47 690	12 680
East Scotland	16 765	4 050
Grampian Region	10 700	2 050

Some idea of the distribution of the forest resources within Deeside can be obtained from the figures for afforestation and replanting (Tables 5 & 6). Excluding an unusually large single afforestation programme in the middle reaches during very recent years, it would seem that, in absolute terms, forest activity is fairly

Table 5. Rate of new afforestation in the Dee catchment by all ownership categories (values in parenthesis are those for private woodlands)

Section of catchment*	1964-68	1969-73	1974-78	1979-84
	Thousand ha in 5-year periods			
Upper	0.3 (0.3)	0.5 (0.4)	0.6 (0.6)	0 —
Middle	0.7 (0.7)	0.5 (0.5)	0.4 (0.4)	2.0 (2.0)
Lower	0.3 (0.1)	0.1 (0)	0 —	0.2 (0.1)
Total catchment	1.3 (1.1)	1.1 (0.9)	1.0 (1.0)	2.2 (2.1)

*Upper — from about Ballater west (including the 5 km east of Ballater)
Middle — area east of upper section as far as Banchory
Lower — east of Banchory

Table 6. Rate of replanting in the Dee catchment by all ownership categories (values in parentheses are those for private woodlands)

Section of catchment*	Thousand ha in 5-year periods			
	1964-68	1969-73	1974-78	1979-84
Upper	0 —	0.1 (0.1)	0 —	0.1 (0.1)
Middle	0.6 (0.4)	0.3 (0.3)	0.1 (0.1)	0.2 (0.2)
Lower	0.2 (0.1)	0.1 (0)	0.1 (0)	0.2 (0.1)
Total catchment	0.8 (0.5)	0.5 (0.4)	0.2 (0.1)	0.5 (0.4)

*For details of partitioning of catchment, see Table 5

evenly spread throughout the valley. Examination of the present position in relation to potentially plantable land would suggest the likelihood of a continued slow expansion in all regions, an expansion that is likely to be fairly evenly distributed between the public and private sectors. It should be emphasized, however, that in this area of relatively stable land use there is unlikely to be any rapid shift favouring the extension of forestry.

3 Forest and river

Unusually large stretches of the Dee and its tributaries are surrounded by coniferous forests, a not unusual situation in most other northern regions of the world but one which appears to invoke some concern in this country, and in this country alone. The fears are seldom well founded or thought out, but nevertheless cannot be casually dismissed.

It is perhaps first necessary to separate the forest *per se* from the single line of trees along the river bank. The latter, usually broadleaved trees, provide the fisherman with shelter, the river with a source of readily decomposable organic matter, the fish with a protected source of terrestrial insects, and the otter with banks well stabilized by tree roots. This tree resource should be protected, although it is presently ageing, and some consideration must be given to its replenishment.

The dark coniferous forest, by contrast, seems to have few advantages. The conifer forest and its managers stand accused of (i) reducing water yield, (ii) allowing silting of streams, (iii) polluting oligotrophic waters with phosphatic fertilizers, (iv) accelerated inputs of nitrate, and (v) increased streamwater acidification. Although there is some justification for each of these accusations, their importance is frequently overstated. Furthermore, the pollution disadvantages can all be minimized, or even eliminated, by adopting a few fairly simple management rules.

Forests reduce water yield by increasing the evaporation of intercepted water, not, as is sometimes implied, by increased rates of transpiration. In recent years, considerable information has become available to explain this feature. Both transpiration and evaporation require energy to vaporize the water, and sufficient dry air to receive further water vapour. Clearly, if the sun is shining, to provide the energy, and the wind is blowing, so ensuring that the air around the leaf is continually changed before it becomes saturated, then both transpiration and evaporation of intercepted water will be high from all vegetation types. The particular difference between forests and grassland, however, is that, because forests have a much rougher upper surface, the wind passing over and through them has a greater turbulence imposed upon it. The resulting eddies and accelerated winds ensure both the removal of energy as heat from leaves and the continual replenishment of air within the canopy with drier air from above. The latter effect has been shown to be most important when the canopy is wet, for it means that there is more rapid evaporation of intercepted rainwater from a forest canopy than from a smooth grass sward, despite the cooler conditions. The same efficient exchange of air should mean that transpiration is also higher from forests. However, as stomata close when evaporative stress is high, any such effect is prevented, so that transpiration from a dry forest canopy tends to be less than from grass, reflecting the cooling effect of the air turbulence.

The net effect of this enhanced loss from tree foliage when wet, and slight reduction when dry, is an overall greater loss from forests. The extent of this increased loss depends on the differences in (i) turbulence, (ii) the surface areas of the canopies being compared, and (iii) the proportion of time that the canopies are wet. At one extreme is the difference between conifer and grassland in areas of relatively flat topography. Work by the Institute of Hydrology suggests that afforestation in these conditions can increase water loss from 18% to 38%, thus confirming earlier American work at Coweeta. The difference is narrowed if any of the 3 factors outlined above are reduced. For example, broadleaved forests, which are leafless in winter, have a lower surface area, heather and bracken invoke more turbulence than grassland, and the duration of wetness is less on the east coast than the west coast of the country.

On Deeside, the difference in turbulence is clearly reduced both by the nature of the hill vegetation and by the fact that the rugged topography itself imposes significant turbulence on the wind. It becomes difficult, therefore, to suggest quite what reduction could be expected following afforestation. It certainly would not be greater than 15%, and could be as low as 10%. If a value of 12.5% is assumed, the 4000 additional ha of forest planted in the 20-year period 1964-84 would have reduced water yield from the 2100 km^2 catchment of the Dee by 0.24%. This would seem an unmeasurable change and one that could hardly have had any economic or ecological significance, particularly in view of the fact that the difference would be greatest during periods of high rainfall.

The silting of streams is much reduced by the presence of a stable forest, loss of silt being limited to the periods of ploughing at the start of the rotation and of felling at the end. It is now many years since forest managers were first issued with instructions as to how to avoid this problem. There are various components but the essential point is that no drain or plough furrow should discharge directly into a stream. Rather, it should be terminated some distance back, thus requiring the drainage water to spill out across the intervening undrained land, and in so doing deposit its silt load before reaching the stream. This is a simple expedient that has proved to be remarkably effective.

Phosphatic fertilizers have been applied to upland forests since the 1920s with few, if any, reports of subsequent algal blooms in streams or reservoirs. However, a recent very stringent EEC guideline as to the levels of phosphate in potable waters has invoked a new debate. The phosphate anion cannot be transported any significant distance through mineral soil before it becomes tenaciously bound by the abundant iron and aluminium in soil. Thus, if drains are terminated well short of streams, as prescribed for removing the silt load, the drainage through the mineral soil of the riparian zone will ensure the effective filtering out of all phosphate before drainage water enters the stream.

A somewhat similar process would ensure that drainage water is purged of high levels of nitrate. In this case, however, removal is not by chemical reaction with the soil, but rather through uptake by vegetation and soil microbes, for these are usually somewhat nitrogen-stressed in upland regions. The fear of such nitrate pollution relates to the flush of decomposition following the felling of forests, and stems largely from a single American study in which re-vegetation after felling was prevented by repeated application of the weedkiller 2,4,5-T. Many subsequent experiments in which re-vegetation was allowed to proceed normally have failed to suggest any real cause for concern, although some small elevation in nitrate levels is not unusual. This finding, of course, is in contrast to the nitrate pollution that can occur in intensive agricultural regions, where repeated heavy applications of fertilizer nitrate may exceed the retention ability of the ecosystem.

The inter-relation of afforestation and streamwater acidification is far from understood. As yet, it appears to be a uniquely British phenomenon. What is undeniable is that both in the Trossachs and in mid-Wales streams flowing through forests have been observed to be consistently more acid than analogous streams flowing through neighbouring heath or moor. Various mechanisms have been suggested, but as yet none is wholly convincing. Most explanations involve the input of pollution-derived acid or sulphate, the latter possibly reacting with mor humus to provide the mobile strong acid. Whatever the derivation of the acidity, the amounts are not significantly greater than can be expected to be generated naturally in upland ecosystems, and should be easily neutralized by reaction with mineral soil. Again, the solution seems to be to ensure that drainage water infiltrates through the mineral soil of the riparian zone prior to entering streams, and drainage schemes should be designed to ensure that this infiltration occurs. To reduce the possibility of sulphuric acid production by the reaction of exchangeable H^+ in humus with pollution-derived sulphate, the vegetation immediately alongside streams should be managed to reduce the accumulation of acid mor humus. Thus, as a generalization, broadleaved species should be encouraged over coniferous species in the riparian zone (perhaps 20 m either side of any *significant* stream). A particular exception is the alder species. The nitric acid production associated with the nitrogen-fixing ability of these species risks not only the increase of acidity in streams but also elevated nitrate levels.

It should be borne in mind that the neutralization reactions that occur as water drains through soil continue between streamwater and the minerals on the stream bed. Acidification, therefore, is essentially a problem of small first order streams and the risk declines with increasing stream size, to the extent that the pH of a river such as the Dee has been shown to vary very little around the circumneutral point.

4 Forest management and the river bank

In areas of poor soils and oligotrophic waters, particularly where there is significant input of pollution-derived acidity (acid rain), the forester may have to take certain simple steps to minimize chemical disturbance to streamwater. Fortunately, these steps are covered by 2 general rules, both of which have already been introduced to routine forest management for other reasons. The drainage guidelines drawn up to eliminate silting of spawning streams, effectively the stopping of all drains well short of the stream bank, will ensure that phosphate and acidity are removed from drainage water prior to it entering streams. To be completely effective, measures should be taken to ensure that drainage is through mineral soil. Similarly, the encouragement of grass and broadleaved trees along riversides, originally advocated for reasons of wildlife conservation, will assist in reducing the loss of both acidity and nitrate into streams.

Although research has still to define quite how wide the undrained zone should be under all conditions of slope and soil, the broad outlines of what is required are now clear, and there would seem to be few problems in ensuring implementation in future afforestation schemes. More worrying, perhaps, is the means of ensuring the continuation of the narrow strip of broadleaved trees that fringe the Dee over many km, particularly through some agricultural areas. Perhaps the most effective expedient would be to capitalize on the very real public interest in environmental matters and to mobilize volunteer labour for replanting and subsequent management. This step, however, must be preceded by appropriate discussions with the owners and all other parties with valid interests. In preparing planting schemes for such areas, the use of alder should perhaps be treated with some caution.

5 Summary

Within the Dee catchment, there is a long history of forest management and, despite heavy felling over the last 200 years, extensive forests remain. These are still largely dominated by the native Scots pine which has continued to be used, despite the financial incentives in planting spruce. Over recent decades, there has been a steady expansion of forestry in the area and some further slow expansion can be expected.

Afforestation may bring with it certain adverse effects, including reduced water yield, silting of streams and an increased loss of phosphate, nitrate and acidity in drainage water. Reduced water yield is the consequence of increased evaporation in the turbulent winds characteristic of forests. However, the increased afforestation over the past 20 years would only have reduced the water reaching the Dee by a fraction of one per cent. Silting should be controlled in properly planned forest operations. Similarly, the suitable planning of drains to utilize the mineral soil of the riparian zone for filtering drainage water will prevent loss of phosphate, nitrate and pollution acidity to streams.

There is a need, however, to find a means of ensuring the replacement and continuation of the narrow strip of broadleaved trees that fringes many parts of the river.

River engineering and the control of erosion

B B WILLETTS
Department of Engineering, University of Aberdeen

1 Introduction

The River Dee is a gravel river. It falls from approximately 330 m above OD at Braemar to sea level in perhaps 110 km. Inspection of its bed anywhere between Braemar and Aberdeen confirms that very little material of sand size or finer is exposed at its surface. Shingle bars occur frequently, often at a bank of the river, but sometimes forming an island in the stream. However, bulk sampling at the bed reveals material of a wide range of sizes, including sands, and even silt, as well as the larger gravel and cobbles seen on surface inspection. The river is said to have an armoured bed. During high flows, finer, more mobile, material is removed from a surface layer which then serves as a protective crust isolating from direct exposure to the flow the finer grains from underlying layers, until that crust is disrupted by another sufficiently large flow.

Because of the phenomenon of armouring, the bed is inactive in all but spate flows, except in localities where bank collapse furnishes a repeated supply of accessible fine material. (Bank retreat is not always confined to periods of high flow.) However, the large-scale movements of bed material which produce changes in boundary geometry, and therefore in flow patterns, occur during flows which are exceeded for a small proportion of time. During these intervals, a large amount of material is dislodged and transported. This process is evidenced by the changes observed in stage discharge characteristics at Cairnton gauging station (McClean 1934; MacDonald 1975, section 5.1.1), and can be detected in comparisons between records (cartographic or photographic) of the same site at different times. Plate 9 illustrates changes since 1946 at Morrison's Bridge, Cults.

The average gradient of the river taken over three-quarters of its length is approximately 3.5 m km^{-1}. The upper valley having been broadened by glacier movement and the lower valley's contours softened by vast accumulations of overlying ice, the river is free to meander or braid over much of its length. The river channel is incised in a valley with floodplains on one or both sides (Figure 1). During the last few thousand years, the river course has probably migrated over at least the width of the present floodplain, where one exists. The tendency to meander depends on channel gradient, grain size, and bank-full discharge. It is clear from the behaviour of unrestrained parts of the river that conditions favour both kinds of feature here and there (where a local gradient obtains an appropriate value). For the lower valley, with a bankfull discharge of perhaps 300 cumecs, a very rough estimate of the critical gradient for the initiation of meandering would be 1 m km^{-1} (Leopold & Wolman 1957).

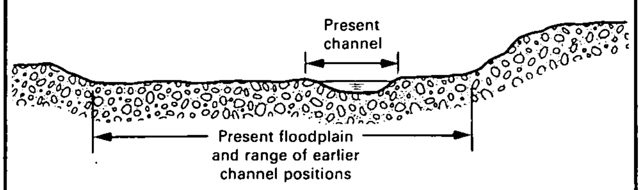


Figure 1. The river channel in its floodplain (schematic only and not to scale)

The floodplain has other important functions besides providing for natural changes in the channel course. As its name implies, it is inundated when river flow exceeds what can be conveyed by the channel, with 2 beneficial consequences.

i. Flow on the floodplain is slower than in the channel. Therefore, water spilled on to the floodplain is delivered later to downstream reaches of the river than it would be otherwise. The floodplain acts as a temporary reservoir which holds back water during peak flows and yields it up when the hydrograph peak is past. It therefore diminishes the risk of flooding downstream.

ii. Although flow velocities on the floodplain are low, the cross-sectional area of the flow over it is often very large. Consequently, a substantial proportion of the total flow may be conveyed by the floodplain rather than by the main channel. The channel velocities are reduced by the floodplain flow from those which would obtain if the channel carried the whole flow.

Artificial encroachments on the floodplain may impair either or both of these functions. Flooding problems may then be aggravated downstream of the encroachment and/or the river channel may be scoured out locally, with deposition of sediment downstream, and thus potential gradient changes.

River engineering is done in 3 circumstances:

i. when the route or site of engineering work coincidentally encroaches on the river, eg Milltimber Bridge, raw-water reservoir at Cults;
ii. when use is deliberately made of the river, eg the water intake at Cults, riverside wharfage at Aberdeen;
iii. when some natural feature of river behaviour is suppressed artificially, eg bank protection to prevent or curb meandering.

Engineering schemes of all 3 kinds are a source of perturbation of the natural solid transport in the river and, in consequence, of the river geometry. The changes produced in the river may be seen as wholly good by all interested parties. It is more usual, however, for some of them to be thought undesirable by some of the people affected. Promoters of such schemes, therefore, have a neighbourly duty to investigate thoroughly the consequences of their proposals, both those consequences which are objectives of the scheme and those which are by-products. Unfortunately, our understanding of river behaviour is incomplete and it is often impossible to predict all the effects of a proposed intervention. It will be the purpose of this paper to review very briefly the techniques available to the river engineer in attempting to make predictions when considering rivers like the Dee. It will also indicate briefly the gaps in what can be done.

2 River processes and calculation methods

A river is primarily an arterial drain in a system which is gravity-powered. (No engineering which neglects this fact is competent.) In a particular reach under consideration, the flow is set by the hydrology of the catchment which feeds it and the channel characteristics upstream of it. Water is driven through the reach by its own weight, which has a component parallel to the channel bed, resisted by traction at the interface between the stream and the bed and banks. This traction is built up from the drag exerted between the flow and individual roughness elements, which in this case are partially exposed grains of the boundary material (predominantly gravel and cobbles in the Dee). It is often expressed in terms of a boundary shear stress which, of course, varies from point to point on the boundary.

As the water descends, its potential energy diminishes. It is expended at the boundary in overcoming flow resistance, and within the stream in sustaining the internal flow structure characteristic of a particular stream geometry. This flow structure is complex, containing both turbulence which is apparently random, and secondary currents which are more orderly circulations normal to the flow direction. Both turbulence and secondary currents have an important influence on the pattern of stream direction velocity in the cross-section and, consequently, on the distribution of boundary shear stress. As this distribution dictates the effect which the river has on its boundaries, an ideal background to the design of river works would be a prediction of the flow which includes lateral as well as streamwise components. This prediction requires the solution of the following set of equations, subject to appropriate boundary conditions:

Continuity $$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (1)$$

Momentum $$\frac{\partial u}{\partial t} + \frac{\partial}{\partial x}(u^2) + \frac{\partial}{\partial y}(uv) + \frac{\partial}{\partial z}(uw) + g\frac{\partial z_s}{\partial x} = 0 \quad (2)$$

$$\frac{\partial v}{\partial t} + \frac{\partial}{\partial x}(uv) + \frac{\partial}{\partial y}(v^2) + \frac{\partial}{\partial z}(vw) + g\frac{\partial z_s}{\partial y} = 0 \quad (3)$$

Here, t is time, g is the acceleration due to gravity, and u, v, w, x, y, z are defined in Figure 2, z being measured vertically from a horizontal datum plane (notations are defined below). A solution cannot be obtained mathematically but numerical solutions can sometimes be achieved at the expense, naturally, of some detail. However, they are time-consuming and expensive, and it is much more common to use simpler equations which employ quantities averaged over the cross-section. From their solution can be obtained the average shear stress at the boundary of each cross-section. The way in which this shear stress is distributed has to be estimated subsequently from empirical results for cross-sections of similar shape.

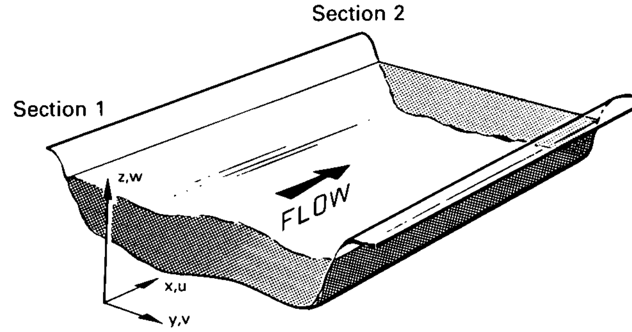


Figure 2. Flow in a prismatic channel showing coordinate axes for analysis

The equations can conveniently be written thus:

Continuity $$\frac{\partial Q}{\partial x} + B\frac{\partial z_s}{\partial t} = 0 \quad (4)$$

Momentum $$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + gA\frac{\partial z_s}{\partial x} + \frac{P\tau_o}{\varrho} = 0 \quad (5)$$

Hence, Q is volumetric discharge rate of water, B is the bank to bank width, A is the cross-sectional area of the stream, P is the length of wetted perimeter, τ_o is the mean boundary shear stress, z_s is the height above datum of the water surface, and ϱ is the density of water. The derivation of these equations (1 to 5) can be found, for example, in Jansen *et al.* (1979).

The answers from one of the 2 equation sets (1, 2 and 3, or 4 and 5) describe the flow in a channel of fixed shape, ie a non-eroding channel. Yet the magnitude of those answers may indicate that the channel boundaries become mobile at the calculated flows. It is necessary then to take the calculation further, estimating the change in channel shape in response to a suitable period of flow and then re-calculating the flow in the modified channel. The effect of the new flow on the channel produces a further channel modification, and the flow again changes in response to it. The calculation must cycle repeatedly between the flow and the sediment movement which produces geometric changes.

Three steps are needed in each cycle to calculate the change of geometry. Referring to Figure 2, the difference between the quantity of sediment transported as bed load past section 1 in a given time interval and that transported past section 2 is equal to the accumulation of bed material in the river between sections 1 and 2 – a continuity equation for sediment. It can be written:

$$Q_{s1} - Q_{s2} = \frac{\varrho_b}{s\varrho} \frac{\delta V}{\delta t} \quad (6)$$

Q_s is sediment transport rate, s is the specific gravity of sediment, ϱ_b is bulk density of deposited material, and V is the volume of material (using an arbitrary datum value) between sections 1 and 2.

Values for Q_s are obtained from a sediment transport formula, of which there are many alternatives. They usually have the general form:

$$Q_s = f(\tau_o, D) \quad (7)$$

D is the size of grains exposed to the flow.

It remains to determine how the deposition of accumulating material or the removal of eroded material is distributed in the cross-section. This distribution will produce the modified shape of which a description is needed for the next stage of flow calculation. Some features of the distribution may be clear in a particular case; for example, a length of bank may be revetted so that erosion is prevented and deposition is unlikely. However, such rules of general application as exist for the mobile parts of the boundary are tentative at present. Consequently, the calculation of shape change is uncertain, which creates difficulty in interpreting the predictions of the whole calculation procedure.

River engineering cannot stop while the research needed to improve calculation methods is completed. Engineers, therefore, have to be particularly careful in selecting 'design conditions' relevant to each scheme and ingenious in applying calculation methods which deal safely with those design cases. Nevertheless, a degree of uncertainty usually remains, and for large schemes it is quite normal to conduct a physical model study to reinforce the design calculations.

3 Application to engineering schemes

The last section outlined the calculations of river behaviour which are technically possible. They were seen to depend upon subordinate calculations of (i) the flow, (ii) the consequent sediment movement, and (iii) the changes in channel shape resulting from sediment motion. It was acknowledged that (iii) still presents unresolved difficulties. Unfortunately, in the particular case of gravel rivers, the prediction (ii) of sediment transport is also problematic, and, as we have seen, the Dee is a gravel river. Transport rate formulae have been devised for armoured rivers, but they have been insufficiently tested and must be regarded cautiously as design tools. Designers, whose clients may outlay large sums of money on their advice, rely only on calculation methods which have a proven record of success. It is instructive to list methods which fall into this category, with particular application to gravel rivers.

The depth and flow velocity can be calculated for a given flow rate in a given cross-section (equations 4 and 5). If the expense is warranted and the plan geometry not complex, the distribution of velocity in the cross-section can be obtained (equations 1, 2, 3), and from it the distribution of shear stress at the boundary. In other cases (which predominate), the distribution of boundary shear stress can be estimated by analogy with cross-sections for which sound measurements have been made and published. On the basis of this knowledge of the flow, all that can safely be deduced about sediment movement is the smallest grain which will not be moved at each point on the flow boundary. For each value of boundary shear stress, there is a stone size at the threshold of motion; larger stones will remain in static equilibrium on the bed (unless made less stable by an unusual shape).

For work on the Dee, this rather limited calculation capacity is nevertheless very useful. Thankfully, the river remains close to its natural state, and the object of most engineering work on it is to prevent undesirable changes in plan geometry. In most cases, this is done by stabilizing a bank in its present, or a recent, position without other changes. The appropriate method is to protect the bank, possibly after some re-shaping, by placing on it material which is below the threshold of motion in the design flow condition. For this purpose, our limited proven predictive capacity is adequate.

The basis of design of such a revetment in a river like the Dee is to provide an immobile bank, while allowing the bed to behave naturally and the channel to convey its natural (occasional) bed load without impediment. The required stone size can be calculated with confidence once the expected boundary shear stress has been determined. The appropriate size will be a function of the slope of the bank, a steep bank requiring larger stones than a flatter one. Where the river course, for example, is curved in plan, the peak boundary shear stress is very much higher than the mean (de Vriend & Geldoff 1983). The distribution of shear stress must be examined for such peaks before a stone size is selected. The procedures (eg Anderson *et al.* 1970) for size selection are adaptations of a threshold criterion empirically obtained by Shields (1936).

Having prevented direct attack by the stream by the provision of immobile surface members, it is necessary to prevent loss of fine material from behind them by interstitial flows and by groundwater seepage into the river course. This prevention can be done by creating a filter of granular material having increasingly finer size with distance from the river towards the natural bank, or by using a porous fabric under the primary armour.

It is important to recognize that any artificial change in the boundary (bed or bank) geometry produces changed flow distribution at any given flow rate. Bank protection on an existing line introduces a small change which can often be ignored. However, any structure which projects into the stream necessarily produces radical flow changes, and may so redistribute boundary shear stress that an erosion or deposition pattern is created which results in a changed stream geometry. In this context, a feature which prevents flow over a floodplain is a projection into the flow when that flow is at its most aggressive. Present knowledge does not permit such geometric changes to be calculated reliably for gravel rivers.

4 Engineering on the Dee

The purpose of engineering is to execute decisions about the use and management of the river and its floodplains. The decisions usually originate from a need perceived in relation to one function only, and there seems to be no effective unifying management agency to reconcile actively the interests of different functions.

The roles expected of the river are to drain the valley, to convey a small amount of domestic and trade effluent, to provide water for the public supply, to provide an important general amenity, and to act as a breeding haven for salmon. The fishing provided by the salmon is valuable. Its requirements are often interpreted to be that both the natural discharge pattern of the river and the natural river geometry remain undisturbed.

The matters in which engineering is likely to be a useful instrument of management can be dealt with under the 2 sub-heads: flood control, and constraint of the main channel.

4.1 Control of flooding

Flood damage is best limited by restricting the use of the floodplain to activities which suffer little from occasional inundation, such as grazing and forestry. Arable farming and building development are kept above the greatest expected flood level of the river. In the Dee and *Feugh* valleys, buildings have been prudently sited but the temptation to plough land in the floodplain has not always been resisted.

During the last century, substantial flood embankment schemes were constructed to exclude flood water from areas of land, so as to fit them for crops other than grass in permanent ley. Provided that the embankment height is correctly chosen and that maintenance is not neglected, this measure provides effective local protection. However, it does remove floodplain storage and flow capacity. The 19th century schemes will, therefore, have aggravated conditions elsewhere on the river downstream of each embankment, and modified the local geometry of the river channel. Were the device to be generally adopted, floods in the river would become flashier, rising more steeply and to greater flood levels. It is clear that some existing schemes have deteriorated for lack of maintenance. Embankments constructed with horse carts and hand labour have not been regularly repaired in an era of mechanized farm and construction work! In consequence, there are occasional losses of soil, fertilizer and seed when land which is no longer protected is used for arable farming.

One modern method of flood control is to regulate a river by damming its headwater and/or those of its major tributaries. The pattern of releases from the resulting reservoirs is then planned so as to avoid undesirable extremes of flow, both floods and drought flows. This method is high in capital cost and appears to have been rejected for the Dee. It is not clear what constraints, if any, would have to be placed on the operational procedures in order to avert potential damage to the salmon fishings.

4.2 Constraint of the river channel

As noted earlier, the Dee (and several of its tributaries) has, in some reaches, a tendency to meander. The changes in plan position which would result from allowing this tendency to develop freely are usually undesirable. Among the consequences would be some of the following.

i. Disruption of established uses of the floodplain (usually loss of pasture at the retreating bank, accompanied by recovery from the river of agriculturally useless land at the other bank).
ii. Change in property boundaries.
iii. Increase in the sediment load of the river, changes in bed topography and character, and consequent changes in fish behaviour.
iv. Loss, or loss of use, of buildings or other structures. (Morrison's Bridge at Cults is perhaps the best-known example.)

Changes, of course, can always be prevented in a comparatively small river like the Dee, provided that the engineer has a client with the will and the necessary financial resources. The client will embark upon a scheme only if the expected benefits to him (or in the case of a syndicate, to them) outweigh the cost. The circumstances of some clients lead to a preference for capital schemes of protection with a long design life; others prefer a regular expenditure on minor works when the nature of the problem permits. Thus, whereas large sums have been invested to provide protection from river misbehaviour at Milltimber Bridge and at the new reservoir at Cults, there are, in contrast, very many private schemes of continuing bank management wherever the river is actively fished.

Landowners are entitled to implement such schemes in order to prevent the loss of land to the river. They frequently do so without regard to the effect on river regime of the replacement of an erodible bank by a hard one.

The principal source of risk in engineering constraint of the river lies in piecemeal consideration of individual problems. It is common to under-estimate the zone of influence of any intervention, and to confine the examination of its consequences to too small a length of river. This situation arises primarily from the circumscription of each client's interest. It is inevitable given the present fragmented control of the river. Nevertheless, it leaves the river system vulnerable to damage from one or a series of incompletely considered schemes. There is a strong case to be made for a management agency with a duty to oversee and co-ordinate proposals to interfere with the river.

5 Research needs

The engineering designer needs 2 categories of information: the first is about the flows to be expected, and the second is about the interaction between these flows, his structure, and the natural river course.

He must know about the flow pattern (the runoff hydrograph) in order to select an appropriate 'design flow'. Its effect on his structure, and the effect of their interaction on the river course then become important constraints on the design of the structure. Historical records of streamflow provide the best basis for selecting appropriate design flows. Flow records for the Dee have been kept for many years (since 1929 at Woodend), and therefore the selection of design flow for a particular purpose is subject to less uncertainty than is the case on most rivers. Nevertheless, there are unresolved difficulties which merit research. Two of them are as follows.

i. Land use in the catchment may change during the life of the installation. This change will, in turn, affect the runoff characteristics and impair the relevance to design of past records. Work is needed on the influence of land use on runoff so that estimates of future runoff can be adjusted appropriately.

ii. The engineering scheme is rarely near the river gauging site. Conventional calculation methods for routing the flood from the gauging station to the site of the proposed works depend on accurate knowledge of any lateral flows into or out of the river course between the 2 sites. For flood flows, this calls for better knowledge of flow from tributaries; for drought flow predictions, work needs to be done on the interchange between river channel flow and groundwater in the gravels of the floodplain.

As will have been detected from earlier sections, some of the difficulties in calculating the effect of the flow on the river channel are still unresolved. Klingeman and Emmett (1982) have found existing sediment transport formulae unsuitable for use in armoured gravel bed rivers. The methods of estimating local boundary shear stress values are often too expensive in one case, and insufficiently versatile (with regard to cross-section shape) in the other. There is no authenticated method of calculating change of cross-section shape when bed and bank mobility occur. One could therefore compile a long list of research needs. Among the most urgent are the following.

i. A more comprehensive library is required of the boundary shear stress distributions which occur in different cross-section shapes.

ii. Overbank flow and its effect on main channel flow need to be better understood.

iii. There is an urgent need for better understanding of, and simulation capacity for, armoured bed activity, leading to a reliable sediment transport formula for armoured bed gravel rivers.

iv. Mechanisms of bank retreat have been categorized (Thorne 1982), but prediction methods have not been developed.

v. The principles upon which calculations of shape change should be based are not established. The current hypotheses about shape change should be evaluated by studying case histories so that a sound prediction method can be evolved.

6 Summary

The Dee is a gravel river with an armoured bed. In many places, it has floodplains which permit meandering and also moderate downstream flooding. Before undertaking engineering work on the river, it is necessary to predict what changes will be produced in the geometry of the river channel and its flows.

For a non-erodible channel of reasonably simple geometry, calculation methods are available for estimating depth and velocity for a given flow rate. At considerable additional cost, velocity distribution in the cross-section can also be calculated. When the boundary is erodible sediment, transport rate for a particular flow condition (characterized by boundary shear stress) can also be calculated from one of a variety of empirically based formulae. It is then possible to compute changes in the cross-sectional area of the channel. Means of predicting the shape changes implied by these area changes are unproven. However, subject to this last uncertainty, progressive changes in channel geometry can be calculated by a method which steps from calculating flow in a given channel to estimating the change wrought by that flow, and then back to re-calculating the flow in the changed channel, and so on.

Unfortunately, sediment transport processes are less well understood for armoured gravel rivers than for sand- and silt-bounded ones. Therefore, for the present, the knowledge of sediment behaviour to be obtained from a calculation of flow in a gravel river is limited to an estimate of the size of material which would be at the threshold of motion at each position in the channel. This estimate can be used to design protective layers to prevent the retreat of particular sections of bed or bank. However, channel changes produced in gravel rivers by engineering installations which induce substantial flow changes cannot be calculated with any reliability at present.

Engineering work is undertaken on the Dee for clients whose interest arises from one or more of the roles of the river. These roles include drainage, conveyance of domestic and trade effluents, water supply, provision of salmon breeding sites and fish passage to them, and general amenity. The 2 main types of work undertaken are flood protection, and the restraint of bank erosion. There is little technical difficulty in providing locally effective schemes for either purpose. However, the consequences of such schemes are not necessarily all local. More remote consequences are difficult to predict and there is little incentive for scheme promoters to pay for any attempt to make the prediction. There is a case for establishing a supervising agency with a duty to co-ordinate engineering on the river in the general interest.

Much needed improvement in prediction methods for gravel rivers calls for research on several particular features of behaviour. Some of the urgent ones are listed in the preceding section. Perhaps the most urgent of all concerns the better understanding of transport processes at armoured beds.

7 Acknowledgements

I thank the Scottish Development Department for permission to publish Plate 9.

8 References

Anderson, A. G., Paintal, A. S. & Davonport, J. T. 1970. *Tentative design procedure for rip-rap lined channels.* Project report no. 96, St Anthony Falls Hydraulic Laboratory, Minneapolis. (Report 108.) Washington: Highway Research Board.

Jansen, P. Ph., van Bendegom, L., van den Berg, J., de Vries, M. & Zanen, A., eds. 1979. *Principles of river engineering.* London: Pitman.

Klingeman, P. C. & Emmett, W. W. 1982. Gravel bedload transport processes. In: *Gravel-bed rivers,* edited by R. D. Hey, J. C. Bathurst & C. R. Thorne, 141-169. Chichester: John Wiley.

Leopold, L. B. & Wolman, M. G. 1957. *River channel patterns: braided, meandering and straight.* (Professional papers 282-B.) Washington: U.S. Geological Survey.

MacDonald, Sir M. & Partners. 1975. *Regional water resources study for North East of Scotland Water Board.* Vol 2. Cambridge: Sir M. MacDonald & Partners Ltd.

McClean, W. N. 1934. Flow of the River Dee. *Engineering, Lond.,* **138,** 338-339.

Shields, A. 1936. Anwendung der Ähnlichkeitsmechanik und der Turbulenzforschung auf die Geschiebebewegung. *Mitt. preuss. VersAnst. Wasserb. Schiffb.,* no. 26.

Thorne, C. R. 1982. Processes and mechanisms of river bank erosion. In: *Gravel-bed rivers,* edited by R. D. Hey, R. D. Bathurst & C. R. Thorne, 227-271. Chichester: John Wiley.

de Vriend, H. J. & Geldoff, H. J. 1983. *Main flow velocity in short and sharply curved river beds.* (Report no. 83-6.) Delft: Dept of Civil Engineering, Delft University of Technology.

Notation

A — area of cross-section of flow,
B — channel width (measured at the water surface),
D — equivalent grain diameter,
g — acceleration due to gravity,
P — length of the wetted perimeter of flow,
Q — volumetric flow rate of water,
Q_s — transport rate of sediment, by volume,
s — specific gravity of sediment,
t — time,
u, v, w — orthogonal components of water velocity (u in the stream direction),
V — volume of bed material in deposit in a specified reach,
x, y, z — orthogonal co-ordinates of position (x in the stream direction),
z_s — height above datum of the water surface,
ϱ — density of water,
ϱ_b — bulk density of sediment deposit,
τ_o — boundary shear stress (tractive force per unit area)

Water abstraction from the River Dee

I D BROWN
Director of Water Services, Grampian Regional Council

1 Introduction
This paper describes the history of the abstraction of water from the Dee to supply the city of Aberdeen and its hinterland. It touches briefly on the means of treating this water and the methods of distributing it.

Most historical records studied refer to measurements in imperial units, but metric units are used here (Table 1).

Table 1. Metric units used in this paper

1 Megalitre	= 1000 cubic metres (1000 m^3)
4.54 Megalitres per day (Ml d^{-1})	= 1 million gallons per day (mgd)
1 metre	= 3.28 feet
1 kilometre (km)	= 0.62 miles
1 cubic metre per second (cumec)	= 19.01 mgd

2 The first abstraction from the River Dee for public water supply purposes
The town of Aberdeen relied on wells, springs and the loch (located near the present Loch Street) for its water supply until the early 1800s. The population in 1792 was about 25 000, and the daily consumption per head was about 5.3 litres. The magistrates of this period were concerned about the sufficiency of the supply, and it appears that a drought in 1826 sparked off positive action. Various schemes to enhance the public water supply were examined, including the possibility of using the Loch of Skene, the Burn of Culter, the Aberdeen-Inverurie Canal and the Dee. The scheme selected was based on abstracting water from the Dee approximately 650 m upstream of the Bridge of Dee on the north bank (Figure 1).

A General Improvements Act, which covered police, paving, lighting, cleansing, watching, etc, was passed in 1829. This Act included the necessary clauses to get the scheme under way. It is interesting to note that many new house owners who had recently dug their own wells objected to the new scheme.

Initially, water infiltrated into a tunnel constructed in the gravels adjacent to the river. This tunnel led to a 3.7 m diameter well which, in turn, was connected by a 600 mm diameter cast iron pipe to a steam pumping house. The pumping house stood at the north-east end of the Bridge of Dee and the pumps were driven by 2 Watt and Boulton steam engines. The site is now occupied by tenement buildings. From the pumping house, water was conveyed by a 380 mm diameter cast iron main along Holburn Street to a reservoir incorporated in the fine building still located at 478-484 Union Street. Round about 1850, the 'infiltration' tunnel was extended to the river to allow direct abstraction.

The abstraction was limited to a 'half inch abstraction from the surface of the water' which appears to have

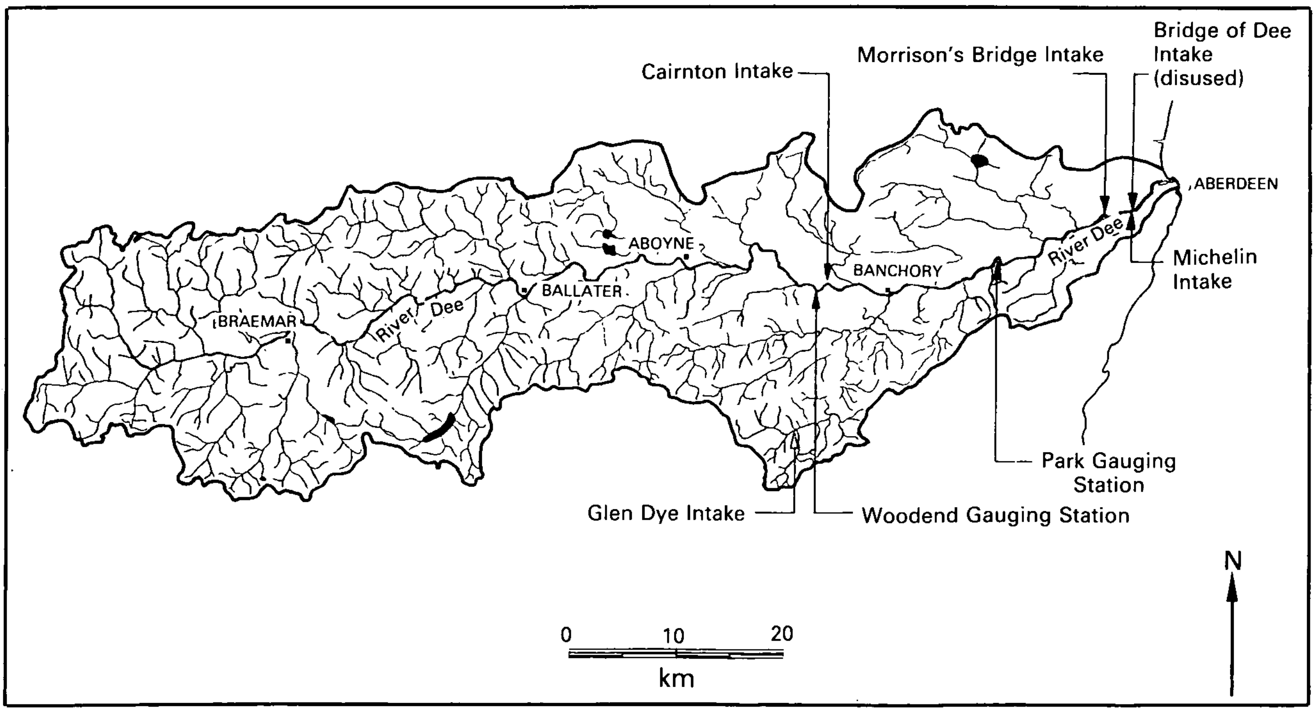


Figure 1. Catchment of the River Dee — water intakes and gauging stations

equated to a maximum of 5.7 Ml per day (5.7 Ml d^{-1}). In the early years of the scheme (the 1830s), pumping was only necessary for about 6 hours each day. By 1851, the population had increased to 72 000 (Figure 2) (Anon 1973), and pumping was necessary for 22 hours each day, approximately 71 litres per head per day. The well house still remains and can be seen on the west side of the now disused Garthdee Works.

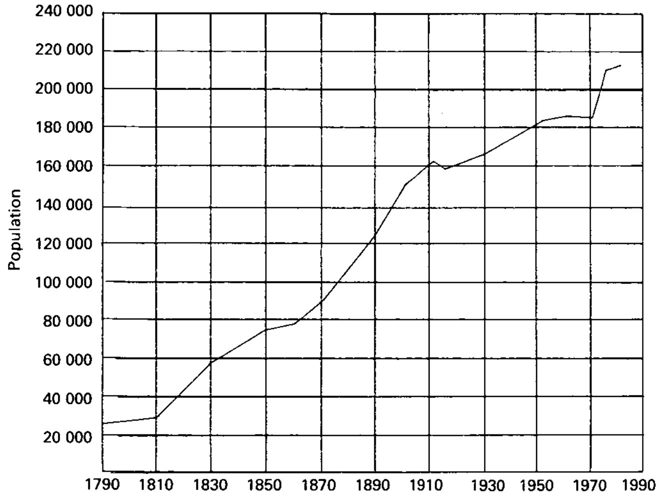


Figure 2. Population of the city of Aberdeen 1790-1981

3 The first Cairnton abstraction scheme

In 1855, the Town Council engaged Mr James Simpson of London, then President of the Institution of Civil Engineers, to investigate and report on how the public water supply could be enhanced. Mr Simpson reported in September of the same year and listed several alternative schemes, including abstraction from the Dee at Potarch, from the Dee at Cairnton (approximately 6 km upstream from Banchory), from the Don at Paradise (north of Monymusk), and from the Denburn.

It appears that the Council took some time to decide which scheme should be adopted, but in 1861 it was finally agreed that the new water supply would be from the Dee at Cairnton. It is recorded that there was much opposition to the Dee schemes, principally because of cost.

In 1862, an Act was passed which allowed 27.2 Ml d^{-1} to be abstracted at Cairnton. The new scheme, construction of which started in 1864, consisted of a side intake, a tunnel to the treatment works at Invercannie, the provision of a circular settling tank and 2 circular slow sand filters. A brick aqueduct was constructed to convey the filtered water to a new reservoir at Mannofield within the city. This scheme was opened by Queen Victoria in 1866.

By 1871, the population had increased to 88 000 (Figure 2) and the consumption had risen to 14.2 Ml d^{-1} (Figure 3). This gave a consumption of 159 l head d^{-1}, more than double that of 1851. In the1870s,

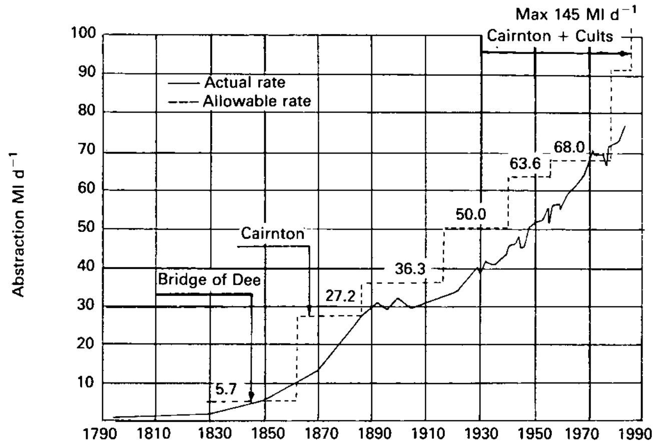


Figure 3. Rates of abstraction of water from the River Dee and the allowable abstraction rates, 1829-1980

big advancements were made in sanitary arrangements, and just after the opening of the Invercannie works a main drainage system was constructed in the city.

4 Changes in the location of the intake

By 1885, the population had increased to about 120 000 and the consumption was now approaching the 27.2 Ml d^{-1} allowable. An Act was passed in that year which allowed the abstraction to be increased to 36.3 Ml d^{-1}. To enable the extra water to be passed to the treatment works, it was necessary to re-site the intake to a point 120 m upstream. The Act also allowed for additional service reservoirs to be constructed in the city at Mannofield and Slopefield, and a steam pumping station at Cults. These works were carried out under the direction of Mr William Boulton, Burgh Surveyor.

Nothing has been said about the quality of the water so far and it must be assumed that the civic fathers and officials considered the Dee to be a relatively clean river. However, the 19th century also saw big improvements in scientific and analytical techniques, and in 1891 some concern was expressed about the quality of the water, with particular emphasis on pollution of the river above the intake. A Mr Gale, Civil Engineer, was appointed in 1891 to report on these matters, and in 1893 an Act was passed which allowed, amongst other things, the construction of sewage farms at Braemar, Ballater, Aboyne and Kincardine O'Neil.

5 The possibility of abstracting from the River Avon

In the early 1900s, abstraction was exceeding the statutory 36.3 Ml d^{-1} quite frequently, and during the winter of 1910 the maximum daily demand had peaked at 45 Ml d^{-1}. Clearly, the existing system had to be expanded or a completely new source found. The Burgh Surveyor at that time, Mr William Dyack, and a local Civil Engineer, Mr George G Jenkins, submitted a report on the possibility of abstracting water from the Avon, a tributary of the Spey, and conveying it to Aberdeen. In 1909, the Town Council promoted a Bill for the supply of 90 Ml d^{-1} from the Avon, but this was opposed by the railway companies, land and property associations, private citizens and manufacturers. Phase 1 of the scheme, which would have provided 54 Ml d^{-1}, was to cost £1,068,000, and it seems that, once again, cost was the main objection. The scheme never got off the ground and in 1910 a Committee was appointed to look at the Dee again.

In 1912, a report was prepared by the then City Water Engineer, Mr Cecil H Roberts, and Mr C P Hogg, Civil Engineer, which set out 2 alternative schemes.

i. An extension of the Cairnton and Invercannie scheme to increase the abstraction by 9.1 Ml d^{-1} to 45.4 Ml d^{-1}, incorporating, among other things, slow sand filters and an additional aqueduct to Aberdeen.
ii. A new scheme based on an impounding reservoir on the *Dye* at Tillyfumerie, with mechanical filters and an aqueduct to Aberdeen.

The estimated development costs, including capital and the capitalizing of annual running costs of both schemes (which allowed for 38 Ml d^{-1}), were Dee £551,900 and *Dye* £481,500.

The saving of £70,400 by adopting the second scheme would have been substantial in 1912, and the report recommended the *Dye* scheme. This scheme had the added bonus that much of the city could be supplied by gravity. It is interesting to note that in this report the population forecast for 1951 (approximately 40 years on) was 237 564. The actual population in 1951 turned out to be about 183 000. There were strong feelings in the city about the future of the water supply and an outspoken champion of the rejected Avon scheme was a Thomas Jamieson, the Public Analyst for Aberdeen, who spoke about the 'foul' Dee.

However, in February 1915, the Town Council decided to proceed with an extended Dee scheme, and the necessary Parliamentary powers were obtained in 1916. Because the First World War was in progress, a start to construction was delayed until 1920.

Although not strictly affecting the abstraction from the river, the following information may be of interest. In the autumn of 1912, there was an outbreak of enteric fever in the city. The outbreak was at first attributed to the water supply, but was later believed to have been due to infected milk. In 1913, a lime sterilizing plant was constructed along with 5 slow sand filters and a spiral baffle wall in the existing circular settling tank.

6 The present Cairnton abstraction scheme

The 1916 Act allowed abstraction to be increased from 36.3 Ml d^{-1} to 50 Ml d^{-1}, and it was necessary to construct a completely new intake in order to cope with the extra abstraction rate. This intake was located about 70 m upstream of the 1886 intake, and is still the intake in use today at most times in the year. The intake is a side intake, ie it is on the side of the river and is basically a reinforced concrete box below ground level measuring approximately 11.0 m × 10.0 m overall. The superstructure is in masonry and the building has a flat roof. Three openings approximately 2.4 m wide are provided on the river side of the intake. The flow through each opening is controlled by a rectangular penstock 0.8 m high × 1.2 m wide. The openings are protected by vertical bars and pressed galvanized steel screens with 6 mm openings. Two sets of copper screens were originally located in the inlet chamber but these were eventually replaced by 0.5 mm mesh stainless steel screens. In 1981, these screens were superseded by a self-cleaning drum screen with 1 mm apertures. This screen is located at the actual water treatment works. The outer mesh screen at the intake is cleaned by impinging air from an air blower on to the outer face. The operation is controlled by time clock and cleaning takes place 3 times a day. From the intake, the water is conveyed to the original tunnel by a 1.5 m diameter concrete conduit cast *in situ*. The tunnel and the conduits at either end can convey a total of 91 Ml d^{-1} from the intake to the treatment works.

Construction of the intake and conduit started in 1922 and was completed in 2 years. During all this time, the whole of the supply to the treatment works had to be pumped from the river.

The new Invercannie/Cairnton scheme was formally opened by HRH Princess Arthur of Connaught on 30 September 1926.

7 Pumped abstraction at Cairnton

The 1926 intake was able to supply water by gravity from the river during the 1920s, 1930s and 1940s, but by the 1950s sufficient water could not be taken into the conduit/tunnel by gravity when the river level dropped. In 1960-61, a permanent electrically driven pump was installed at Cairnton at the old 1886 intake house. It is a 760 mm diameter low lift axial flow pump. When this pump is in use, it is necessary to shut the 1926 inlet penstocks. In the past few years the pump use has increased, and in 1984 up until 20 September it had been in use 154 days out of 264. This inlet is also screened by a bar screen and a 6 mm mesh screen.

8 Increase in allowable abstraction rates

Because of the increase in water consumption in the 1930s, the Aberdeen Corporation (Water, Gas, Electricity and Transport) Order Confirmation Act 1937 allowed the abstraction to increase to 68 Ml d^{-1}. However, the abstraction was limited to 63.6 Ml d^{-1} until certain sewerage works between Peterculter and the City had been constructed by the then Aberdeen County Council and Aberdeen Corporation. The Aberdeen Corporation Order Confirmation Act 1955 allowed Aberdeen Corporation to abstract 68 Ml d^{-1} at any time when the total flow in the river was equal to, or exceeded, 120 million gallons per day (mgd) or 6.3 cumecs measured at Cairnton. When the river flow dropped below this level, the abstraction rate had to be reduced to 63.6 Ml d^{-1}.

9 The new River Dee abstraction scheme

With the discovery of oil and gas resources in the North Sea in the 1960s, it was evident that Aberdeen would become a base for the necessary on-shore and off-shore operations. This would mean an influx of people seeking houses and a development boom was forecast. Although the former Aberdeen County Council, and their water authority successors of 1968, the North East of Scotland Water Board, had a large scheme in being for supplying the small towns and villages north and west of Aberdeen, it was clear that more water had to be found for the city and its suburbs. The Board commissioned Sir M MacDonald and Partners, Consulting Engineers, Cambridge, to undertake a water resources study of the whole of the Board's area. The results of this study (MacDonald & Partners 1975) were produced in the year of the local government re-organization in Scotland, and it was left to the Board's successors, Grampian Regional Council, to put the consulting engineers' recommendations into practice. The main recommendations were that:

i. additional abstraction should take place from the Dee at Cults;
ii. temporary additional abstraction should take place at Cairnton until the Cults scheme was completed;
iii. water should be abstracted from the Spey to supply the northern coastal belt.

Scheme (i) included a reservoir on the *Dye* at Tillyfumerie.

During the late 1970s, extensive discussions were held with the fishing interests of Dee (the Dee District Salmon Fishery Board and the Dee Salmon Fishing Improvement Association) and other interested bodies. Water Orders were obtained in 1978 and 1980 (Grampian Regional Council (River Dee) Water Order 1978 and the Grampian Regional Council (River Dee, Morrison's Bridge Intake) Water Order 1980), which allowed the extra abstraction at Cairnton and the new abstraction at Cults near Morrison's Bridge. After discussions with fishery interests, it was decided that a reservoir on the *Dye* was not desirable. The 1978 Order allows a total abstraction at Cairnton of 91 Ml d^{-1}, but, when the flow in the river measured at the North East River Purification Board's gauge at Woodend (about 2 km upstream of Cairnton) falls below 680 Ml d^{-1} (7.9 cumecs) for 7 consecutive days, hosepipe restrictions in areas served by the Dee have to be introduced. When the river flow exceeds 770 Ml d^{-1} for 7 consecutive days, the restrictions can be removed. After the end of 1985, the allowable abstraction will fall to 70 Ml d^{-1} and the hosepipe rules will no longer apply. The hosepipe restrictions apply to the washing of private motor cars and watering private gardens.

The 1980 Water Order allows for a total abstraction of 75 Ml d^{-1} from the river at a point approximately 550 m downstream of Morrison's Bridge (the Shakin' Briggie). To allow fish to 'run' during low flows, the Order incorporates a provision that all abstraction will cease for a period of 6 hours each day when the river flow at Park (near Drumoak) is 640 Ml d^{-1} or less. The actual times of shut-down will be determined by the Dee District Salmon Fishery Board. In addition, an agreement exists with Aberdeen Harbour Board that they will suspend their sweep net operations when the flow at Park drops below 454 Ml d^{-1} (5.26 cumecs). Compensation will be paid by the Council during this suspension period. The interruption to pumping and the suspension of net fishing were a result of the discussions with the fishing interests.

10 The new river intake

Sir M MacDonald and Partners were chosen to design the new scheme, which includes the intake, a pumping station, a bankside raw water storage reservoir, rising mains and a treatment works located at Mannofield within the city.

The intake is a bed intake, ie the actual intake is located below the bed of the river. A bed intake was chosen after examination of the performance of the Council's bed intake on the Deveron at Turriff and after trials with a pilot intake on the Dee at the site of the proposed operational intake. The bed intake has a number of merits.

i. It leaves the river bank unchanged as abstraction is through river gravels into boxes constructed below the bed of the river.
ii. The bed of the river is almost unchanged, thus benefiting the fishery interests.
iii. The alternative side intake would have to be very long in a shallow river such as the Dee.

The intake consists basically of 6 adjacent concrete boxes, each measuring 2.75 m × 2.0 m internally. A stainless steel distributor plate with 2240 10 mm diameter holes is located 400 mm above the floor of each box. This supports 100 mm of washed river gravel, 300 mm of 12-19 mm crushed granite and 350 mm of 20-50 mm washed river gravel, all surmounted by 150 mm of 50-100 mm cobbles.

The approach velocity at full allowable abstraction is 27 mm s^{-1}, two-thirds of the value tested in the pilot intake; 400 mm diameter ductile iron pipes lead from each box to the low lift pump sump located in the pumping station on the north bank. Valving is arranged such that each intake box can be backwashed at rates up to 150 mm s^{-1} from the high lift delivery main between the station and the treatment works located at Mannofield within the city.

The intake is not intended to serve as a filter, but rather to provide a means of reducing the approach velocity to such a value as to create no problem to fish. It is, however, essential to ensure that the intake does not become blocked and is stable under all conditions of river flow. The pilot intake was operated for a period of about 2000 hours and parallel tests were carried out at Aberdeen University upon a pilot intake built in a laboratory. Backwashing at rates within the range 100-115 mm s^{-1} was found to be effective without the use of air. During periods of low river flow, the rate of intake blocking should be very low, but at high flows backwashing is likely to be required every few days. A problem experienced at the Deveron intake at Turriff was associated with short-circuiting during backwashing, which led to a blow-out of bed material. This problem was overcome by the use of a distribution plate, and an even flow distribution during backwashing should be assured under all conditions.

The raw water reservoir incorporates a flood relief structure such that in flood conditions water can enter the reservoir through non-return valves. The ingress of fish is prevented by mesh screens with 25 mm × 12 mm openings.

11 The Michelin Tyre Company Ltd intake

In the early 1970s, the Michelin Tyre Company Ltd decided to set up a factory in Aberdeen and required approximately 10 Ml d^{-1} of untreated water. The North East of Scotland Water Board promoted a Water Order in 1972 which would allow the Board to abstract 9.84 Ml d^{-1} solely from the Dee for supplying the Michelin Factory located at Redmoss on the south side of the city.

The intake was designed by Robert Cuthbertson and Partners, Consulting Engineers, Edinburgh, and is located on the south bank of the river approximately 620 m upstream of the Bridge of Dee. It is a bed intake and consists of 3 concrete boxes sunk into the bed of the river. The boxes are 2 m square and about 850 mm deep. Each box is covered by 4 stainless steel mesh trays which support a 225 mm layer of gravel surmounted by 300 mm of broken stone. A pipe leads from each box to the pump well located on the bankside. Two pumps are housed in the pumping station, one of which is a reserve pump. The water is pumped to the Michelin Factory where a proportion of it is used for processing and cooling water. Although allowing a total abstraction of 9.8 Ml d^{-1}, the Water Order also calls for 80% of this water to be passed back to the river via a return main from the factory to the river. The outfall of this return main is just downstream of the pumps. Backwashing of the intake boxes can take place by feeding water from the above return main to any one of the 3 abstraction pipes located in the river.

In November 1984, the average daily abstraction was only approximately 1.4 Ml d^{-1}, approximately 14% of the allowable abstraction.

12 Other water supplies derived from the Dee catchment

This paper has concentrated on the major abstractions from the Dee for public water supply. However, there are a number of settlements which derive their water supplies from the Dee catchment, and these are listed below with their average consumption.

Settlement	*Tributary*	*Average daily consumption* (m^3 d^{-1})
Braemar	Unnamed	290
Dinnet	Springs	16
Ballater	River *Gairn*	520
Aboyne	Springs/*Allt Roy* burn	480
Kincardine O'Neil	(Cairnton)	
Lumphanan	(Cairnton)	
Torphins	(Cairnton)	
Tarland	Springs	159
Birse	Springs	6
Glendye WTW	Water of *Dye*	4500
Crathie	Springs/Well at bank of River Dee (Emergency)	22
Banchory	(Cairnton)	
Logie Coldstone	Springs	55
Coull	Springs	3

A proportion of this water is returned to the Dee.

13 River quality as it pertains to public water supply

From the point of view of its suitability for public water supply, the Dee at Cairnton is a high quality source of water which requires only limited treatment before being supplied to the consumer.

The river at this point contains no harmful or objectionable chemicals in significant amounts. There is little manufacturing industry, and therefore there are no problems from industrial effluents. The principal aims of treatment are to ensure the absence of faecal bacteria in the product water, to prevent silt brought down the river during high flows from entering the supply system, and to guard against the unexpected, eg spillage from tankers.

Treatment consists of settlement, slow sand filtration, chlorination and lime dosing. In slow sand filtration, the water flows by gravity through large beds of fine sand. The community of micro-organisms which becomes established in the filter greatly reduces the numbers of faecal bacteria in the water. This is then chlorinated to ensure disinfection. As humic substances are not readily biodegraded, they pass through treatment, which accounts for the pale yellow colour observable in Aberdeen water. The final treatment step is to add hydrated lime to the water in order to reduce its corrosive effect on lead pipes which have been widely used in the past as service pipes connecting the consumers' taps to the water mains.

14 Factors affecting the quantity of water available for abstraction

In recent years, scientists and engineers have been interested in the effect of evaporation from forests in catchment areas and the effects of climatic change on runoff. It is not known if any such investigations have been carried out in the Dee catchment, but a recent study of hydrological records from the 1930s to date indicates that no dramatic changes have taken place. There has been a claim from some quarters that prolonged periods of low flow have been increasing, but there is no evidence to sustain this claim. However, if the resources were made available it might be interesting to study the matter of evaporation further.

This paper has concentrated on the use of the Dee for public water supply purposes. The Regional Council recognizes, however, that the river is used for other purposes and that is why all interested parties were consulted and had a chance to air their views before the Cults scheme was progressed. No formal objections to the Water Order were made and therefore no Public Inquiry was necessary. The Council retained 2 fishery consultants to advise on fishery matters, and, although allowable abstraction is many times that allowed in the 1800s, the Council are confident that this level can be sustained without damage to the flora and fauna of the river.

15 Summary

15.1 The Dee is the source of the water supply for Aberdeen and its suburbs. The river's tributaries also supply water to Braemar, Ballater, Aboyne and north Kincardineshire. Other villages in the Dee catchment are supplied from springs within the catchment.

15.2 The first Aberdeen supply from the Dee was approved by Parliament in 1829 and the abstraction took place 650 m upstream of the Bridge of Dee in Aberdeen. The allowable abstraction was 5.7 Ml d^{-1}.

15.3 By the 1850s, the quantity available was not sufficient to meet the demand of an expanding population in Aberdeen. In 1862, an Act was passed which allowed a new water supply scheme to be constructed with an intake located at Cairnton, about 6 km upstream from Banchory. The treatment works were constructed at Invercannie about 2 km east of Cairnton. The allowable abstraction was 27.2 Ml d^{-1}.

15.4 Because of mounting consumption, an Act of 1885 allowed the abstraction to be increased to 36.3 Ml d^{-1}. The intake was relocated 120 m upstream.

15.5 Again to meet increasing demand, an Act of 1916 allowed the abstraction to be increased to 50 Ml d^{-1}. Because of the First World War, it was not until 1926 that the works necessary to cope with this quantity were completed. These included a new intake about 70 m upstream of no. 2 intake.

15.6 In 1937, an Act allowed the abstraction to be increased to 68 Ml d^{-1} under certain conditions. It was modified by another Act in 1955.

15.7 To enable abstraction to take place during periods of low flow, a pump was located in the no. 2 intake in the early 1960s.

15.8 In 1972, the North East of Scotland Water Board promoted a Water Order to enable 9.84 Ml d^{-1} to be abstracted from the Dee 620 m upstream of the Bridge of Dee, to supply the Michelin Tyre Company Ltd located at Redmoss in Aberdeen.

15.9 The coming of the oil industry to Aberdeen called for even more water, and a Water Order of 1978 allowed the abstraction at Cairnton to be increased to 91 Ml d^{-1} until the end of 1985. Certain conditions were imposed.

15.10 To meet the forecast demand into the early years of the 21st century, a new abstraction scheme based on abstraction at Cults was promoted during the 1970s. The authority to abstract water was confirmed by a Water Order in 1980. The total allowable abstraction at Cults will be 75 Ml d^{-1}. Abstraction will be restricted to 18 hours each day when the river flow measured at Park drops to 640 Ml d^{-1}. Sweep netting at Aberdeen Harbour will be suspended when the river flow drops to 454 Ml d^{-1}.

16 References

Anon. 1973. *Census 1971 Scotland — county report: Aberdeen city.* Edinburgh: HMSO.

MacDonald, Sir M. & Partners. 1975. *Regional water resources study for North East of Scotland Water Board.* Vol. 2. Cambridge: Sir M. MacDonald & Partners Ltd.

Fishery management on the River Dee

J OSWALD
Glen Tanar Estates, Aboyne

1 Introduction
I write this paper as someone who is directly involved with the day-to-day management of 23.6 km of salmon fishing on the Dee between Aboyne and Ballater. With 34 years of experience of the river, to me it is more than an academic feature on the map. It is a living thing that we must care for, through the hard frosts of winter, the spring spates, and the droughts of summer. Salmon fishing by rod and line has a position on a market. Giving a good service to the fisherman by having a well-maintained section finds the best out of that market. Naturally it is necessary in salmon fishery management to have a plentiful supply of salmon, and also to have good access tracks, nice fishing huts and well-trimmed pools in which to fish. There is also the wildlife consideration, from freshwater mussel to the humble dipper, whose lives are entirely dependent on the river.

The way we conserve all the things we like for future generations must be high on the order of priorities. Many things that concern the fisherman are now completely out of his control, and we have to rely on the good offices of the people in positions of authority and power to use their wisdom when dealing with such matters. I hope the following may help to give them a better understanding of some of the practical problems.

2 History
The Dee is one of the most prolific rivers in the United Kingdom, and probably holds more salmon and sea trout per unit volume than any other. It has a course of some 140 km (87 miles) to the sea, starting high in the Cairngorm Mountains and entering the sea through the harbour at Aberdeen. There is virtually no sewage pollution in the river, which has supplied fresh water to the city of Aberdeen for many years. Some of the earliest settlers in Britain chose a site between Aberdeen and Banchory for their encampments, in places where no doubt a good source of food was available from the river nearby, in the form of salmon. In the last century, farm workers would not take up a contract of employment 'fee', unless guaranteed that salmon would not be served more than twice a week.

Various methods evolved for catching salmon. The net was the most efficient, but the wattle fence trap would also have played a big part in medieval times. Although traces of these traps have long disappeared from the Dee, they have been dug up on other slower and muddier rivers, and there is good reason to believe that they were used on the Dee. Various types of barbed spears or multi-toed forks called 'leisters' were common and easy to make. They were quite heavy and had a long shaft, with a spear-head made from wrought iron with 4-6 toes, barbed on both sides so that the fish was well impaled. (In 1850, just above Balmoral bridge, Queen Victoria and Prince Albert witnessed an exhibition of salmon leistering. 'It had a very pretty effect; about 100 men wading through the river, some in kilts with poles and spears very much excited' (Victoria, Queen 1868).) In the tributaries, the farm folk used the gaff, a simple steel hook, as their main weapon. In medieval times, virtually any method of getting salmon from the river was acceptable, as they were so abundant.

Fishing for salmon as a 'field sport' probably started in earnest around the mid-17th century. A trooper in Cromwell's army, Richard Frank, recognized the potential while stationed in Scotland, and after being demobbed returned in 1650 to fish for salmon. With the ever improving transport systems of road, sea and rail, by the middle of the 19th century salmon fishing had become a popular recreation in Scotland. At this period, the river was netted for the 26 km up to Banchory by a series of sweep nets.

The demand for rod and line fishing increased every year, but a decline in the number of salmon reaching the spawning grounds in the upper regions of the river was attributed to over-fishing by the nets between Banchory and Aberdeen. The District Board could not undertake the removal of the nets, so the proprietors above Banchory formed an Association (Dee Salmon Fishing Improvement Association) for this purpose. On the initiative of the Marquis of Huntley, the Dee Salmon Fishing Improvement Association was formed in 1872. Its purpose was to control and lease the net fishing, and it was very successful.

Commencing at Banchory, 27 km distant from the mouth, the river nets were leased and removed as funds permitted. In the first 10 years of its existence, the Association spent nearly £4,000, until there were no nets in the river above the railway bridge at Aberdeen. In 1882, the river apparently yielded a rich harvest, for in that season upwards of 5000 salmon and grilse (fish returning to the river after spending one winter at sea) were taken by the rods. In 1902, the collective value of the angling rents produced 8 times the income paid by the netting rents in 1871.

From that time, the Dee has never looked back. It has had its bad years and good ones, like all other rivers, with the difference that a bad angling season on the Dee means a nearly absolute dearth of sport on any other river. By degrees, however, the increase of nets on the coast began to have its effect. As early as the turn of the century. Grimble (1902) wrote that 'the Association must now turn their attention in that direction'.

However, despite the coastal nets, salmon fishing remained fairly constant and predictable until the 1960s, when a localized salmon fishery in west Greenland developed into a significant autumn inshore gillnet fishery, exceeding 1500 tonnes (t) by 1965. An offshore drift net fishery also developed from that time in Greenland and the combined annual catch exceeded 2600 tonnes in 1969-73, when regulations limiting the quantities of salmon caught in the fishery were introduced by the North West Atlantic Fisheries Commission (Association of Scottish District Salmon Fishery Boards 1977).

From 1968, a small long-line fishery for salmon developed off the Faroes, extending up to 112 km north of the islands. Catches had built up to 40 t yr^{-1} by 1977. Vessels from Denmark then became involved, and catches subsequently increased and peaked at about 1000 t yr^{-1} in 1981. In the early phase of this fishery, until the late 1970s, most of the catch consisted of one sea-winter fish. More recent observations made on commercial vessels have suggested that about 90% of the landed catch was of 2 or more sea-winter fish and that only about 2% had spent one winter in the sea. From 1982, the Faroese government agreed to a voluntary quota system, with a total catch limit of 750 t yr^{-1} in 1982, reducing to 625 t in 1983 (Shearer & Clarke 1983).

Two other fisheries are known to exploit salmon stocks of Scottish origin, from the capture of adults tagged as smolts. These are the Irish drift net fishery and a somewhat similar fishery operated in the North Sea off the coast of Northumberland and, to a lesser extent, Yorkshire. The catching power of both these fisheries increased in the 1960s with the introduction of nets manufactured from synthetic twine. Both fisheries catch mainly grilse. The influence of the Northumbrian fishery is confined primarily to the east coast of Scotland, between the Rivers Bervie and Tweed, but there is a lack of information regarding the area affected by the Irish drift net fishery.

In 1962, a legal drift net fishery operated off the Scottish coast. This method of fishing was banned in 1963, but illegal fishing using similar techniques continues and none of the catch appears in the national statistics.

By the end of the 1960s, fishermen on the Dee were having great difficulty in catching salmon on rod and line. Salmon were being caught in February with damage to fins and recent signs of being tangled in nets. The disease UDN (ulcerative dermal necrosis), which arrived in Scotland in 1966, also started to take its toll. A combination of this disease and drift netting lowered salmon stocks to rock bottom, and they have been struggling to reach anywhere near their former level on the river as a whole ever since. The decline is shown clearly by data from a salmon trap in the *Girnock*, a tributary of the Dee above Ballater (Table 1). To help combat the decline, a salmon hatchery was built at Dinnet in 1964, but its use has not increased catches markedly.

Table 1. Numbers of adult salmon trapped experimentally when they were travelling upstream in the *Girnock* burn, Aberdeenshire (source: Buck & Hay 1984)

Year	Males	Females	Total
1966	113	156	269
1967	99	115	214
1968	85	111	196
1969	18	31	49
1970	56	34	90
1971	64	61	125
1972	58	79	137
1973	98	127	225
1974	79	105	184
1975	56	65	121
1976	74	90	164
1977	66	49	115
1978	22	16	38
1979	33	49	82
1980	82	121	203
1981	26	41	67
1982	30	43	73
1983	37	26	63

3 Preventing poaching

While control of the fishermen is kept in the hands of the riparian owners, the policing of illegal fishing falls to the Dee District Fishery Board. Its team consists of an inspector and 7 water bailiffs who patrol the river, mainly in the dark, and have radio-equipped vans for quick communication. The use of the trammel or gill net seems to be the favoured illegal method for poaching salmon from the river. In low water conditions, 'Cymag' gas is sometimes used, and kills all fish without distinction. Over the years, many attempts to foil net poachers with various types of anti-net hooks have been made. These are called cleeks, anchors or huds; most are of the 3-hook type with inside barbs. Some have been loaded into big rocks, and others are embedded into concrete blocks, many of which are upturned or broken off. A revival of the anti-net hook would certainly trap many of the poachers' modern nylon nets, which are so light and strong that they can be carried in a rucksack. The combination of nylon net and the wet suit has made illegal fishing so much easier than yesteryear, when it almost needed a horse and cart to carry a wet cord net. The main powers of the water bailiffs are set out in the Salmon Fisheries (Scotland) Act 1868 and the Salmon and Freshwater Fisheries (Protection) (Scotland) Act 1951. A close season extends from 1 October to 31 January.

4 Rod and line fishing

In February and March, spinning lures such as 'Devons' and 'Spoons' are allowed. From 16 April onward, it is 'fly only' for those fishers who adhere to the guidelines of the Dee Salmon Fishing Improvement Association, during high water. Water gauges on most beats define the level where the change from fly to spinning takes place. Prawn and worm fishing is frowned upon, and on most beats totally banned. A strict control is kept on the number of rods allowed to fish at any one time, and this is supervised by a member of estate staff (eg factor, gamekeeper or ghillie). A detailed and accurate record of all salmon and sea trout caught is kept by the fishing proprietor, and is used by the assessors to determine the rates in the 'Valuation Roll for the Grampian Region Valuation Area'. An important contribution is made by the salmon fishery to the Grampian Region.

In the early days of salmon fishing, rods were made of heavy greenheart wood and could measure 5 m. Reels were made of brass with heavy linen lines, and fly hooks were dressed with exotic bird feathers and could measure up to 10 cm in length. They were joined to the line by a gut cast. The method was known as 'sunk fly' fishing, and continued to the 1930s. A new technique was then developed called 'greased line' fishing which involved using a light 'split-cane' (bamboo) rod, and tiny flies of some 2 cm in length dressed very lightly with a dull game feather attached by gut to a dressed linen line. This line had to be dried 3 or 4 times a day and greased with a water repellent, so that it would float on the surface. It was very effective in warm water and more than doubled the catch from the sunk line method. Sandy Thompson, a ghillie from Aboyne, described to me in 1951 the start of the greased line in the 1930s, 'I niver saw salmon tak' a fly like it; they rose, showing head, back and tail an' then a pause, a great rug, an' they were on'.

This is the current method, but the equipment has advanced. The early 1950s saw the introduction of nylon for casts, together with fibreglass rods and lines made of plastic-coated fibres, giving them good floating qualities. In more recent times, fly-fishing rods have benefited from the latest technology in carbon fibre.

Spinning lure techniques have not changed much from the early days, except for the tackle, ie rods, lines and reels. The old wooden rods and brass reels with linen lines have been superseded by a big variety of fixed-spool and level cross-wind reels. These combinations have brought almost every salmon within range of the fisherman on nearly every pool of the Dee. Charlie Milne from Glen Tanar told me in 1951 that, in the old days when they could not cast very far, 'we used to link our lines together with horse hair, and wind the lure back and forth the wide parts, and when the salmon took, the hair broke and one was left to land it'. He also told me that pickled gudgeon, loach, sand eel and sprat were the favourite live baits. Sprats dyed with yellow and pickled in a bottle, called 'golden sprats', were acknowledged to be the best. At the present time, the main lures are the wooden 'Devon' and 'Blair' spoon.

5 Recreation

One of the main attractions for tourists on Deeside is the river, with its spectacle of salmon leaping in the pools such as there is at the Linn of Dee. Salmon fishing is a recreation and is enjoyed by a wide spectrum of people, from the Queen to the ordinary working man. A new sport on the river has arrived with the introduction of the fibreglass canoe some 10 years ago. This has resulted in some disturbance. However, salmon adapt quickly to a floating object, provided there is no prolonged disturbance. In my experience, canoeists are sensible and respond to requests made of them. Camping is allowed in some areas near the river, and some bathing occurs during prolonged spells of hot weather, but temperatures seldom reach this level before the end of June. A favourite pastime of the day-tripper is to sit by the river, throw in his rubbish and let it float away. This habit can only be prevented by education.

6 Agriculture and wildlife conservation

Fast-flowing rivers bring their own problems where they run through cultivated land. There is a continual fight to prevent the river cutting into fields and eroding the banks. During the autumn floods of 1982, trees were torn out, and stable banks adjoining arable ground were ripped away. To counter this on Glen Tanar, during the winter thousands of kilograms of stones were tipped at the vulnerable points. I find that rocks of 50-100 kg fall into place and lock together well; if filled with some loose earth, they become colonized with plants and bushes in a year or so to form a semi-natural river bank profile.

In a natural situation, the river would be unseen by the passer-by as it would be hidden by trees and bushes along its banks. Owing to salmon fishing interests, the banks of the pools have been shorn of their bushy vegetation so that the fisherman can get access to the pools. No more than is absolutely necessary is cut by the ghillies, as this work is labour-intensive and expensive.

With a river like the Dee which is virtually free from pollution, great care should be taken in future over any development, whether industrial or agricultural. Such items as large exotic plantations in the catchment area of the tributaries can alter the water to such an extent that young salmon cannot live. Large-scale drainage on peat-covered hills causes flash floods which are unwelcome on any river. Tearing up large areas of scrub land for re-seeding, or the deep draining of marsh land with the consequent loss of insect life, can greatly affect the diet of young salmon. Many features make a river a good place for fish to live, and to keep it this way there should be some form of consultation on any development. Bodies like the Nature Conservancy Council, the Department of Agriculture and Fisheries for Scotland, and the Institute of Terrestrial Ecology are readily available, with scientists qualified in every sector of environmental research. Traditional landowners of the past have had long experience of good land management, and have cared for the countryside. With the smaller land units coming into being, and new owners, there is a chance of radical new land management, and the new owners should keep the welfare of the river in mind.

7 Water abstraction

Water authorities in Scotland have powers under Section 21 of the Water (Scotland) Act 1946 to acquire water from any stream or other source by agreement or compulsion. At Common Law, District Fishery Boards may object to the abstraction proposals of public water undertakings and, in some cases, this may result in a Public Inquiry. Under the existing Water Order, the local authority is allowed to extract 'a maximum of 20 M gallons a day' from the Dee, which generally meets the city's daily needs, at least for the present. However, in the past 2 dry summers of 1983 and 1984, river levels have been very low, and we read in the press that, 'while the number of gallons extracted from the river above Invercannie will be reduced to 15 M gallons a day, the local authority will be allowed to take a further 17 M gallons daily (8 500 000 gallons in 2 phases) for the new supply lower downriver at Cults' (Press & Journal, 10 September 1984). It is frightening to think that around one third of the river in a dry spell should be extracted to supplement other regional supplies. Surely, action should be taken to provide adequate storage to fill this need in time of drought, as, in my opinion, the level of abstraction has already reached the maximum that can be tolerated by fishery interests.

8 Future

We may have seen the end of good salmon fishing for a long time to come. Gone are the days when we were sure the 'spring runs' would come in. So many factors, very complex and beyond the immediate control of the river fishing manager, have now come into being. The trends (Table 1) show the river catches to be in decline, and the point will come where the impact will be felt beyond the fishers, and by such people as hoteliers and shop-keepers, coupled with a loss in rates and a loss of employment. The main hope to avoid disaster is the conservation of salmon on the high seas. The problems are well enough known; it is a matter of finding the will by international agreement to resolve a complex situation.

9 Summary

Salmon fishing on the River Dee is more than a luxury for a few sportsmen; it has an important part to play in the economy of Deeside.

We must look after this asset in every practical way possible, so that salmon may enjoy the freedom to return to the headwaters for many hundreds of years to come.

A little over a century ago, our grandfathers took one positive step in removing all the nets from Banchory to Aberdeen, with a subsequent improvement in salmon stocks.

In the last 20 years, we have seen a demolition of this good conservation work. Heavy fishing at sea is taking a big toll of salmon on the feeding grounds and homeward bound routes. Only international agreement can resolve this sea fishing problem. At home, increased direct water abstraction from the river during spells of drought can only spell disaster for salmon trying to smell the river out at sea. A large reservoir is needed to supplement the regional demands during dry weather, and proposals for further direct abstraction should be resisted.

Land use in the catchment areas should be monitored carefully, so that the breeding grounds in the tributaries are not destroyed by excessive draining and by plantations of exotic trees. Little is known about the long-term effects of the policy of blanket planting of non-native forests throughout the feeding grounds of young salmon. In many cases, trees of American origin are over-hanging the streams for miles on end.

A revival of the anti-net hooks on the river beds would allay the worries of fishing proprietors on many stretches that are susceptible to the ravages of the poachers' nets.

Co-ordination of all the interested parties must prevail if the future of salmon in the river is to be assured. No single group alone can stand up to the pressures of the contemporary world, however well meaning they may be. Only action on a broad front by people of knowledge and authority can succeed.

10 References

Association of Scottish District Salmon Fishery Boards. 1977. *Salmon fisheries of Scotland.* Addlestone: Fishing News Books Ltd.

Buck, R. J. G. & Hay, D. W. 1984. The relation between stock size and progeny of Atlantic salmon (*Salmo salar*) in a Scottish stream. *J. Fish. Biol.*, **24,** 1-11.

Calderwood, W. L. 1909. *The salmon rivers and lochs of Scotland.* London: Arnold.

Fishery Board for Scotland. 1885. *Annual report* no. 4.

Grimble, A. 1902. *The salmon rivers of Scotland.* London: Kegan Paul, Trench & Trubner.

Victoria, Queen. 1868. *Mountain rock and glen: illustrating our life in the Highlands.* London: Bell & D.

Shearer, W. M. & Clarke, D. R. 1983. *Long term trends in Scottish salmon catches.* (CM 1983/M:24.) Copenhagen: International Council for the Exploration of the Sea, Anadromous and Catadromous Fish Committee.

Amenity and recreation on the River Dee

R D WATSON
North East Mountain Trust, 396 King Street, Aberdeen

1 Introduction

1.1 Definitions

Amenity commonly includes both services and pleasant surroundings, and both apply here. Informal recreation, by its very nature, often needs few services, but picnic areas and caravan and camping sites are required. Landscape is a term that conveniently covers much of 'pleasant surroundings', the other aspect of amenity. Countryside users would increasingly include wildlife as part of these pleasant surroundings. Some points discussed, such as amenity and enjoyment, are subjective. Thus, much of what follows is personal opinion, albeit shared with many others, and obviously cannot be given the status of scientific conclusions.

There is no precise dividing line between formal and informal recreation. For example, canoeing encompasses formal slalom competitions and informal river touring. Similarly, participants in some activities do not represent separate 'user groups'. Almost everyone who is appreciative of countryside is active in more than one of them. To take an obvious example, the family who drive to a favoured place, walk along the bank for pleasure, see interesting flowers and photograph them, have participated in a wide range of activities. These are problems familiar to anyone who attempts to categorize the behaviour of people, but they need not trouble us here, provided we do not attempt to make our classification too rigid.

1.2 Scope and nature of informal recreation

The more popular activities classed as informal recreation on Deeside include touring by road, walking, canoeing, nature study including bird-watching, photography, swimming, picnicking, camping, and caravanning. No overall data exist on the level of participation in outdoor recreation by residents in Grampian. It is fairly certain, however, that it has been increasing for some years, and is still increasing, perhaps rapidly. The clearest indicator of this increase is for rambling, walking, and canoeing, for which some information can be obtained. Both the numbers of clubs and the membership within clubs are increasing fairly rapidly.

These trends may partly reflect national ones, but it would be difficult to prove that such a national trend has existed since the late 1970s. A major reason for local increases is probably the increase in population in Grampian, which grew by about 50 000 (14%) between 1971 and 1984. This is a large percentage increase over 13 years. In addition, almost certainly an untypically high proportion of those attracted to the area are young, well-paid, middle-class professionals with considerable disposable income. These are the social groups most active in outdoor recreation.

To many local participants in outdoor recreation, the catchment of the Dee is a huge country park. People walk, drive, climb, and ski in it, and in later years take their children to it as they would to a huge adventure playground. The social significance of Deeside to the Aberdeen urban area as a recreational resource is thus enormous.

2 Informal recreations

This paper concentrates on the relevant activities shown to be the most important in a survey organized by Survey Research Associates (1981), plus those lesser activities particularly associated with the river. Considerable information is available on the relative importance of the major activities in the Scottish countryside (Tables 1 & 2).

Table 1. Proportion of people (%) involved, at least once, in recreational activities in the Scottish countryside in the year prior to survey (source: Survey Research Associates 1981)

Drives, picnics, outings	Long walks >3.2 km	Visiting nature reserves	Visiting stately homes/museums	Fishing	Pony trekking, riding
59	36	12	10	9	2

(Derived from 2905 interviews in 150 polling districts, with sample figures weighted to represent the Scottish adult population)

Table 2. How holiday-makers first heard about their main stop in Scotland (%) (source: as Table 1)

Always known about it*	Recommended by relative or friend†	Found by chance*	All media	School work or trip	Seen on map	Guide book or gazetteer	Tourist Office information
45	29	11	3	2	1	1	1

*The majority of these making repeated visits to their destination
†The majority of these making first-time visit to their destination

2.1 Road touring and riverside views

This survey shows that about 66% of tourists come to Scotland by car. It also (Table 1) shows the high importance of driving in the countryside for local people. Driving is also part of most other activities, and for many people it is the experience of the whole day that counts, and not just that part of it spent, for example, canoeing or walking. The importance of the 'journey to play', as it has been called, is considerable for almost all participants in outdoor recreation. Surveys show that the dominant factor that attracts visitors to Scotland, and local people to its countryside, is the scenery. Consequently, the view from the road is important both socially and economically.

With the car tourer especially, the eye roams at will over the entire landscape, and my comments must therefore take in a similar sweep of the strath. In this broad sweep of the Deeside landscape, the river is an important unifying feature, giving it a significance far greater than any quantitative assessment of it as a landscape feature might suggest.

Deeside owes much of its appeal as a tourist route to frequent and characteristic vistas from the road across river, moors and fields to a backdrop of hills in which the varied and subtle hues of bracken, heather, birch, and other local vegetation are the most outstanding feature. It is this feature of the scenery that is distinctively Scottish and thus attractive in the eyes of foreign tourists, many of whom are already acquainted, in their own countries, with more spectacular hills and mountains, and more impressive forests than they see here.

Both North and South Deeside Roads give close-up views of the river itself over short occasional stretches. Perhaps the finest views are offered at the rare places where the road provides a vista up or down the strath, giving a view of great depth, with the river, fringed with tree and rock, sparkling through the middle. However, many of these views are being reduced in quality or being obscured. The main cause is the growth of trees, either by afforestation or through natural regeneration following the withdrawal of grazing or burning in some areas. Trees are having negative effects on the landscape here.

Often, fringes of regenerating birch add colour and interest to the view at all seasons. Over quite substantial hillsides, such as on parts of Morven, Culblean, and a long series of hills west therefrom, bordering on the north side of the North Deeside Road, mixed regeneration of trees is adding to the variety of textures and hues. Further, at points, the over-mature amenity plantings around old country houses such as at Durris House, Invercauld, and Mar Lodge contribute greatly to the scene, despite the relatively small numbers of trees involved. The impact derives partly from the mature status of the trees, partly from their parkland setting, and partly from the landscaping skills of the original planters. It is a matter of concern that these impressive but ageing larches and spruce, among other species, are in most instances not being replaced. There is surely a good case for a programme of selective replanting in such circumstances, to be carried out without delay.

On the negative side, large forestry plantations are covering extensive areas of hill. Large-scale planting of hill slopes with single species stands of conifers, however well managed, replaces the attractive and varied shading of the open hill with a more uniform and sombre green, as on the eastern approaches to Banchory and Aboyne and around Ballater. In places, plantations on both sides of the route reduce vision to a conifer-lined tunnel, as on the North Deeside Road west of Dinnet. An alternative, under-used, measure is fringing roads with native broadleaves. Among the Deeside estates, only Glen Tanar has done this to a reasonable degree.

Where the route rises to well above the river, giving an elevated view of the scene, it provides vistas in depth across or along the strath. Most of these have, unfortunately, been obscured by roadside plantations taken right up to the downhill side of the road margin, along quite extensive stretches, most notably before and after the Coilacriech Inn. The same has happened along the approach to the Pannanich Wells, till then noted for superb views of sunset over river and hills. No great restraint would be necessary in managing the woodland on the downhill side to retain such outstanding views.

Occasionally, mass regeneration of birch is obscuring views at certain points. In selected places, this may need to be restrained, such as below the road at Cambus O'May, where birch growth obscures fine views of the river, and at the old Invercauld bridge where it is hiding a famous view of the bridge from the road. Regrowth of shrubs and trees along the abandoned Deeside railway line is also producing similar effects due to the siting of the route between river and road.

Given the importance of tourism in the Grampian Region, and the popularity of driving as a recreational pastime, the economic and social value of all these scenes is very great. We cannot afford to allow the quality of our riverside scenery to decline for lack of thought and management. Table 3 provides some data on why visitors selected their main stop in Scotland. It is interesting to see how few were motivated to do so by 'marketing' channels and how many came on the strength of recommendations by friends or their own past experience of the area.

3 Camping, caravanning and picnicking

This group of activities is shared by participants in many forms of recreation, but it is particularly related to the car-borne tourist, and therefore conveniently

Table 3. Holiday-makers in Scotland — activities indulged in at least once during stay (% participants) (source: as Table 1)

Visit loch/ riverside	Drives/picnics in countryside	Visit sea coast	Long walks >3 km	Visit nature reserve	Fishing	Rowing/ sculling/ canoeing	Climbing
55	49	47	33	13	10	5	4

considered at this point. A noteworthy characteristic of the Dee is that there are extremely few points at which the public can gain access officially to the river bank. Only in the Duthie Park is any sizeable area open to the public for picnicking. That apart, a small area on the north bank west of Ballater is the only official access for anything except walking. At other points, such as at Aboyne, Park, Potarch and the Linn of Dee, access is 'informal'.

There is some sign that overt attempts by estates to restrict informal access have decreased in recent years, probably under pressure of numbers of people, and as a response to changes in public attitudes to access to the countryside. Nonetheless, in stretches below Aboyne, where the need for such access to serve the local car-borne visitor is greatest, the lack of this kind of facility is acute. One questions the wisdom, for example, of promoting the green at Potarch as a picnic area, for which it is now heavily used, without making any formal access agreement for the people who then frequent the river in numbers. For the caravanner and camper, there is a similar shortage of sites. The new site at Braemar may help matters, but in recent years the traditional 'informal' sites at Potarch, Coilacriech, and Linn of Dee have been closed, without a balancing development of new official sites. Only at Ballater is there a single, crowded, riverside camp site, and this is too close to the town. Mainly as a result of this shortage, 'wild' camping and caravanning have become common in some areas such as along the *Cluny*. There is obviously a need to provide more sites for these activities, both for touring holiday-makers and for more local visitors.

4 Swimming

Closely associated with outings to the river is the time-honoured pastime of 'river-dookin'. Traditional swimming pools are found at various points along the river, often at bridge points such as at Dinnet, Potarch, and the footbridge at Cambus O'May, although perhaps the finest of all is the Chest of Dee above the confluence of the Dee and the *Geldie*. Although it can hardly be classed as a mass participation sport, a surprisingly high proportion of the people who frequent the countryside have enduring memories of this pastime, and its significance should not be under-estimated. Whether swimming people significantly disturb fish for any length of time could be a matter for argument, but if they do the problem does not seem to surface as a conflict.

5 Walking

Nationally, the importance of walking in the countryside, as opposed to strenuous hill-walking, continues to be demonstrated as the most important form of outdoor recreation by the most recent results from Survey Research Associates (1981) (Tables 1 & 2). Locally, Walton (1969) showed its importance on Deeside (Table 4). Other indicators since then are sparse, but significant. The local branch of the Ramblers' Association, founded in 1983, has reached a membership of over 200, and is still growing. The North East Mountain Trust has gained the impression that there remains considerable unsatisfied demand for this form of recreation. The position for such people in the Aberdeen area is not satisfactory. The city is largely surrounded by enclosed farmland, and the nearby areas of open land such as the Kincardineshire moors and the Hill of Fare have been afforested en masse with little regard to the need of people for open space for such activities as walking. To the north, the south, and in Donside, the countryside is also enclosed farmland.

Table 4. Main recreational or leisure pursuits of visitors to a craft centre in Deeside (source: Walton 1969, Table 5, p 74)

% of visitors					
Walking	68	Climbing	7	Golfing	3
Sightseeing	51	Fishing	6	Picnics	3
Visit historic places	19	Lazing	5	Swimming	3
Studying wildlife	9	Geology	3	Reading	2
Photography	7	Shipping	3	Painting	2

(Sample size is not given in the original)

Deeside is the sole large area of opportunity for countryside walking. However, there are relatively few stretches of river bank with right of access for walkers, and these tend to be short. Within the city boundary, they occur in the Duthie Park and at Peterculter. Outwith the city, they are found on both banks above Banchory, along the old railway line west of the Cambus O'May footbridge, and on the north bank west of Ballater. The lack of riverside walks reflects a lack of known public footpaths generally in the strath. Such as there are tend to climb above the valley floor, and the vistas and views of the river from them can be very fine, as on Craigendarroch.

For the casual walker, in purely physical terms, much of the river is very accessible with easy anglers' paths along the banks. Except in a few areas, however, little use is made of these paths for riverside walking.

Casual visitors are probably deterred from using them as it is private land. Modest levels of walking should be compatible with fishing, and it is worth suggesting that consideration should be given to access agreements or other means of facilitating this use.

A potential for conflict exists between the interests of wildlife and an extension of riverside footpaths. Secluded areas of bank may be disturbed. There is no need for such walks always to stick to the bank. Discrete diversions, even quite extensive ones, around important bank areas can leave such sections undisturbed, and even add variety to the day's walk. The problem of disturbance by walkers' dogs is not so easily solved. Neither, for that matter, are the problems which the same animals create for other walkers by fouling footpaths and picnic areas. It may be that a 'Keep Dogs on the Lead' rule would have to be prominently displayed for certain walks.

Most people now agree that the local authorities should have tried to acquire the whole of the disused Deeside railway line. The assessment that parts of the line did not pass through scenery of outstanding quality on lower Deeside did not allow for the fact that, in areas such as Crathes, the route of the line was the only way on foot through the countryside, and that it occurred near a large urban centre. Perhaps we should not give up the idea that the existing bits of the line might be connected up with old fragments of road, and perhaps the occasional riverside walk, to give a Royal Deeside Way. It might prove an interesting route, with the great advantage of frequent, convenient services and accommodation centres at reasonable intervals.

Beyond the Linn of Dee, up to the river's source, it is hill-walking that is the dominant form of informal recreation, along with back-packing along the important hill passes that converge around the Chest of Dee area. Such conflicts as occur are related to other uses of the hill land, not of the river or its banks. Their resolution depends on the production of a much needed Cairngorms Management Plan, including management of the river.

6 Canoeing

People are attracted to canoeing by the sheer delight and excitement of moving about on running water and coping with its variety and challenge, and by the whole ambience of the river: the trees running down to the river's edge, the quietness, the cowslips in May, and the sunlight flickering through the branches of the trees. In both respects, the Aberdeenshire Dee has much to offer, and some of its canoeing enthusiasts have called it a 'magic' river.

For the canoeist, the Dee is a world of its own. Its course runs mainly away from the road, and there are few houses along its banks. The banks often rise higher than the canoeist's eye level, restricting the paddler's view of things beyond. This tendency is encouraged by the Dee's often steep-sloping banks, and the very extensive wooded fringes. Few human artefacts can be seen from the river and there is little traffic noise, with such as there is being drowned by the noise of the water or filtered out by the trees. There is a sense of isolation and tranquillity, and much wildlife is seen. The river is now the only way of travelling along the strath for any distance except on tarmac roads. Between the wooded banks of the Dee lies the last lengthy woodland journey one can make in these islands.

Canoeing is becoming more popular in Grampian. There are approximately 10 canoeing groups or clubs in the Region. Some of them are still small, but 5 have been formed within the last year or so, and the Aberdeen Kayak Club has more than doubled its membership in the last year, from about 35 to nearly 80. This is partly due to the publicity that the sport has received on television.

The Dee also offers an excellent range of white waters. On its lowest stretches, where it is tidal, are quiet waters suited to the beginner. This stretch also harbours a recently formed group of racing paddlers. There are no real conflicts along this stretch. From Banchory down, there is a stretch of water of intermediate difficulty, but the stretch from Potarch to Banchory is one of the finest stretches of white water in Britain. Above Potarch, the river is canoeable only in spate.

Several types of activity are found. There are competitions at manoeuvering on white water, slaloms centred at one spot, 'white water races' taking place over long distances, and perhaps as part of a triathlon, and there is river touring. There is also some simple 'mucking about in boats' in pools such as at Dinnet or Aboyne. There is some conflict between canoeists and fishing interests, with at least 4 possible kinds of disturbance that might be caused by canoeists. People sometimes confuse them, but they are as follows.

i. Disturbance of fish, ie the fish themselves are in some way significantly injured, or their growth or reproduction is harmed.
ii. Disturbance of fishing, ie the business of catching fish is in some way hindered.
iii. Disturbance of fishers. This is a different phenomenon, in which all that is disturbed is the sense of seclusion or peace on the part of the fisher.
iv. Disturbance of riparian owners. These people may not even be there at the time the canoeists pass, but may feel some anxiety at the activity.

To the best of my knowledge, nobody has ever suggested that canoeing on a river like the Dee significantly disturbed fish for any length of time. The question of disturbance of fishing seems equally problematical. Canoeists report that they almost invariably have cordial relations with fishers on the Dee, and that the difficulties usually arise with the anxieties of the riparian owners. Some disturbance of wildlife on the river may be caused by canoeing, but probably this has little long-term effect, because canoeists land infrequently, and then mainly on open grassy sections of bank.

Conflicts stem basically from touring, as slaloms and races are arranged in co-operation with the riparian owners, with whom the main organizers go to considerable lengths to preserve good relations. Conflict with touring canoeists is minimal because most canoeists touring on the Dee are local people, who canoe mainly on Sundays when there is no fishing, or they canoe outside the fishing season. Because fishing on the Dee finishes in late September, the marvellous month of October is free for canoeing. Above Potarch, canoeing largely takes place in spate conditions under which fishing is temporarily suspended. Also, canoeing use of the Dee is still at a low level compared with other rivers.

Thus, it may well be that, although the number of canoeists has increased and is increasing, conflict will not become a serious problem, especially if canoeists continue to operate the courtesy code of waiting upstream till the fishers signal them to pass, and then passing quickly and quietly on the far side of the river. It has been suggested that a formal access agreement could be arranged, but the Scottish Canoe Association would never recognize any agreement between local parties as binding on its membership nationally, and nobody can make an access agreement for the many touring canoeists unattached to any club or formal group. No foreseeable agreement could guarantee uninterrupted fishing.

7 Natural history study and wildlife

The millionth visitor to see the ospreys at Boat of Garten was clear proof, if any were needed, of the extremely widespread interest that the public has in wildlife. Visits to nature reserves figure large in countryside activities (Tables 1 & 2). However, it has always seemed to me to be a mistake to think that wildlife has to be spectacular to hold the public's interest. Quite ordinary animals, such as red squirrels, are fascinating to people if a clear view of them is obtainable, and the wildlife does not have to be continually in view. The memory of short encounters with wild mammals and birds is often enduring. It is remarkable how a brief sight of an eagle soaring or the discovery of a rich bank of primroses in flower is a high point in the day for many walkers or car-borne tourists. The river banks, because of their variety of habitats, and strips of ungrazed, unfertilized floras and frequent scrub, are rich in such memorable encounters.

Deeside, while it is rich in such resources, is very poor in visitor centres where wildlife can be viewed, or where general countryside interpretation is offered. Crathes Castle is one of the few places catering for visitors. The visitor centre at Loch Muick allows deer to be viewed at a distance, but is badly in need of enhancement of its facilities, and is far off the main tourist routes. There is not a single place where the wildlife of the river can be viewed and where its significance is being interpreted to the general public.

8 The use of the river area by children

There is one last group of informal recreationists for whom I would enter a plea. They seldom get mentioned in surveys or recreational statistics, yet they are very numerous. I refer to children and young adolescents at play. Having spent much of my spare time over 20 years in youth leadership, I have always been perplexed at why we are very bad as a society at catering for youth, and so under-value those early adventurous experiences of children. It seems to me that we fail to cater for their informal activities, or more simply in just leaving them room to get on with climbing trees, making hideouts in the woods, illicitly fishing in the river, and so on. These experiences are important for the growth of their imaginations, their sense of adventure, and their love of countryside.

One of the most important parts of the whole river bank is on the north bank, just above the old Bridge of Dee, in Aberdeen. It is a forgotten corner, but here the children from Garthdee and Kincorth come, escaping from the carefully laundered grass spreads of the housing estates, and their boring adventure playgrounds. The children have no right to be there, of course. The landowners have put up fences in the far past. It's illegal what the children do. They are not supposed to dangle worms in the water, or go whooping through the woods disturbing the birds and breaking the bushes. All up and down the river there are similar corners sheltering small populations of this endangered species, the joyful child. I live in fear as the developers fill in the last bit of 'waste ground', as we finish planning and planting, and conserving our wildlife, that these places will have been decently tidied out of the way, and with them the children. Whatever else this symposium decides to recommend, leave room for them.

9 General points on management and recreation

As the question of management always arises where public access is considered, it is worth making a few general points. First, where 'mass access' is planned to an area, eg a new picnic or camping site, then it must be axiomatic that the staff and money to maintain the area must also be provided.

The second general point is about the introduction of rules such as bye-laws to regulate informal outdoor recreation. Spontaneity and freedom are valued characteristics of such recreation. Indeed, they are somewhere near the heart of the matter to many participants, who are strongly antipathetic to restrictions. Further, such restrictions, if introduced, are often costly and difficult to enforce. In the end, they depend on the voluntary co-operation of participants based on an understanding of the real need for rules, rather than on simple obedience. It is often better, in fact, to use more positive and perhaps more subtle management methods to achieve ends, such as leading a path off in an interesting diversion, rather than forbidding access to a sensitive area.

Restrictions should be kept to a minimum, and only introduced when it has been clearly demonstrated that a real conflict exists, and other methods have failed or are very likely to do so. Introduced without public education as to the need for them, they may fail for lack of support or even be counter-productive. Unnecessary rules, or ill-conceived ones can, in fact, become a source of conflict where no real problem existed before. The bye-laws introduced to the Muir of Dinnet National Nature Reserve seem a good example of unnecessary proliferation of such restrictions, creating a potential for conflict.

Is there, in the light of this, a need for a 'river code' on the Dee at present? I would suggest not. Conflicts between canoeists and riparian owners are handled by co-operation between canoeing event organizers and these owners, and by the canoeists' own code of conduct when touring. For other forms of recreation, the normal 'country code' seems able to handle such problems as might arise.

10 Summary

Informal recreation cannot be distinguished clearly from formal recreation, but includes car-borne touring, walking, canoeing, camping and caravanning, nature study, photography, swimming, picnicking, and children at play. For most people, it is the broad sweep of scenery that is important, with the river acting as a major unifying theme in the landscape.

Extensive afforestation is replacing the varied hues of the open hill with a more uniform green, and roadside tree planting, regeneration and afforestation are blocking economically and socially important views.

For camping, caravanning, and picnicking, the Dee is characterized by the extremely limited public access to its banks, especially above Ballater. Very little of the river bank is officially open to walkers. Most people are uncertain where they may walk. In some areas, deer fences and plantations reduce access.

For canoeists, the attractions of a river lie in the variety and extent of white water, and the quality of the whole ambience of the river. For both of these, the Aberdeenshire Dee is outstanding. Some conflict exists, but the pastime remains almost entirely locally based, and the problem should not become serious.

From the point of view of all groups, except perhaps the canoeists, the Dee is a much under-used, high-quality, resource. However, the level of participation in most activities in the north-east is increasing, perhaps sharply. It is suggested that there may be considerable underlying unsatisfied local demand for walking, picnicking, and some other pursuits.

Given this situation, and the increasing level of public awareness of such issues as access to the countryside, and interest in wildlife, it is likely that pressure for picnic sites, river bank walks, and such facilities will increase. Nonetheless, rules and regulations to control informal recreation should be kept to a minimum. Ensuring the wisest use for the interests of everyone requires the informed co-operation of participants rather than their obedience to rules. At present, there appears to be no proven need for restrictions in the use of the river.

11 References

Survey Research Associates. 1981. *Market survey of holiday-making and countryside recreation in Scotland.* Scottish Tourist Board and Countryside Commission for Scotland. (Published privately.)

Walton, K. 1969. *Royal Grampian country.* Aberdeen: Department of Geography, University of Aberdeen.

Salmon catch statistics for the River Dee, 1952-83

W M SHEARER
Department of Agriculture and Fisheries for Scotland, Montrose

1 Introduction

This paper examines the reported catches by each of the 2 legal methods of fishing for salmon within the estuarial limits of the Dee (rod and line, and net and coble) in 1952-83. In Scotland, salmon are harvested by bag and stake nets along the coast, and by net and coble (seine nets) and rod and line in estuaries and in freshwater (Strange 1981).

2 History

Fishing seasons and the number of netting stations have both changed. In 1852, the season lasted from 1 December to 20 September, and from 1902 from 11 February to 26 August (nets) or 31 October (rods) (Grimble 1902). Up to 1872, netting extended to Banchory. However, as netting in the river declined (Oswald 1985), coastal fisheries increased. In the Dee district, extending 29 km south along the coast, there were 102 bag and stake nets in 1882 and nearly 200 in 1894 (Grimble 1902). A decline began in the late 1950s and has continued.

Published catch records, particularly after the mid-1850s and before 1952, are fragmentary. The growing secrecy of net fishing proprietors and lessees stemmed from a hostility between netsmen and the riparian owners. The monetary value of leased fishings, which periodically came up for renewal, imposed further constraints on the free exchange of information. Because of the many changes in the fisheries, including changes in the start and end of fishing seasons and the inclusion of kelts in earlier catch totals, the early data can seldom be compared with more recent information. Nevertheless, the available historical records indicate that periods of low catches are characteristic of the Scottish salmon fishery. Low catches appear to have been associated with changes in the timing of the runs. Following the decline of grilse (fish which have spent one winter in the sea) catches in the late 1880s, the fishery remained depressed until the 1920s when the number of salmon (multi sea-winter fish) caught in the spring began to increase. The Fishery Board for Scotland Report for 1921 stated that 'the season of 1921 showed a remarkable recovery from the depressed condition which had been reported for some years'. Six years later, the Inspector of Salmon Fisheries was able to report that 'in 1927 the salmon fisheries of Scotland were even more successful than in 1926. The catch sent to the market amounted to 2910 tons (gross), a figure which has not been reached since 1896'. As described, the situation experienced by the salmon fishermen (rod and net) of that time appears to be rather similar to the present position.

3 Material

3.1 Traditional fisheries

Before 1952, there was no statutory obligation to make data on catch and effort on salmon catches available to the Department of Agriculture and Fisheries for Scotland (DAFS). However, since then, this information has been provided annually, in confidence, to the Department as a statutory requirement under the Salmon and Freshwater Fisheries (Protection) (Scotland) Act 1951. Catches, divided between salmon, grilse and sea trout, are recorded monthly by number, by weight and by method of capture (fixed-engine, net and coble, and rod and line). In addition, net fisheries are required to supply the minimum and maximum number of netting crews fishing each month, and fixed-engine (ie fixed nets, mainly in the sea) fisheries the minimum and maximum number of traps operated. No effort data are requested from rod fisheries. As a supplement to these data, the annual catches of salmon and grilse taken during the period 1872-1984 in the net and coble fishery operated by Aberdeen Harbour Board were readily made available.

The catch figures examined are those supplied, in confidence, to DAFS by the proprietors and lessees of fishings within the estuarial limits of the Dee. Catches taken outwith the river but still within the area of the Dee District Salmon Fishery Board have been excluded from the analysis mainly because they could contain a substantial proportion of fish not native to the Dee. To maintain confidentiality, it has not been possible, except in one instance, to quote actual catch figures. The Aberdeen Harbour Board, who supplied the catch data from its net and coble fishery dating back to 1872, has given permission to use this information without restriction. Otherwise, all catches have had to be expressed as percentages, which is unfortunate because it obscures the relative magnitude of the catches taken by the different gears. Fishing effort has been omitted from the analysis mainly because it is not available for the rod fishery, and the units which have been used to collect netting effort have been found to be insensitive to observed changes in the fishing intensity.

3.2 Interception fisheries

Since the early 1960s, a number of high-sea fisheries have caught fish of Dee origin, among others. Salmon catches in excess of 100 tonnes (t) were first recorded at west Greenland in 1961, and over 2600 t were reported caught in 1971. Recently, agreed quotas for this fishery were increased from 1190 t (1976) to 1270 t (1981), primarily to take account of the decrease in the number of fish caught per tonne as a result of the later opening date. Subsequently, the quota was decreased to 870 t (1984) in order to afford some protection to multi sea-winter salmon stocks. Fishing normally takes place between August and October. For comparison, 1010 t were caught by all methods in Scotland in 1976. However, the agreed quota for Greenland has not been caught in the last 4 years, and in 1983 the shortfall amounted to some 980 t. Apart from fish of Greenland origin, no fish which would have returned to 'home waters' as grilse are taken in this fishery, and the average stock composition is of 40% North American and 60% European origin, as determined by scale discriminant analysis. Presently, it is not possible to break down the European component into countries of origin.

Since 1968, a long-line fishery has developed about 112 km north of the Faroes, with catches up to 40 t in 1977. From 1977-82, Danish vessels took part in this fishery. Total landings rose to about 1000 t in 1981, partly because the season was lengthened in 1979 to run from October to June, and because the number of boats increased from 9 in 1977 to 44 in 1981. In addition, the fishery moved further north (up to 576 km) in 1977-83, and at this time the average weight of the fish increased. Until the late 1970s, most fish caught in this fishery were grilse. The recent extension in fishing areas resulted in the exploitation of salmon with a higher average sea age. In March 1981, and in 1982/83 and 1983/84, about 99% of the catch landed was of 2 or more sea-winter fish and only about 1% was one sea-winter fish. In addition, about 5% of the catch was discarded and consisted predominantly of one sea-winter fish. In 1982, the Faroese government agreed to a total catch limit of 750 t and to 625 t (25 boats allowed a quota of 25 t each) in 1983 and 1984. All boats participating do so under licence, and from 1983 the fishery was confined within the Faroese 320 km limit under the terms of the Convention for the Conservation of Salmon in the North Atlantic Ocean. At present, it is not possible to apportion the catch to countries of origin.

Two other fisheries are also known, from the capture of adults tagged as smolts, to exploit salmon of Scottish, including Dee, origin. These are drift net fisheries off Ireland and in the North Sea off Northumberland and Yorkshire. Both these fisheries tend to catch a preponderance of grilse. In 1982, these 2 fisheries caught about 710 and 177 t respectively. Although the rivers of origin of these fish are not precisely known, present data suggest that those situated between the Ugie and the Tweed make the biggest contribution to the fishery located off the Northumberland and Yorkshire coasts. In 1961 and 1962, a legal drift net fishery operated off the Scottish coast, but this was banned following the introduction of legislation in 1962. However, an illegal fishery using similar techniques continues to operate off the Scottish coast, in spite of a considerable enforcement effort.

3.3 Fishing season

Fishing seasons on the Dee now extend from 11 February to 26 August for netting (usually stopping earlier) and for angling between 1 February and 30 September. In addition to the Annual Close Time, there is a Weekly Close Time for nets from noon Saturday to 0600 h on Monday and for rods on Sunday.

Since 1983, DAFS staff have sampled the Dee net and coble catch weekly to obtain information on the weight, length, and the river and sea ages of the fish being exploited.

3.4 Biases in data

3.4.1 Relationship between catch and stock

Salmon runs do not necessarily conform to fishing season. In 1981, 1982 and 1983 (the years for which data are available), approximately 40% of the North Esk spawning stock moved upstream over the Logie fish counter (3 km upstream from the sea) after the end of the net fishing season. Fish which enter rivers outwith the fishing season do not contribute to catches taken in rivers. Thus, changes in the timing of the runs could bias estimates of annual stock abundance based solely on catch data in the fishing season. Futhermore, it is unlikely that the amount of fishing effort or the rate at which the stock is exploited or the catchability of fish remains constant throughout a fishing season or from one season to another.

Biological differences between catch and stock can also exist, for a number of reasons, including gear selectivity and differences in the level at which the various components of the stock are harvested. Also, a relationship is known to exist between river and sea age and the calendar date when fish belonging to particular river and sea age groups return to fresh water (Shearer 1984). The age composition of the catch will be biased towards those age groups which return in greatest proportion during the fishing season.

The rod catch could be particularly sensitive to physical changes in the river system, such as the gravelling of pools and changes in discharge rates and temperature. Furthermore, any change in the sea age composition of stock could be important because it would alter the timing of the runs and, therefore, the availability of catchable fish.

In addition, losses attributable to non-catch fishing mortality include the non-reporting of catches by some owners and lessees of fishings and the number of fish caught annually by illegal methods. These figures are not included in the official returns and no reliable estimate is available.

3.4.2 Limitations of the data

i. Annual fluctuation in fish numbers

All the data discussed refer to reported catch figures. Fluctuations occur in annual catches for a number of reasons. A bad year in a single river or fishery must not be assumed to be evidence of a general deterioration of the stocks of salmon, although it is reasonable to assume that increased catches are usually related to an increase in the total number of salmon available for exploitation during the fishing season. The spawning escapement, ie the proportion of returning salmon that is not taken by nets or rods, cannot be estimated directly from numbers of fish caught, because a large number could migrate after the end of the fishing season, having made no contribution to catches, and exploitation rates could vary.

ii. 'Grilse error'

In the catch returns submitted to DAFS, lessees and owners of salmon fisheries, with few exceptions, have separated their catches into salmon and grilse on the basis of weight. Fish weighing less than 3.6 kg have been classed as grilse and the rest as salmon when both sea age groups were present. In 1952-83, the proportions of fish classed as grilse by this method in the annual catches have varied as a result of changes in the growth rate of grilse in the sea. Furthermore, since grilse generally increase in weight as the season advances, the magnitude of this reporting error does not remain constant throughout the fishing season. In August, 'salmon' catches will contain relatively more over-weight grilse than in June or July. In general, those years when grilse were most abundant were also characterized by above average proportions of over-sized grilse.

4 Analyses of available data

Salmon catches can conveniently be broken down into 3 major components. These are (i) grilse, (ii) spring fish (multi sea-winter fish caught up to and including 30 April), and (iii) summer fish (multi sea-winter fish caught after 30 April). Typically, grilse and summer salmon come into rivers from May to December and spring fish from November to April. Some fish running into freshwater in November 1984 can remain in the river and not spawn until October 1985. If these fish move upstream of the netting zone before 11 February, they will not be available to the nets but they will be available to angling for all of the fishing season, although not necessarily catchable.

Total catches for the Dee of salmon plus grilse, salmon, and grilse caught by the 2 methods of fishing are expressed as percentages of the 1952-83 means in Figure 1. Figure 2 shows these data broken down into their angling and netting components. Figure 3 shows total numbers caught for all Scotland, and Figure 4 illustrates the total, rod and line, and net and coble spring catches as percentages of the respective combined catches. Figure 5 gives the catch data for the net and coble fishery operated in the estuary of the Dee by the Aberdeen Harbour Board from 1872 to 1984 expressed as 5-year means, and Figure 6 shows the proportions of grilse in these catches. Figures 7-9 compare data from the Dee with those from other nearby rivers.

The river and sea age composition and the average weight of the various sea age groups of fish caught in 1983 by the nets are compared with similar data relating to the 1920s (Menzies 1922; Menzies & Macfarlane 1924, 1926, 1927, 1932).

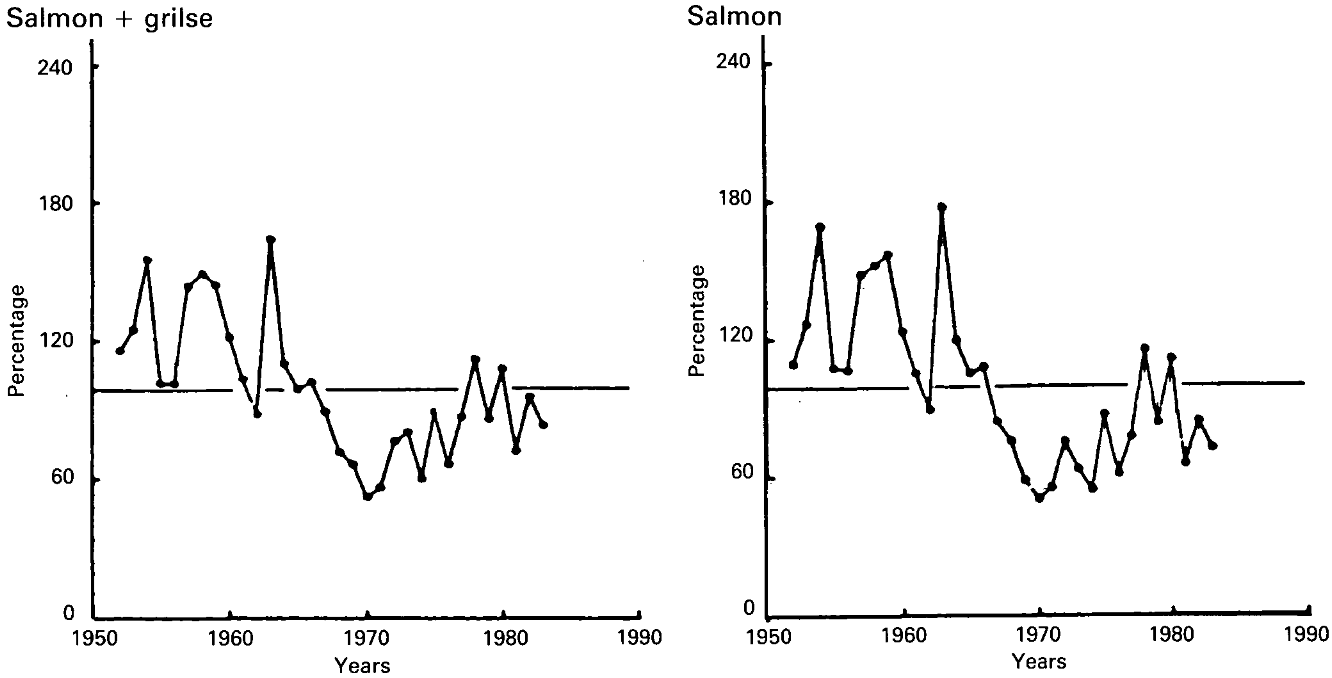
5 Results

5.1 Catch data

The total catches of salmon, grilse (uncorrected for grilse error) and salmon plus grilse fluctuated widely between years (Figure 1). Because grilse catches throughout the period 1952-83 were relatively small in relation to total catches, their influence when added to the salmon catch was negligible. Salmon and grilse catches combined, and salmon catches alone fell into 2 distinct groups, 1952-66 and 1967-83. There was a big decrease between these 2 periods, and the groups were significantly different from each other at the 0.1% level. Whereas most annual catches prior to 1966 were above the long-term mean, all catches but 2 after 1966 were below it. There was no obvious trend in 1952-66, but, following the big decrease, an upward trend was apparent in 1967-83. Grilse catches fluctuated widely but showed an upward trend latterly. The smallest and largest catches of grilse were in 1964 and 1973 respectively, and the second largest in 1982.

Catches of salmon plus grilse and salmon taken by the 2 methods of fishing fell into the same 2 groups but, whereas the decrease in net catches began about 1963, it was delayed until 1966 in the case of rod catches (Figure 2). Subsequently, the rod catches fluctuated around the new lower level, but the net catches tended to show a slight increase. Nonetheless, most annual catches in the second period remained below the long-term mean. The difference between the results from the 2 catching methods occurred because relatively few (5-21% of the total) grilse were caught by rod compared with by net, especially since the mid-1960s. However, since the early 1960s, the increase in the average weight of grilse, and presumably also in the number of grilse of 3.6 kg and over, led to a large but variable overstatement of the number of salmon reported caught. These data need further analysis.

For the whole of Scotland, while the catches by the 2 netting methods varied together, the trend shown by the rod and line catches was rather different. Catches in the net fisheries increased in 1962 and this new catch level was maintained until about 1975. Since 1976, catches by both types of netting have declined and recent figures are among the lowest recorded since 1952. On the other hand, annual catches of salmon by rod and line have not decreased significantly in recent years (Figure 3). Catches of spring salmon taken by all methods showed a gradual but steady downward trend which began during the early 1960s. However, when the rod and line catches were examined separately, no trend was evident. Nevertheless, it is perhaps worth noting that, while spring



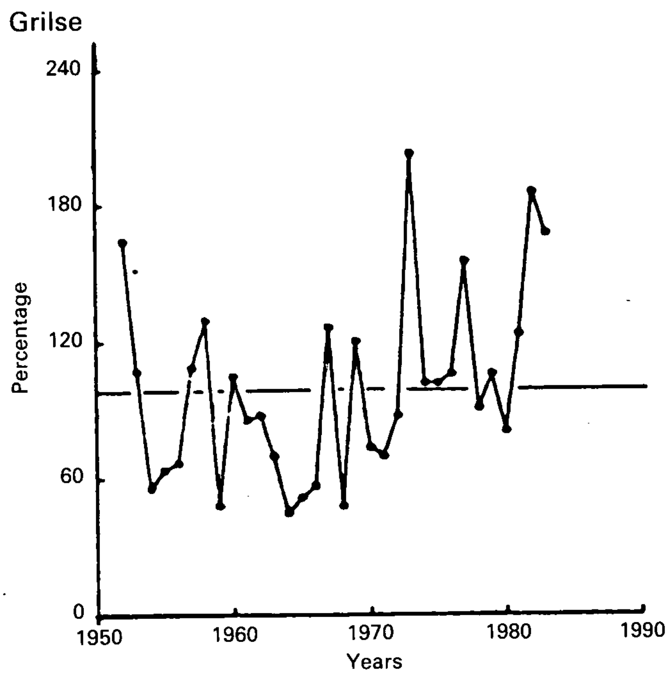


Figure 1. Total catches of salmon, salmon plus grilse, and grilse on the Dee, expressed as proportions of the means for 1952-83 (at 100%, the horizontal line is the long-term mean)

catches in the Dee in 1981, 1982 and 1983 were proportionally the smallest in the time series, the value for 1980 was the highest since 1963 (Figure 4). The proportion of the total salmon and grilse catch in the Dee taken by rods increased between 1952 and 1983 (40% in 1952, and 78% in 1971).

In 1872-1984, annual net and coble catches of salmon increased (Figure 5), mostly due to more salmon but with more grilse after 1955. However, there were big fluctuations and the mean catch of salmon in 5-year periods fell to its lowest level during the last 50 years in the period 1970-74; since then, it has steadily increased. On the other hand, catches of grilse remained remarkably stable until 1960-64, since when they too have shown a steady increase.

Expressed as percentages, the grilse proportion of the total salmon plus grilse catch varied widely (Figure 6). From 1875, a decline continued until the second half of the 1920s. Subsequently, the proportion of grilse in the net catches increased nearly to the same level as in the late 1800s. Because the catchability of grilse by rod appears to be considerably less than that of salmon, any factor which increased the ratio of grilse to salmon in a stock returning to spawn without changing its overall numerical strength will depress the rod catch without having a similar effect on net catches.

5.2 Biological data

In 1983, grilse comprised 49% of the total net catch but in 1921-82 they did not exceed 32% in any year. Nevertheless, grilse were relatively more abundant in May in the earlier period, contributing 8% to the total catch in that month compared with only 2% in 1983. The position was reversed later in the season and by August the corresponding values were 32% and 62%, suggesting that the peak of the grilse run into fresh water had shifted and was now nearer the end of the net fishing season than formerly.

Table 1 shows that, in months with comparable data, the proportions of grilse and 2 sea-winter salmon were similar in February-July in the 1920s and in 1983. However, in August 1983, grilse were dominant in the catch. The proportion of 3 sea-winter fish in the overall catch did not change, but there were small differences in the manner in which this age group was distributed throughout the season. Some fish which had spent 4

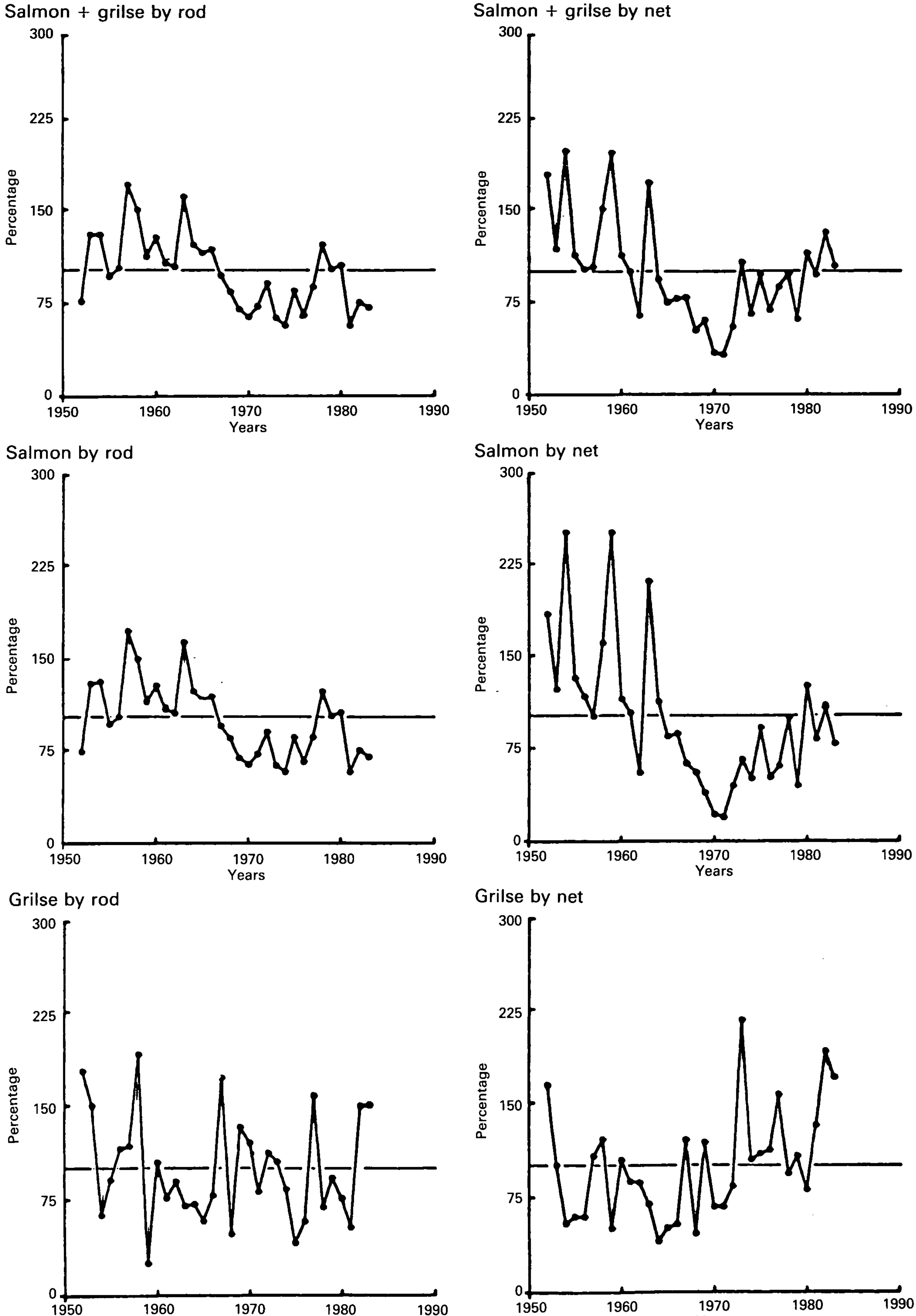


Figure 2. Total catches on the Dee according to method of capture, expressed as proportions of means for 1952-83

Table 1. Percentage of fish of different sea age caught in each month, February-August, in 1921-25 and in 1983 (sources (data for 1921-25): Menzies 1922; Menzies & Macfarlane 1924, 1926, 1927, 1932)

Percentage monthly sea age composition of net and coble catch

	Sea age (years)							
	1		2		3		4	
Month	1921-25	1983	1921-25	1983	1921-25	1983	1921-25	1983
February	—	—	90.0	—	9.9	—	0.1	—
March	—	—	89.3	82.3	10.5	17.7	0.2	—
April	0.2	—	92.4	70.6	7.4	29.4	0.1	—
May	8.1	1.9	86.4	89.4	5.5	8.7	0.1	—
June	79.3	75.6	19.4	22.8	1.3	1.6	<0.1	—
July	83.3	85.5	15.4	14.1	1.2	0.4	<0.1	—
August	31.8	61.9	59.7	38.1	8.5	—	—	—

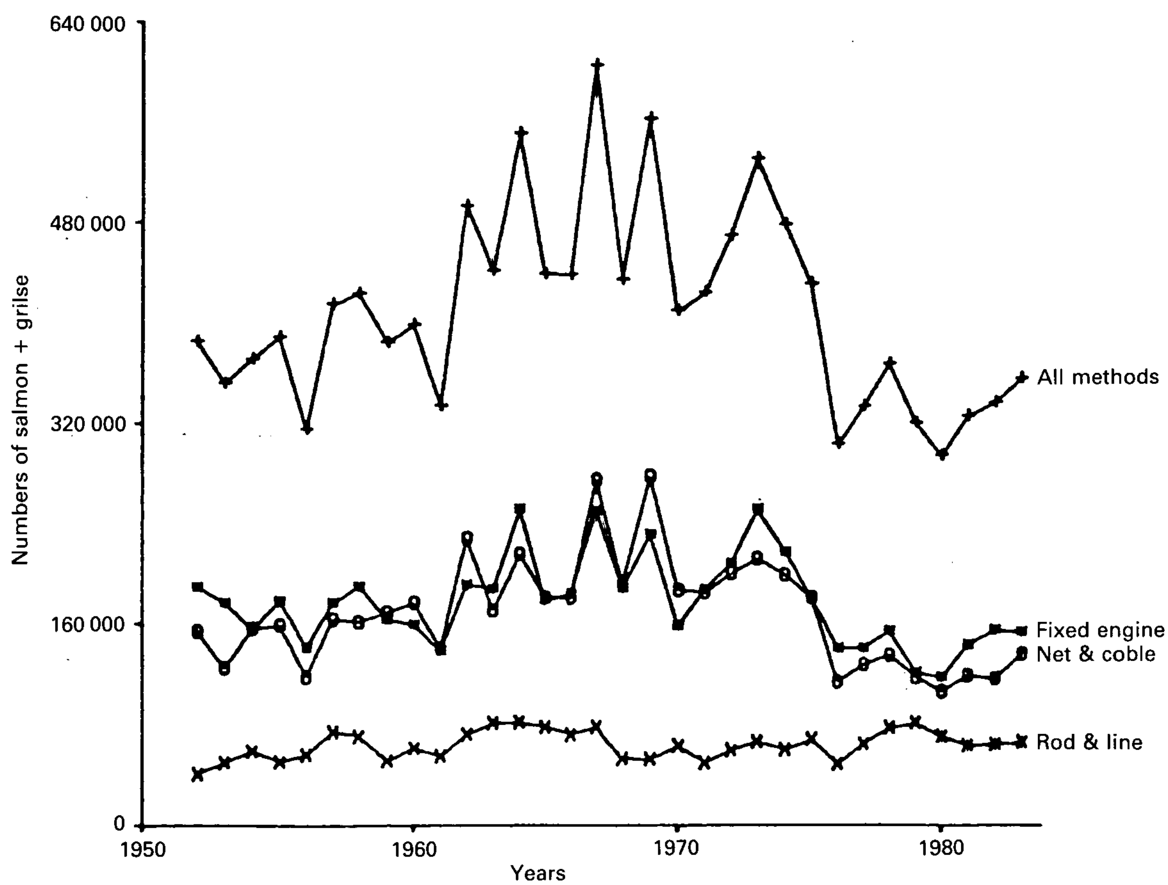


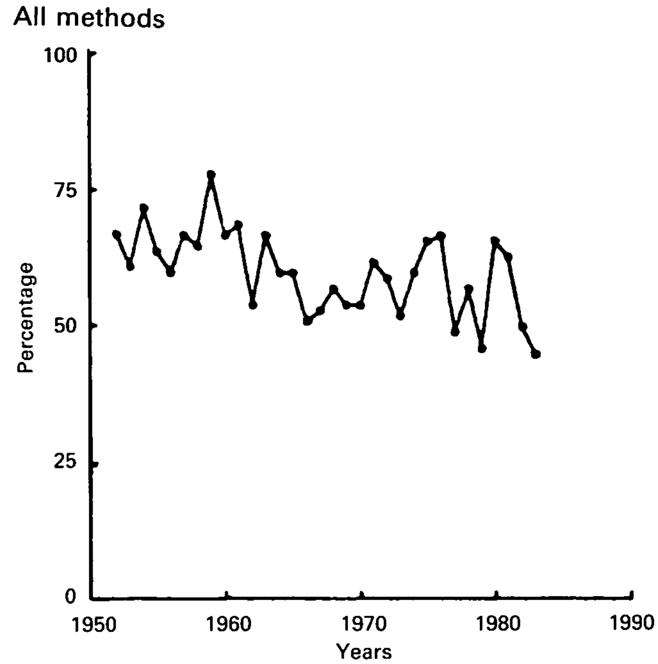
Figure 3. Total catches of salmon plus grilse in Scotland in 1952-83

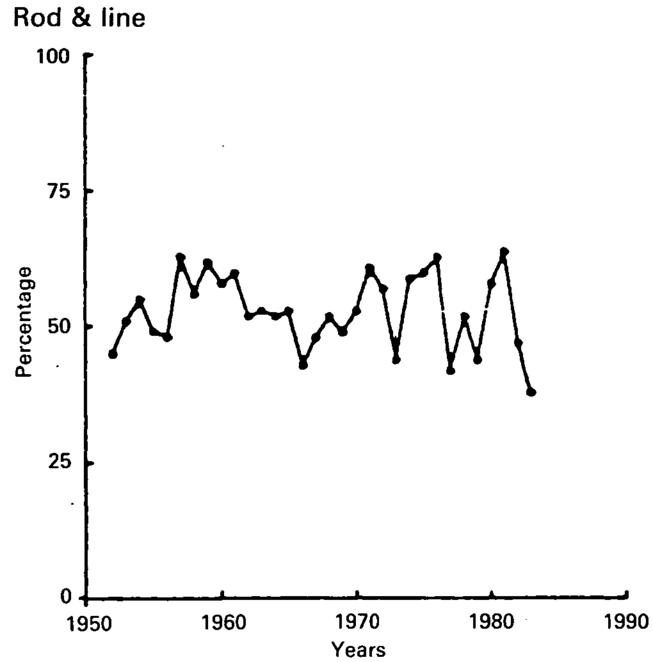
winters in the sea were present in the catches taken in the 1920s (<1% of the total catch) but not in 1983.

Two-year-old smolts formed the most numerous single age group in the catches in the 1920s and 1983. However, approximately 78% of the catch in the 1920s had migrated to sea after spending 2 years in freshwater, compared with 56% in 1983. The increase in the average smolt age was not limited to one particular sea age group, but it was most marked in the 2 sea-winter age group (Table 2).

Table 2. Smolt age (%) of fish caught in the Dee by net and coble (sources (data for 1921-25): Menzies 1922; Menzies & Macfarlane 1924, 1926, 1927, 1932)

River age (years)	1921-25	1983
1	0.8	2.2
2	78.4	56.0
3	20.4	36.4
4	0.4	5.4





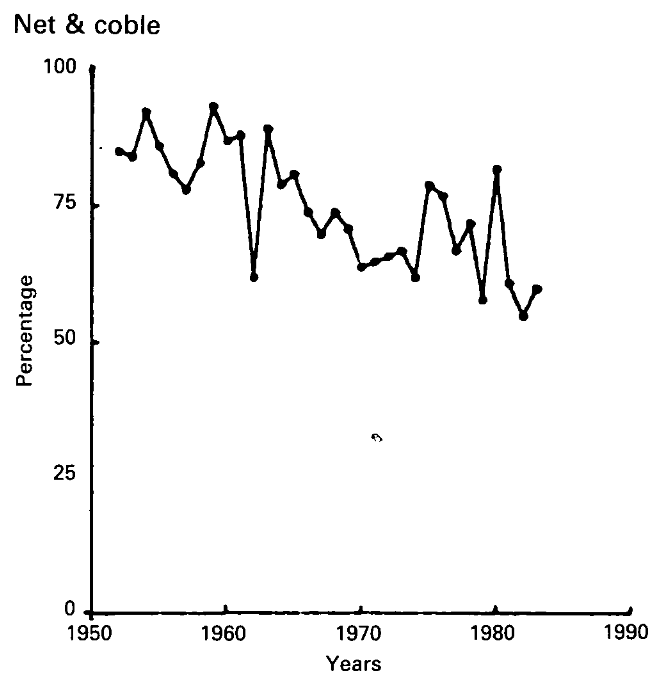
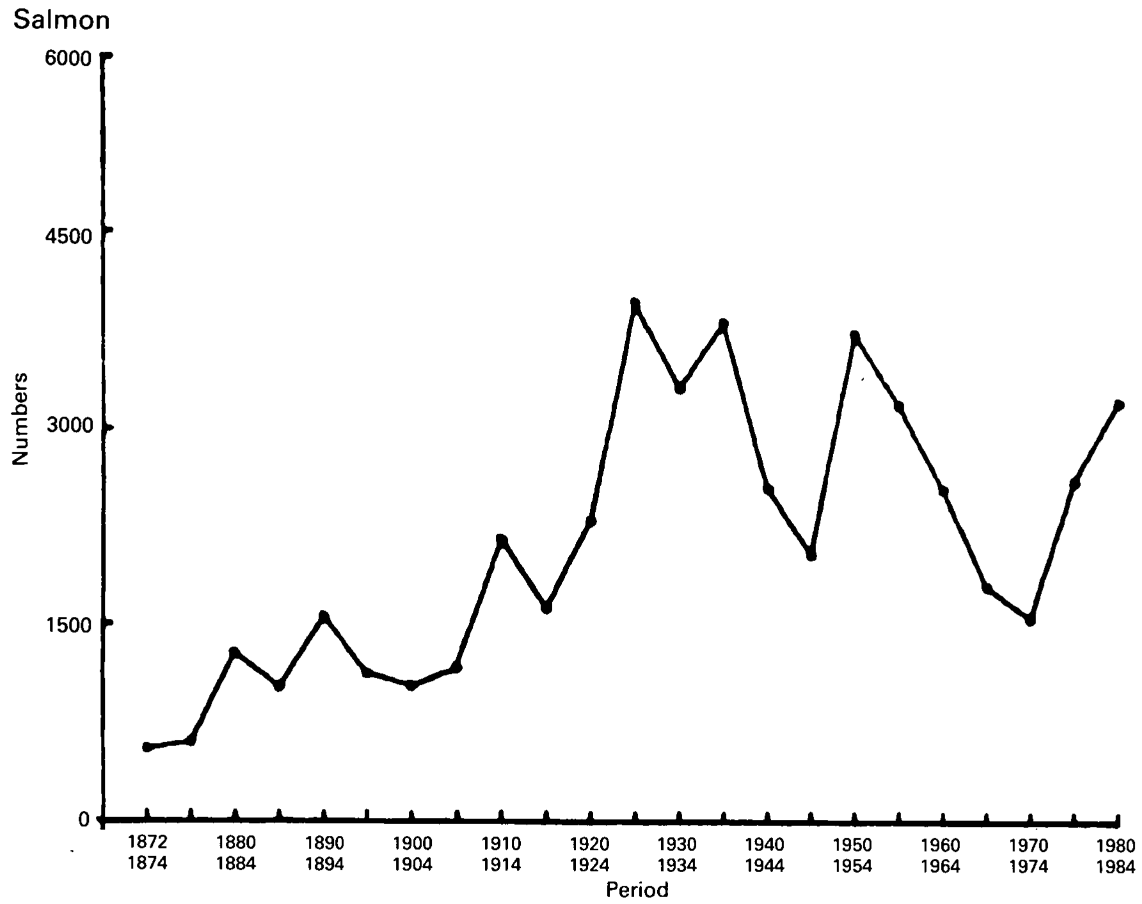


Figure 4. *Catches of spring salmon on the Dee, expressed as proportions of the mean for 1952-83*

The other biological parameter examined was average weight (Table 3). Grilse caught each month in May-August 1983 were on average heavier than comparable fish taken in the 1920s. Over the season, the difference between the 2 mean values was 0.4 kg or approximately 20%. Although there was no difference between the annual average weight of the 2 sea-winter fish caught in the 1920s and 1983, those caught in 5 of the 6 months for which comparable data were available were lighter on average in 1983 than in the 1920s. If data had been available for February 1983, it is a reasonable assumption that the overall figure for that month would also have been less. The differences observed were greater in July and August than in March and April. Three sea-winter fish caught in 1983 were on average lighter both at the monthly and annual levels, compared with the same age group caught in the 1920s. In most months, these differences amounted to more than 1 kg.

Table 3. Average weight (kg) of fish caught in the Dee by net and coble (sources (data for 1921-25): Menzies 1922; Menzies & Macfarlane 1924, 1926, 1927, 1932)

	Sea age (years)							
	1		2		3		4	
Month	1921-25	1983	1921-25	1983	1921-25	1983	1921-25	1983
February	—	—	3.6	—	7.8	—	14.2	—
March	—	—	3.8	3.9	8.4	7.7	15.3	—
April	1.1	—	4.2	4.1	9.3	8.0	14.2	—
May	1.4	2.7	4.4	4.2	9.8	8.2	17.2	—
June	1.7	1.9	5.2	4.9	9.7	9.8	11.8	—
July	2.0	2.4	6.8	5.5	11.8	7.8	18.1	—
August	2.6	2.9	8.3	6.1	11.1	—	—	—
Overall	1.9	2.3	4.3	4.3	8.8	7.9	14.9	—



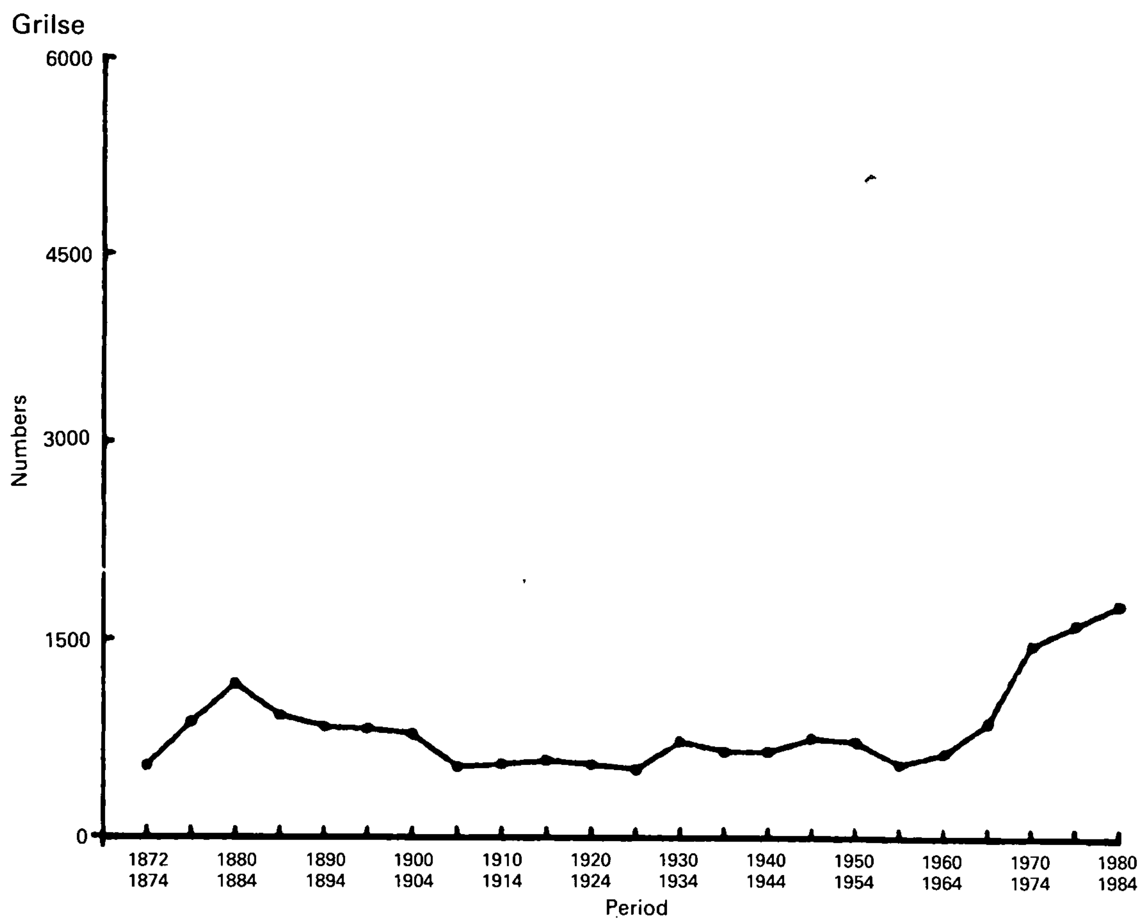


Figure 5. Catches of salmon and grilse by net and coble on the Dee in 1872-1984, expressed as 5-year means

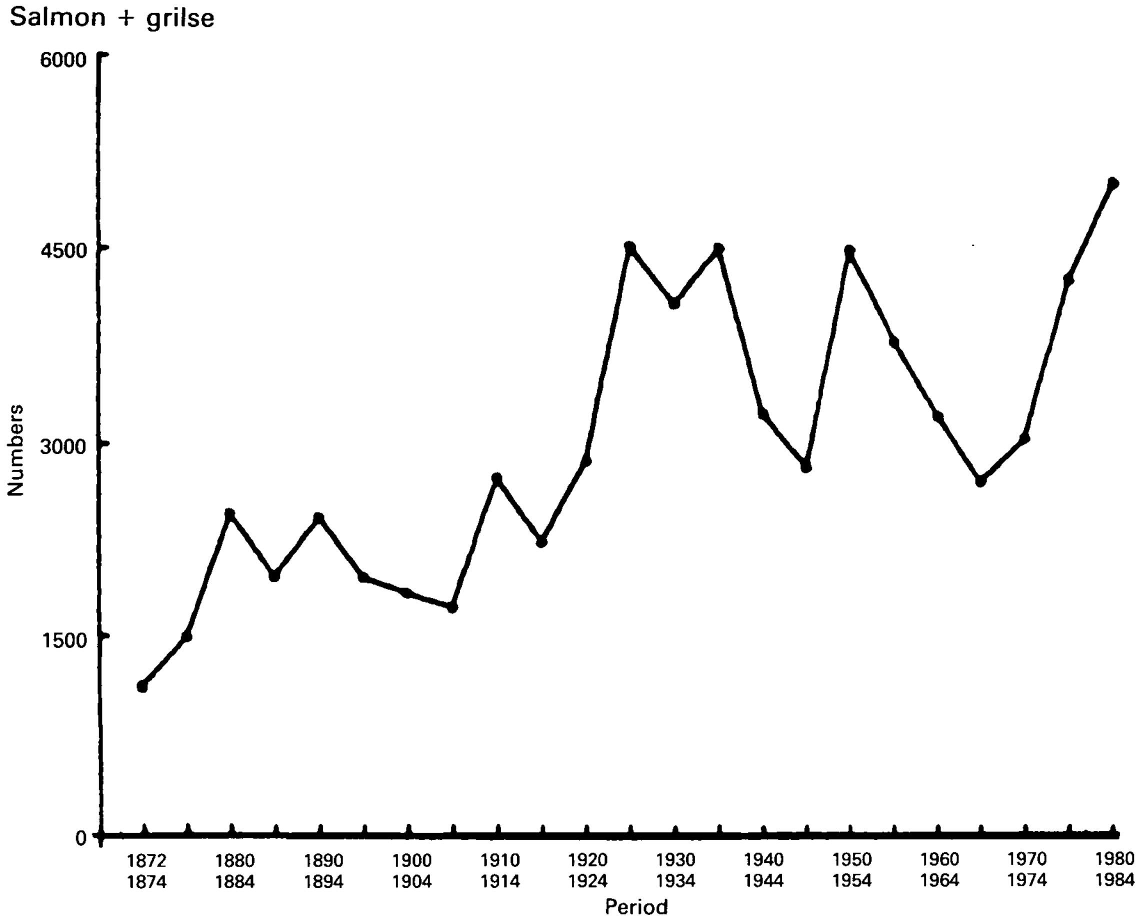


Figure 5 (continued). Catches of salmon and grilse by net and coble on the Dee in 1872-1984, expressed as 5-year means

5.3 River characteristics

Not every river and tributary contains spring salmon, summer salmon and grilse. In those that do, the proportions can vary both between rivers and between years. Although all 3 groups are found in the Dee, the fishery is mainly in the spring. Figures 7, 8 and 9 compare data from the Dee with those from neighbouring rivers which support both net and coble and rod and line fisheries. The data show that catches in all rivers have fluctuated, without following the same pattern between years. For example, catches in the Tay fisheries in the 1960s and 1970s reached a peak at a time when other rivers yielded low catches. The relative importance of the contribution of one sea-winter fish (grilse) to total catches has varied both between rivers and between years. Grilse have been important in the Findhorn fishery and relatively unimportant in the Dee fishery.

6 Discussion

6.1 Main features of these data

The main features of these data are the following.

i. There was a decrease in reported catches in the Dee in the 1960s which has not been made up.

ii. This decrease was shown by both net and rod fisheries.

iii. However, in the case of data for Scotland as a whole, the main decrease occurred in the early 1970s, and was mainly confined to the net fishery. There has been little change overall in the numbers caught by rods.

iv. Catches of salmon, but not of grilse, taken in the net and coble fishery operated by the Aberdeen Harbour Board have shown an increase over the last 100 years, despite large annual fluctuations. Grilse catches only show an increase from the 1950s.

v. The proportion of grilse caught by the net and coble fishery operated by the Aberdeen Harbour Board has fluctuated, with peaks in the 1870s and the 1970s and a big trough in the 1920-30s.

vi. Decreases in catches by all methods have occurred in 4 out of 5 east coast rivers, but not in the fifth, where there was an increase around 1970 in contrast to the others.

vii. The proportion of grilse caught by all methods has fluctuated in all rivers but is increasing in the Dee, a trend sustained since the 1950s.

viii. However, grilse are relatively unimportant in the Dee catches and the main feature characterizing the Dee fishery is a decline over the last 20 years in the spring catch of multi sea-winter salmon taken by the net and coble fishery.

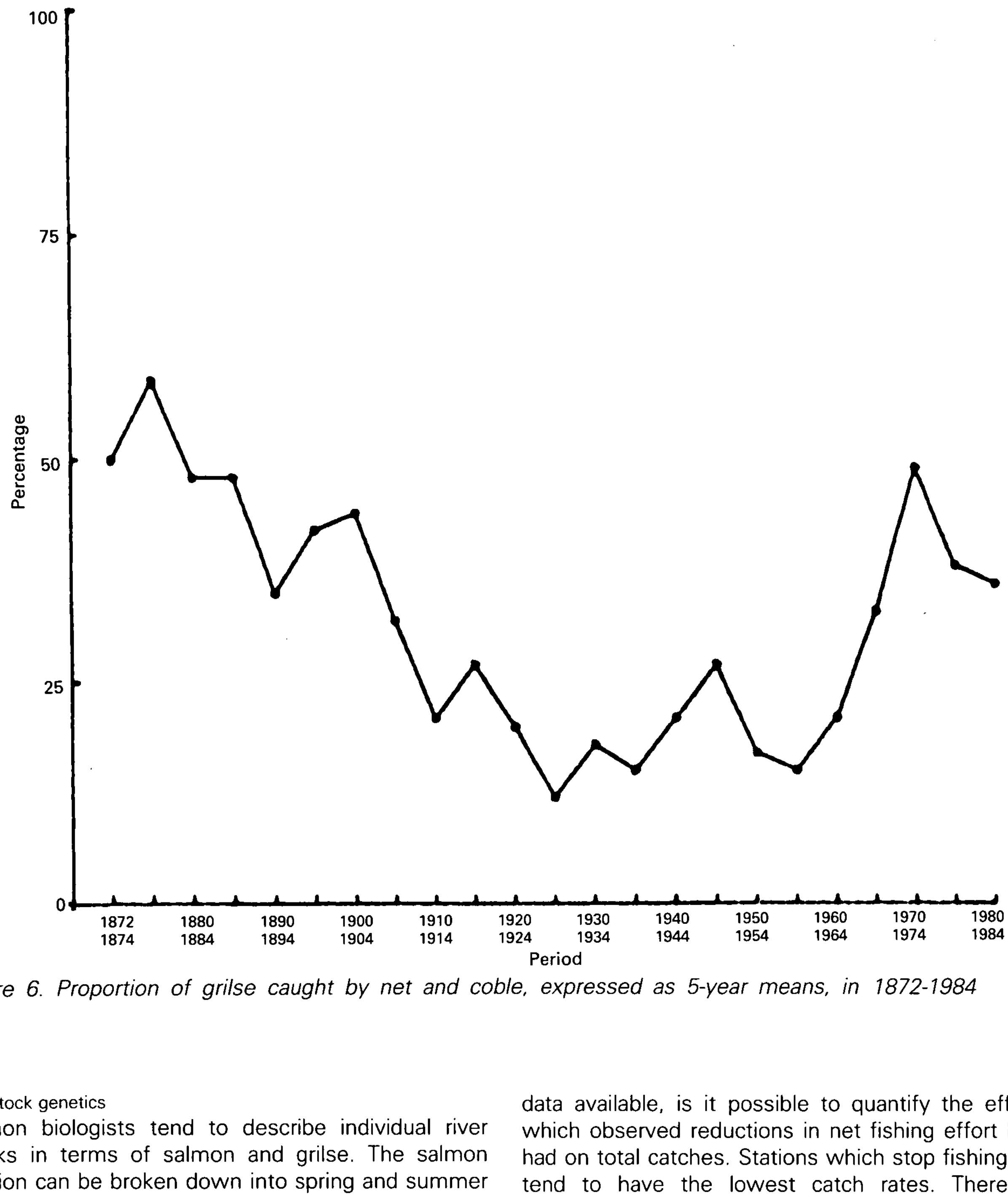


Figure 6. Proportion of grilse caught by net and coble, expressed as 5-year means, in 1872-1984

6.2 Stock genetics

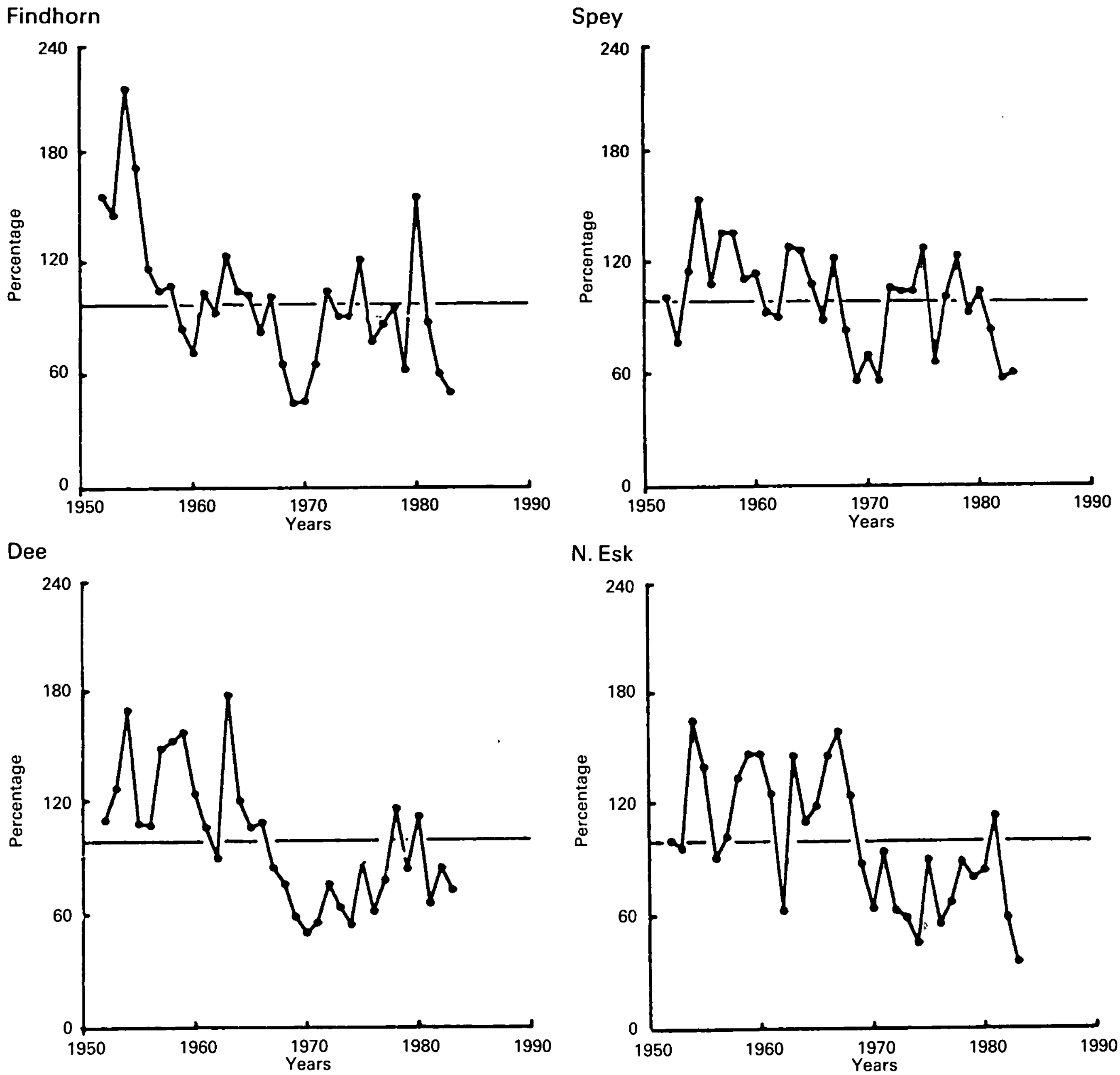
Salmon biologists tend to describe individual river stocks in terms of salmon and grilse. The salmon fraction can be broken down into spring and summer components, depending on the calendar date when the fish return to fresh water. At present, it is not at all certain whether these groups are genetically distinct or whether the distinction is based on environmental and other factors to which the fish were exposed either during their early freshwater life or their period in the sea. Nevertheless, at spawning time, there is some degree of isolation because spring salmon are normally found in those tributaries which join the main river nearer its source than those frequented by summer salmon and grilse. In addition, spring salmon tend to spawn earlier.

6.3 Effort

It was not possible to ascertain whether any of the observed catch trends were related to changes in effort or to the availability of salmon. Neither, with the data available, is it possible to quantify the effects which observed reductions in net fishing effort have had on total catches. Stations which stop fishing first tend to have the lowest catch rates. Therefore, reductions in total catch due to the closing of fishing stations may not be directly proportional to the number of stations which have closed. No data describing the effort for rod fisheries are available, because it cannot be assumed that all anglers and tackle are equally efficient. Nonetheless, variation in effort possibly presents a major difficulty in interpreting the data.

6.4 Effects of Faroese and Greenland fisheries

Although it is by no means certain that all salmon feed at some time during their life cycle in either of these 2 areas, estimating total losses to European home water stocks for each tonne landed from the Faroese and Greenland fisheries presents no great difficulty. However, the biological data currently available are insufficient to calculate these losses at the individual river level. Nevertheless, as both Faroese and Green-



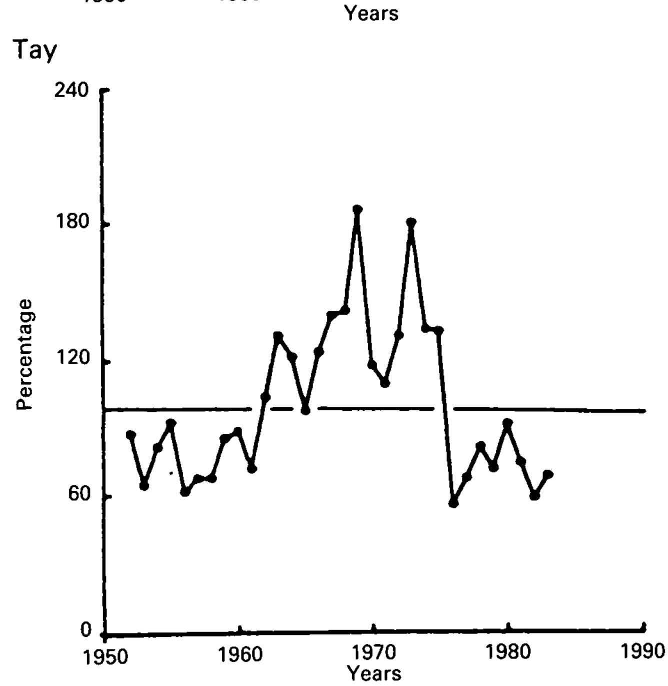
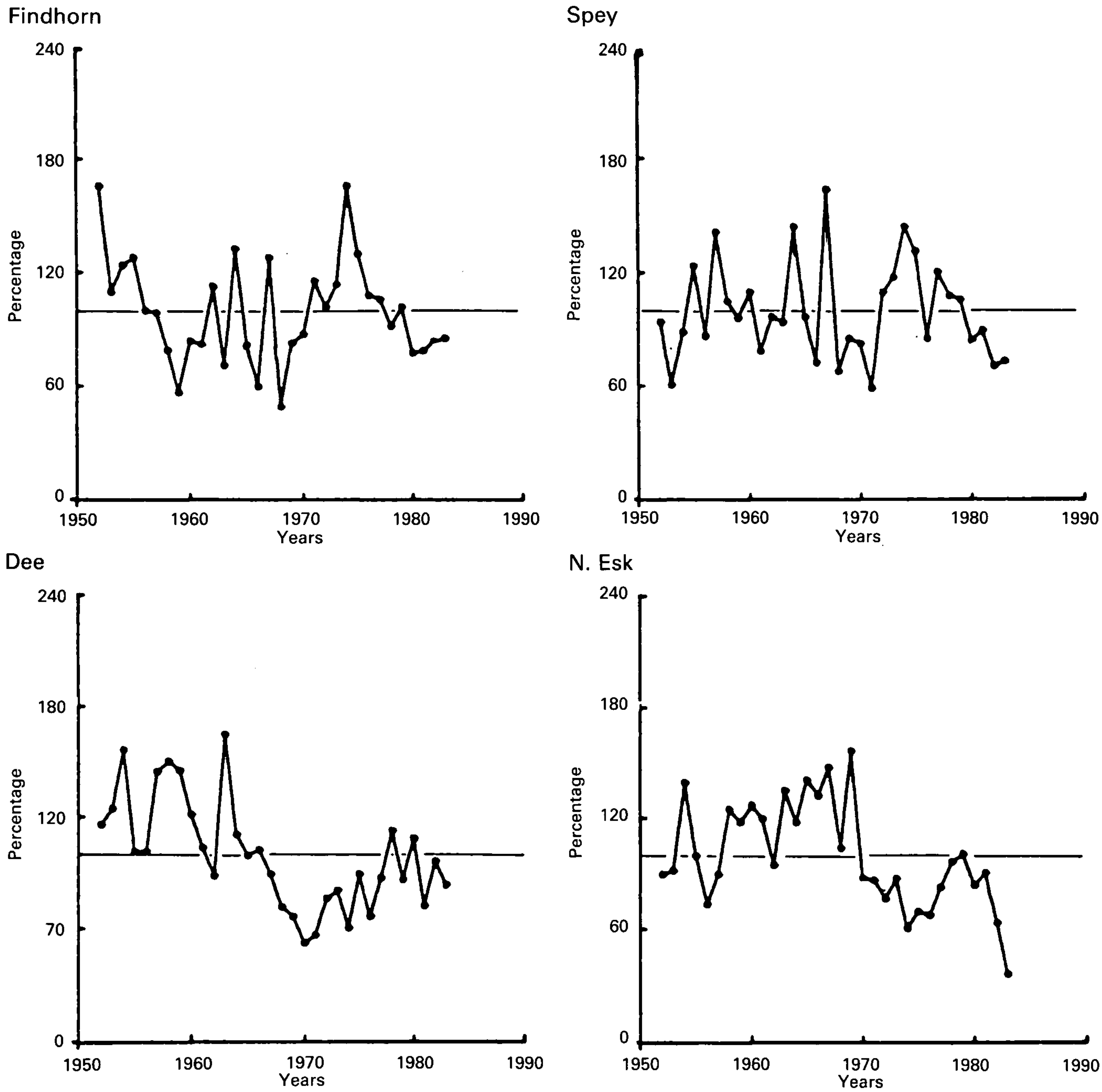


Figure 7. Total annual catches of salmon for 5 east coast rivers, expressed as proportions of the mean for 1952-83

land fisheries exploit salmon rather than grilse, any effect on rivers possessing only a grilse stock is likely to be marginal. The results of smolt tagging experiments in home rivers and adult tagging experiments at Greenland suggest that most salmon of Scottish origin which feed off the Greenland coast have come from tributaries normally favoured by spring, rather than summer, fish. Furthermore, the majority of fish tagged at Greenland and recaptured in home waters were caught in the spring rather than the summer of the year following that in which they were tagged (Jensen 1980). Because the Dee fishery is largely dependent on multi sea-winter fish returning to the home waters in the spring, the effects of the Faroese and Greenland fisheries on Dee stocks are likely to be greater than the



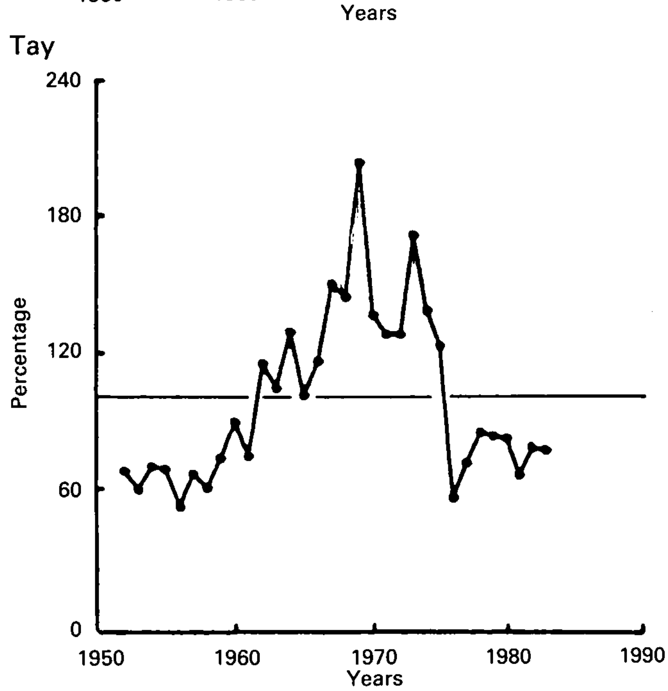
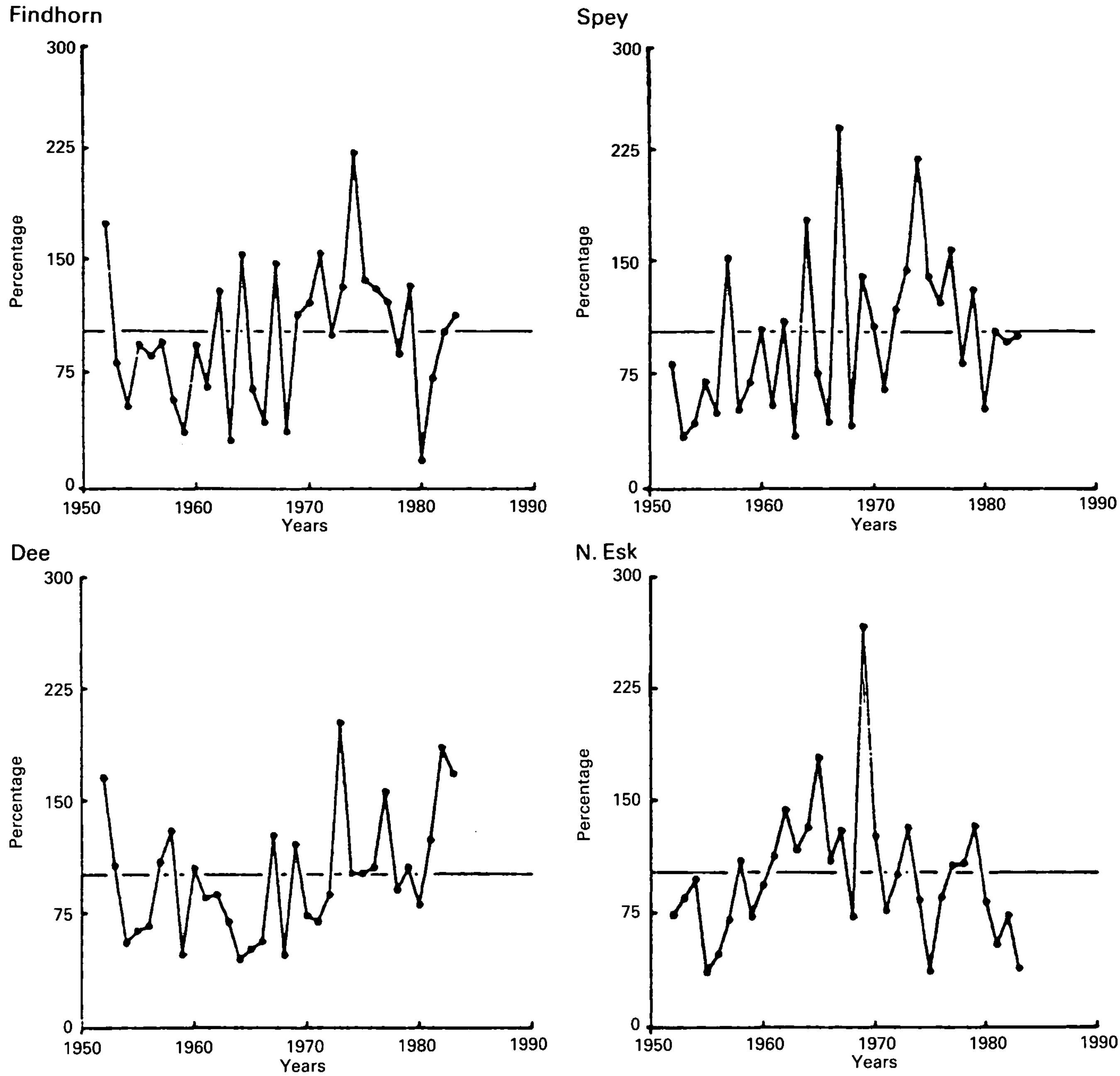


Figure 8. Total annual catches of grilse for 5 east coast rivers, expressed as proportions of the mean for 1952-83

average figure (mostly for summer fish only) derived from the estimated total European loss.

6.5 Sea temperature

After studying Aberdeen Harbour Board catch data recorded between 1872 and 1960 and the sea surface temperatures at Grimsey, north Iceland, over roughly the same time period, Martin and Mitchell (1985) suggested that the sub-arctic sea temperature, although not influencing the total number of fish returning from particular smolt year classes, has a major influence on whether a fish returns as a grilse or a salmon. During periods when sub-arctic temper-



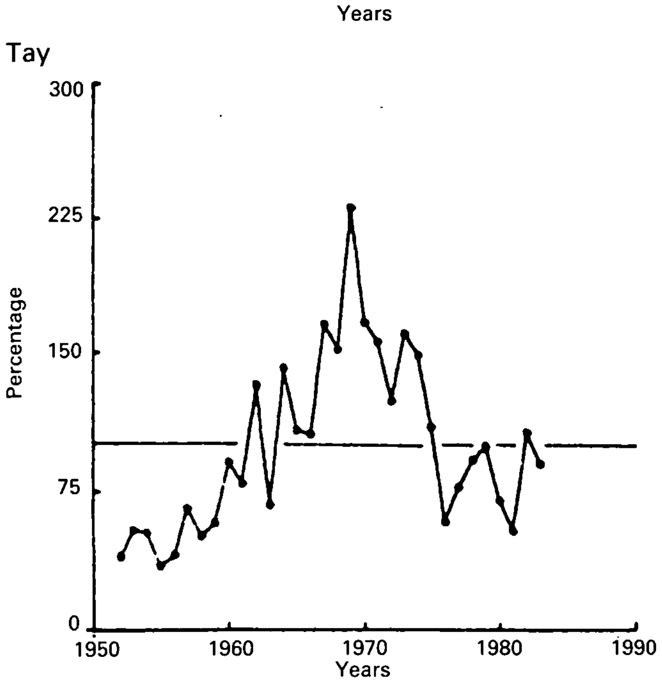


Figure 9. Total annual catches of salmon plus grilse for 5 east coast rivers, expressed as proportions of the mean for 1952-83

atures were below average, the percentage of fish returning as grilse increased. Since 1960, the grilse proportion of the catch returning after one sea-winter has risen as the surface sea temperature in the sub-arctic has fallen steeply.

6.6 Mortality

For most years in 1961-76, the estimated natural sea mortality of North Esk salmon varied between 54% and 79% (Shearer 1984). In 1980-82, it increased to 86% and did not fall below 83% in any year. During the same period, the smolt production of the North Esk did not show any marked downward trend.

6.7 Age and weight

The increase in the average smolt age noted in the Dee net catch between the 1920s and 1983 did not occur in the Spey. Both at the Spey, and at the North Esk in 1964-84, the average smolt age decreased. The increase in the contribution which grilse made to the Dee August catch, the later arrival of the grilse run at the net and coble fishery, and the increase in their monthly average weight in 1983 compared with the 1920s are similar to data from catches in the Spey and North Esk nets over similar periods. The general decrease in the average weight of the Dee multi sea-winter fish did not occur at either of the other 2 net and coble fisheries.

6.8 Juvenile migrant production

Investigations carried out in the *Girnock* burn, a tributary in the headwaters of the Dee, in 1966-76 have shown that, although the number of female adult salmon spawning in that burn each year varied widely (28-127), the annual variation in the number of juvenile migrants produced was much smaller (2900-5600). As a result, it was suggested that there may be no advantage in allowing ova deposition to exceed a level around 200 000. This number would give rise to an average of about 4000 juvenile migrants per season. The number of juvenile migrants leaving the *Girnock* burn has not been limited by the number of spawners in recent years. In most years, the *Girnock* burn appears to have excess spawning. Therefore, extra cropping of adults would seem possible in some years as the burn appears to have more than sufficient adult fish returning to spawn (Buck & Hay 1984).

6.9 Conclusions

Climate and ocean conditions interact with density-dependent growth and smolt production to produce short-term and long-term fluctuations in abundance and yield of salmon and the proportion of different age groups of fish occurring in individual years. It remains to be seen whether the marked reduction in the Greenland fishery in 1983 and 1984 will have any effect on Dee salmon catches. However, the only firm data on fish numbers are those in Figure 3 for the whole of Scotland and in Figure 5 for the Dee nets. They show for all Scotland that the big increase in salmon caught in the late 1960s and early 1970s was not sustained and that numbers are now back to the level of the 1950s. However, for the net and coble fishery operated by the Aberdeen Harbour Board, the trend over the last 100 years is for a steady increase in catches. Firm conclusions about the rod fishery cannot be drawn without more precise data on catch and effort. Although the sea ages of salmon caught off the west coast of Greenland and north of the Faroes are similar to those caught on the Dee, it has not been possible to relate the decline in the total Dee spring catch directly to either of these 2 fisheries.

7 Summary

7.1 This paper analyses catch statistics from the Dee, mainly for 1952-83, but includes data from the net and coble fishery operated by the Aberdeen Harbour Board from 1872. The data are analysed in terms of percentage variation from annual or longer period means. The relative numbers of fish caught cannot be given. It is possible to analyse the catch data qualitatively in terms of relative changes in the different components of the population and to establish whether trends occur in some or all of these groups.

7.2 Catches on the Dee of salmon, grilse, and salmon plus grilse taken by all methods fluctuated widely between years. Catches of salmon, and salmon plus grilse, prior to 1966, except for one year, were above the long-term mean, while catches after that date, except for 2 years, were below it. No marked downward trend was noted in 1952-66 but the trend has been upward since 1970.

7.3 Over the period 1952-83, grilse made a relatively small contribution to both the rod and line and net and coble catches.

7.4 Since 1960, spring salmon net and coble catches have gradually declined, but no trend was evident in the corresponding rod and line catch.

7.5 Each year, the rods caught between 40% and 78% of the total catch of salmon and grilse.

7.6 A marked upward trend was observed in the net and coble catches in 1872-1984. The ratio of grilse to salmon in the catches varied widely, principally due to variations in the salmon rather than the grilse component (Figures 5 and 7).

7.7 Although the grilse caught by net and coble in 1983 were on average heavier than in the 1920s, the multi sea-winter sea age groups of salmon in net catches were on average lighter.

7.8 Fish which had spent 4 winters in the sea were missing from the net and coble catch in 1983, and the peak of the grilse run may now be later than in the early 1920s.

7.9 The average smolt ages of the one and multi sea-winter fish caught in 1983 were greater than the corresponding figures for captures in the earlier period.

7.10 The data available from the *Girnock* Burn suggest that juvenile migrant production is not presently a limiting factor.

7.11 Historical records suggest that not only have salmon catches fluctuated widely but also the timing of the return migration to fresh water.

7.12 Present data are insufficient to relate the alleged decline in the spring run of salmon in the Dee to the operation of the Faroese and Greenland fisheries which are known to catch fish originating in eastern Scotland.

7.13 The main requirements now for further analysis are information on the effort put into catch salmon by each method, including rod and line, and for consistent catch reporting.

8 Acknowledgements

I am most grateful to the Aberdeen Harbour Board, for permission to use the catch data from the net and coble fishery operated by the Board in the estuary of the Dee.

9 References

Anon. 1825. *Minutes of 1825 Salmon Commission.* Edinburgh.

Buck, R. J. G. & Hay, D. W. 1984. The relation between stock size and progeny of Atlantic salmon, *Salmo salar* L., in a Scottish stream. *J. Fish Biol.*, **24**, 1-11.

Fishery Board for Scotland. 1922. *Annual report, 1921.*

Fishery Board for Scotland. 1928. *Annual report, 1927.*

Grimble A. 1902. *The salmon rivers of Scotland.* London: Kegan Paul, Trench & Trubner.

Jensen, J. M. 1980. Recaptures from international tagging experiment at west Greenland. In: *ICES/ICNAF joint investigation on North Atlantic salmon,* edited by B. B. Parrish & SV. AA. Horsted, 114-135. Copenhagen: International Council for the Exploration of the Sea.

Martin, J. H. A. & Mitchell, K. A. 1985. Influence of sea temperature upon the numbers of grilse and multi-sea-winter Atlantic salmon (*Salmo salar*) caught in the vicinity of the River Dee (Aberdeenshire). *Can. J. Fish. Aguat. Sci.*, **42**, 1513-1521.

Menzies, W. J. M. 1922. Salmon investigations in Scotland, 1921. I. Salmon of the River Dee (Aberdeenshire). *Salm. Fish., Edinb.*, (1), 3-48.

Menzies, W. J. M. & Macfarlane, P. R. C. 1924. Salmon investigations in Scotland, 1922. II. Salmon of the River Dee (Aberdeenshire). *Salm. Fish., Edinb.*, (3), 5-52.

Menzies, W. J. M. & Macfarlane, P. R. C. 1926. Salmon investigations in Scotland, 1923. I. Salmon of the River Dee (Aberdeenshire). *Salm. Fish., Edinb.*, (4) 4-46.

Menzies, W. J. M. & Macfarlane, P. R. C. 1927. Salmon of the River Dee (Aberdeen) 1924. *Salm. Fish., Edinb.*, (3), 3-30.

Menzies, W. J. M. & Macfarlane, P. R. C. 1932. Salmon of the River Dee (Aberdeen) in 1925. *Salm. Fish., Edinb.*, 1931, (4), 3-22.

Oswald, J. 1985. Fishery management. In: *The biology and management of the River Dee,* edited by D. Jenkins, 117-126. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Shearer, W. M. 1984. Research activities within the Spey Salmon Fishery District. *Annu. Rep. Spey District Salmon Fishery Board,* 1-44.

Shearer, W. M. 1984. *The natural mortality at sea for North Esk salmon.* (ICES CM 1984/M:23.) Copenhagen: International Council for the Exploration of the Sea.

Shearer, W. M. 1984. *The relationship between both river and sea age and return to home waters in Atlantic salmon.* (ICES CM 1984/M:24.) Copenhagen: International Council for the Exploration of the Sea.

Strange, E. S. 1981. An introduction to commercial fishing gear and methods used in Scotland. *Scott. Fish. Inf. Pam.*, no. 1.

The status of the River Dee in a national and international context

P S MAITLAND
Institute of Terrestrial Ecology, Edinburgh

1 Introduction

The classification of river systems has received considerable attention from freshwater scientists, and a wide variety of parameters has been proposed as the basis of different schemes of typology. Early workers used physical attributes such as flow and temperature (Ricker 1934), geological origin and substrate (Carpenter 1927; Butcher 1933) and the erosion and deposition of sediments (Moon 1938). Other workers have used biological features, such as fish (Huet 1946), invertebrates (Illies 1953) and plants (Haslam 1982), and there is often a reasonable cross-correlation among the different schemes (Pennak 1971). Many of the different schemes have been reviewed by Hawkes (1975) and recent proposals (Maitland 1979; Wright *et al.* 1984) have moved towards sophisticated multivariate analyses using both physico-chemical and biological data. Constant problems are that the characteristics of rivers change (sometimes dramatically) from source to mouth (Maitland 1966; Cummins *et al.* 1966), and that many differences in the biota (eg the fish: Maitland 1985) may be due to historical and not ecological factors.

The conservation of fresh waters has received more attention in recent years, but the attention given to running waters has lagged far behind that given to standing waters. Thus, in Project Aqua (Luther & Rzoska 1971), 'a source book of inland waters proposed for conservation', a total of 108 running waters is listed (Table 1), compared with a standing water list of 526. Within the United Kingdom, about 52 standing waters and one running water are listed for England, about 14 standing waters and no running waters for Wales, and about 15 standing waters and no running waters for Scotland. The single running water listed for the United Kingdom (Bere Stream) is actually not of particular conservation importance.

Table 1. Fresh waters listed for their conservation value

Source	Running waters	Standing waters
Luther and Rzoska (1971)		
International	108	526
Great Britain	1	81
Ratcliffe (1977)		
Great Britain	19	104

In Great Britain, the most recent and authoritative review of sites of national importance is that of Ratcliffe (1977). It gives less attention to running waters than to standing waters, but the coverage is nevertheless much better than in most comparable documents. In the index of open water sites (grades 1 and 2), there are 104 standing waters and 19 running waters. Eighteen of the standing waters and 2 of the running waters are regarded as internationally important. The Dee (Aberdeenshire/Kincardineshire) is listed as an upland running water of grade 1 national (but not international) importance.

2 The River Dee

The Dee rises as a large number of streams draining the east central highlands of Scotland, some of which form the outflows of high-altitude lochs such as Loch Etchachan and Loch Muick. The traditional source is the Springs of Dee, but the highest sources are found on the slopes of Ben Macdui within the Cairngorms National Nature Reserve (Ratcliffe 1977). Compared to the source streams of the Spey, within the Cairngorms, those of the Dee are more precipitous, and streams, such as the *Allt a' Choire Mhoir*, after rising on a gently sloping boulder field at 1220 m above OD then plunge 600 m down the 40° slopes of the Lairig Ghru. In its upper reaches, the substrate of this stream is granite gravel and stones, but on the steep slopes the stream cascades over bedrock and boulders. In both sections, most of the rock surfaces are covered in dense growths of bryophytes such as *Scapania undulata, Jungermannia cordifolia* and *Marsupella emarginata*. The maximum width here is about 3 m and the greatest depth only 20 cm. The water is low in pH (5.1) and extremely deficient in dissolved salts, the conductivity being low (12-19 µmhos), but nitrate levels are relatively high (0.24-0.25 mg l^{-1} NO_3–N). For most of the year, the flow consists largely of snowmelt and even in late summer the temperature rarely rises much above 5°C. The invertebrate fauna includes species of Oligochaeta, Plecoptera, Tricladida, Trichoptera and Diptera typical of arctic-alpine streams, with the larvae of orthoclad chironomids dominating numerically. There are no fish or aquatic angiosperms.

Lower down, these small alpine streams converge to form a small fast-flowing river, prone to heavy spating. It is characterized by clear waters and unstable shingle beds, interrupted at some points by areas of smooth flat bedrock. The water is extremely poor in nutrients but is less acid than higher up. Higher aquatic vegetation is virtually absent, and the stones are almost free of epilithic algae. The invertebrate fauna is sparse, and large areas of the bed can be virtually devoid of animals after floods. The fauna still contains an important arctic-alpine element, but also species characteristic of lower elevations, such as the caddis

Polycentropus flavomaculatus, the alderfly *Sialis fuliginosa*, the stonefly *Taeniopteryx nebulosa*, the water bug *Gerris costai* and Hydracarina.

Below the Linn of Dee, the river becomes broader and is moderate to fast flowing, with a more stable bed consisting of stones and gravel, a few boulders and a little sand. It remains similar throughout most of its length, gradually increasing in size so that at Cults it is up to 60 m wide. The dissolved nutrient content of the water also increases downstream as the river enters farmland, and at Peterculter it is mesotrophic (alkalinity 16 mg l^{-1} as $CaCO_3$) but nitrate levels are still relatively low (average 0.5 mg l^{-1} NO_3-N). In its lower reaches, the water is less clear and sometimes slightly discoloured by plankton from the Loch of Skene, which drains into the river. Macrophytic vegetation is virtually absent throughout the river, only a few clumps of bryophytes being found.

Associated with the increasing nutrient content, there is an increase in the biomass and variety of benthic invertebrates as one moves downstream. A number of montane species such as *Simulium monticola*, *Protonemura montana*, *Diura bicaudata* and *Crenobia alpina* disappear, and in the lower mesotrophic sections the fauna is augmented by *Polycelis tenuis/nigra*, *Gammarus pulex*, *Simulium reptans*, *Baetis pumilus*, *Ephemerella ignita*, a number of caddis species and a few gastropods, all of which appear in increasing numbers downstream.

3 International aspects

Conservation assessment criteria are notoriously subjective, and there have been far too few serious attempts to outline objective criteria which are quantifiable in some way, and which would serve as guidelines both for comparing one system with another and also for assessing any changes in time within one system. The initial selection of aquatic nature reserves in Great Britain was by ornithologists, and only recently have other (more fundamental) criteria been used (Ratcliffe 1977). A wide variety of such criteria must be considered in any general scheme of site selection.

Although the Dee is listed as a grade 1 site of national importance, there has been no suggestion so far that it could be important internationally. Examination of the available data seems to confirm that it is not. All physical comparisons with important international running water systems would seem to place the Dee low down, regardless of the parameter or rating system used (Table 2). The same seems to be true of biological factors, including important features like plant, invertebrate, fish and bird diversity, as well as various facets of organic production and community structure.

The importance of the Dee must be viewed in a national, rather than an international, context. Does it justify its rating (Ratcliffe 1977) as a grade 1 national site? If so, can the assessment criteria used be made more objective and quantifiable than has been the case in the past?

Table 2. Comparative data for world and British rivers (source: Lewin 1981)

River	Length (km)	Catchment area ('000 km²)	Q bar ('000 cumecs)
Amazon	6437	7050	180
Congo	4700	3457	41
Ob-Irtysh	5410	2975	15
Mackenzie	4241	1841	11
Ganges-Brahmaputra	2897	1621	38
Zambezi	3540	1330	7
Tigris-Euphrates	2740	1114	1
Danube	2850	816	7
Colombia	1950	668	7
Rhine	1320	160	2
Thames	239	10	0.06
Tay	188	5	0.15
Dee	140	2	0.04

4 National comparisons

4.1 Physical characteristics

Ward (in Lewin 1981) has ranked major British rivers in terms of length, area and mean annual discharge. The Dee is included in his list of rivers and falls 10th in length, 21st in catchment area, and 18th in terms of flow, eventually being ranked 18th in terms of these 3 characters. However, there are many other relevant river characteristics, some of them probably much more important in biological terms, which should be considered when comparing the attributes of different running water systems. Two of the most important of these are the altitude of the upper reaches and the extent of the lowland (and estuary) sections of each river.

Table 3 indicates that, according to the Water Data Unit (1982), the Dee rises higher than any other major British river (1310 m)*, closely followed by the Spey (1309 m), the Tay (1215 m) and the Ness. No other large river rises above 1000 m. As discussed below, this high-altitude section can be of considerable ecological importance. At the other end of the river, the Dee (unlike most of the other large rivers) is almost devoid of an estuary and has a relatively short lowland section.

In physical terms, therefore, it would be true to say that the Dee is one of the most highland in character of all the large British rivers. This statement is confirmed by an analysis of its flow regime which Warren (1985) describes as 'alpine' in character.

4.2 Chemical characteristics

It is difficult to obtain comparable chemical data for rivers in different areas. However, Table 4 gives a general chemical classification of series of stations

*but see Maizels (1985) who states that the Dee rises at 1220 m (Ed).

Table 3. Major British rivers ranked in terms of flow, length, catchment areas and maximum altitude

	Flow (cumecs)	Length (km)	Catchment area (km^2)	Maximum altitude (m)
Tay	152.2	188	4587	1215
Trent	82.2	149	8547	636
Ness	76.6	107	1792	1120
Tweed	73.9	140	4390	839
Wye	71.4	225	4040	752
Thames	67.4	239	9950	330
Severn	62.7	206	9983	827
Spey	55.9	137	2655	1309
Tyne	43.5	89	2176	839
Ouse	40.5	117	3315	713
Tywi	38.3	82	1088	792
Clyde	37.4	105	1903	732
Aire	36.9	114	1932	594
Dee	35.7	140	2100	1310
Ribble	31.7	94	1140	680
Eden	31.0	102	2287	950

4.3 Botanical characteristics

Morgan and Britton (in Ratcliffe 1977) give a brief description of the macroflora of the Dee, emphasizing the importance of the bryophytes in the upper reaches. In a more detailed survey, Holmes (1985) showed that several zones of vegetation could be distinguished on passing downstream and that, when compared to other large rivers in Great Britain, the Dee has a unique succession of communities, exemplifying a large oligotrophic highland river. Due to this representativeness and its naturalness, Holmes confirms the Dee as being of prime nature conservation interest.

4.4 Invertebrate characteristics

The invertebrate fauna of many Scottish rivers was studied at the same time as their water chemistry (Table 3) and comparable data are available for 1974 and 1980 (Scottish Development Department 1976, 1983). Both sets of samples were taken in the spring,

Table 4. Chemical classification of various stations on the large Scottish rivers (source: SDD 1976). The classes are: 1. unpolluted; 2. fairly good quality; 3. poor quality; 4. grossly polluted. The sampling stations on each river are listed numerically from mouth towards source, but the distance between each varies

STATIONS: MOUTH ← → SOURCE	1	2	3	4	5	6	7	8	9	10	11	12	13
Ness	1	1	1	1	1								
Spey	1	1	1	1	1	1	1	1	1	1			
Don	4	1	1	1	1	1	1	1	1	1			
Dee	1	1	1	1	1	1	1	1	1	1	1	1	
Tay	2	1	2	2	2	2	2	2	2	1	1	1	1
Forth	2	1	1	1	1	1	1						
Tyne	2	1	1	2	1	1	1	1	1	1	1	1	1
Tweed	1	1	1	1	1	1	1	1	1	1	1	1	1
Annan	1	1	1	1	1								
Stinchar	1	1	1	1	1	1							
Clyde	4	3	3	2	2	2	1	1	1	1	1	1	1
Leven	1	1	1	1	1								

from near the mouth towards the source of 12 of the larger Scottish rivers. The chemical classification is related to pollution (Scottish Development Department 1976) and the classes are defined as follows: 1. unpolluted; 2. fairly good quality; 3. poor quality; 4. grossly polluted.

It is clear that, although several of the rivers concerned have sections where the chemical quality of the water is poor, this is not true of the Dee, which is one of the least contaminated of the larger Scottish rivers. It should follow, therefore, that its biota include mainly natural communities, relatively little influenced by man.

Pugh (1985) describes the Dee as being in pristine condition, emphasizing that its size and chemical nature set it apart from many other rivers. It is a fine example of a river which is oligotrophic from source to mouth.

but the 1974 data (Table 5) are expressed in the form of Trent indices, whereas the 1980 data are represented as biological scores (Scottish Development Department 1983). As with the chemical data, it is clear that, unlike several of the other large Scottish rivers, the Dee gives every indication of healthy, uncontaminated invertebrate communities along most of its length.

Other, more detailed, studies have been made of the invertebrate fauna of the Dee (Ratcliffe 1977; Wright *et al.* 1984; Davidson *et al.* 1985). Unfortunately, only Morgan and Britton (in Ratcliffe 1977) covered sites in the upper reaches of the river. Wright *et al.* (1984) compared the invertebrate fauna of the Dee with those of 41 other river systems in Great Britain, using an analysis of data at species level by multivariate statistical techniques. The Dee was characterized in this study as being 'upland' for most of its length, confirming the physical data discussed above. How-

Table 5. Invertebrate classification of various stations on the larger Scottish rivers (source: SDD 1976). The sampling stations on each river are listed numerically from mouth towards source, but the distance between each varies

	STATIONS: MOUTH ←									——SOURCE			
	1	2	3	4	5	6	7	8	9	10	11	12	13
Ness	X	X	X	X	X								
Spey	X	IX	X	X	X	X	X	IX	X	VIII			
Don	VI	IX	X	IX	X	X	X	X	X	X			
Dee	VIII	IX	X	X	VII	VIII	IX	X	X	IX	X	VIII	
Tay	X	X	X	X	X	X	X	X	X	X	X	X	X
Forth	VI	X	IX	X	X	IX	IX						
Tyne	VI	VIII	IV	III	IV	VII	VIII	VIII	VIII	VII	VIII	IX	X
Tweed	IX	IX	IX	X	X	X	X	X	X	X	X	X	X
Annan	X	VIII	X	X	X								
Stinchar	VIII	IX	VIII	VIII	VIII	IX							
Clyde	II	III	VII	VI	VIII	IX	VIII	VIII	VIII	VIII	X	IX	VII
Leven	X	VIII	VII	X	X								

ever, as none of the stations sampled in this study were above 375 m and as the river rises above 1000 m, it is likely that the really interesting and characteristic part of this river has been missed by this and several other studies.

Davidson *et al.* (1985) found through an association analysis of invertebrate samples that sites on the main river were similar to each other and characteristic of an unpolluted highland river system.

4.5 Fish

A comparison of the species composition of the fish fauna of the larger Scottish rivers (Table 6) shows that, although the Dee is certainly truly highland in character, there is nothing especially remarkable about its fish community. Application of the criteria for the selection of important systems for freshwater fish recommended by Maitland (1985) confirms that the Dee is not especially noteworthy, as far as its fish are concerned.

5 Discussion

The problem of reaching an objective decision about the status of any ecosystem is a difficult one and has been discussed by a number of authors. Ratcliffe (1977) used the following criteria in his assessment of British ecosystems: extent, diversity, naturalness, rarity, fragility, representativeness, recorded history, position in an eco-geographical unit and potential value. In estimating the importance of the Dee, the author developed the procedure shown in Table 7 for the selection of running waters of conservation value. It follows the pattern of the successful procedure previously used for selecting waters important for fish conservation (Maitland 1985).

It is clear that the Dee is of relatively little importance internationally, except perhaps as a prime example of a west European highland river. It is of national importance in this category, and is probably the best example in the British Isles of a relatively natural highland river. Its particular characteristics include a

Table 6. The fish fauna of the larger Scottish rivers (updated from Maitland 1972)

	Sea lamprey	River lamprey	Brook lamprey	Salmon	Sea trout	Grayling	Smelt	Pike	Gudgeon	Minnow	Roach	Chub	Dace	Stone loach	Eel	Three-spined stickleback	Perch	Flounder	TOTAL
Ness	+	–	+	+	+	–	–	+	–	+	–	–	–	–	+	+	–	+	9
Spey	+	+	+	+	+	–	–	+	–	+	–	–	–	–	+	+	+	+	11
Don	+	+	+	+	+	–	–	+	+	+	–	–	–	+	+	+	+	+	13
Dee	+	+	+	+	+	–	–	+	–	+	–	–	–	–	+	+	+	+	11
Tay	+	+	+	+	+	+	+	+	–	+	+	–	–	+	+	+	+	+	15
Forth	+	+	+	+	+	–	–	+	–	+	+	–	–	+	+	+	+	+	13
Tyne	+	+	+	+	+	–	–	+	–	+	+	–	–	+	+	+	+	+	13
Tweed	+	+	+	+	+	+	–	+	+	+	+	–	+	+	+	+	+	+	16
Annan	+	+	+	+	+	+	–	+	–	+	+	+	–	+	+	+	+	+	15
Stinchar	+	+	+	+	+	–	–	–	–	+	–	–	–	+	+	+	–	+	9
Clyde	–	–	+	+	+	+	–	+	–	+	+	–	+	+	+	+	+	–	12
Leven	+	+	+	+	+	–	–	+	+	+	+	–	–	+	+	+	+	+	14

Table 7. Procedure for the selection of running waters of conservation value

1. Is sufficient information available about the system to characterize it from source to mouth?	YES NO	2 A
2. Are there any physico-chemical or biological features sufficiently outstanding to warrant international status?	YES NO	B 3
3. Are any of the physico-chemical or biological characteristics sufficiently important to warrant national recognition?	YES NO	C 4
4. Are any man-made developments likely to be having a significant effect on the river?	YES NO	D E

A. More research is required.
B. The system should be notified internationally.
C. The system should be notified nationally.
D. The conservation value of the system is reduced.
E. The conservation value of the system is increased.

greater altitudinal range than any other large British river, virtual absence of a meandering lowland section or estuary, and very little impact from man in terms of pollution, abstraction and hydro-electric or other abstractions. Its flora and fauna are typical of an uncontaminated highland system typically rather low in diversity, especially compared to lowland systems.

There were 2 main problems in making this review. The first is that there is still insufficient ecological information concerning the Dee. This is particularly true of most aspects of the extremely important (and potentially unique) upper reaches but also of some basic aspects such as the distribution and status of its fish populations (Jenkins & Bell 1985). Figure 1 emphasizes the upland character of the Dee compared to another, even larger, British river, the Trent. The distribution of stations for most types of sampling seems to be limited by accessibility from road bridges, and more research is needed in the mountainous

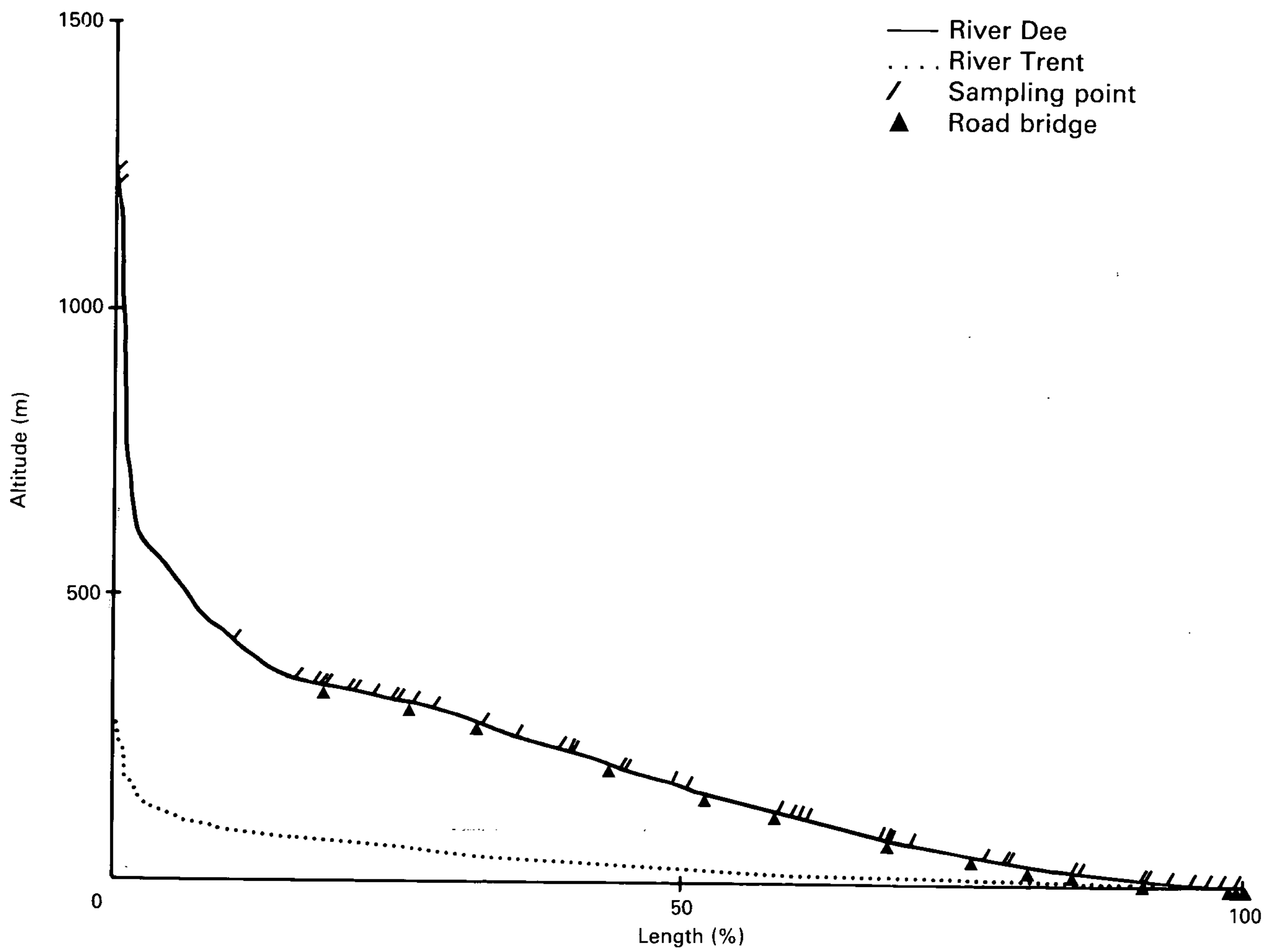


Figure 1. A profile of the River Dee (140 km) from source to mouth contrasting with the River Trent (256 km) drawn to the same percentage scale. Recent sampling points on the Dee by various organizations are shown just above the profile in relation to the main road bridges, below

upper reaches; these are, after all, one of the most important features of this river.

The second problem is that comparisons with other systems are difficult because of the absence of data and also because data are rarely available in a consistent form. For this reason, much of the information produced by the Scottish River Purification Boards and published in their Annual Reports cannot be used directly. The same is true for many data presented by local authorities and other regional organizations.

This review confirms the grade 1 national rating given to the Dee during the Nature Conservation Review (Ratcliffe 1977). However, in spite of this rating, relatively little specific action, in nature conservation terms, has been taken. The North East River Purification Board is well aware of the high quality of the river and continues its efforts to maintain this, but there remains a need for more integrated conservation plan for the whole river basin which takes into account all the various demands on the resource while keeping as its top priority the conservation of water quality and the flora and fauna of the main river. Its major features of national importance are summarized in Table 8.

Table 8. Why is the River Dee important? A summary of features of importance in a national context

1. An excellent example of a highland eroding river.
2. Its headwaters are probably the best alpine streams in Great Britain.
3. It has virtually no lowland depositing section or estuary.
4. Its waters are nutrient-poor and water quality is always high.
5. Man-made impacts are low, so the system is highly natural.
6. The plant communities show a unique succession, and are intact and representative.
7. The invertebrate communities are characteristically highland throughout most of the river.
8. The fish and other vertebrates are poor in diversity, but the salmonid fishery is important.
9. The catchment area is scenically attractive.
10. The recreational value of the river system is high.

6 Summary

The general ecological status of the Dee is reviewed. In international terms, for virtually all assessment criteria, the Dee is unimportant compared to the large rivers of the world. Its most important role is as the best example of a large natural highland river in Scotland. Its most characteristic and important features are as follows: its headwaters are among the highest of any river in the British Isles; there is virtually no lowland section (or estuary) and the substrate is eroding virtually to the river mouth; the aquatic flora and fauna are highly characteristic of this type of system and are relatively unaffected by man. In view of its national importance, strong conservation measures should be adopted to preserve its status.

7 References

Butcher, R. W. 1933. Studies on the ecology of rivers: 1. On the distribution of the macrophytic vegetation in the rivers of Britain. *J. Ecol.*, **21,** 58-91.

Carpenter, K. E. 1927. Faunistic ecology of some Cardiganshire streams. *J. Ecol.*, **15,** 33-54.

Cummins, K. W., Coffman, W. P. & Roff, P. A. 1966. Trophic relationships in a small woodland stream. *Verh. int. Verein. theor. angew. Limnol.*, **16,** 627-638.

Davidson, M. B., Owen, R. P. & Young, M. R. 1985. Invertebrates of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 64-82. (ITE symposium volume no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Haslam, S. M. 1982. *Vegetation in British rivers.* Huntingdon: Nature Conservancy Council.

Hawkes, H. A. 1975. River zonation and classification. In: *River ecology,* edited by B. A. Whitton, 312-374. Oxford: Blackwell Scientific.

Holmes, N. T. H. 1985. Vegetation of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 42-55. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Huet, M. 1946. Note préliminaire sur les relations entre la pente et les populations piscicoles des eaux courantes. *Biol. Jaarb.*, **13,** 232-243.

Illies, J. 1953. Die Besiedlung der Fulda (insbesondere das Benthos der Salmonidregion) nach dem jetzigen Stand der Untersuchungen. *Ber. limnol. Flussstn Freudenthal,* **5,** 1-28.

Jenkins, D. & Bell, M. V. 1985. Vertebrates, except salmon and trout, of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 83-93. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Lewin, J., ed. 1981. *British rivers.* London: Allen & Unwin.

Luther, H. & Rzoska, J. 1971. *Project Aqua: a source book of inland waters proposed for conservation.* Oxford: Blackwell Scientific.

Maitland, P. S. 1966. *The fauna of the River Endrick.* Glasgow: Blackie.

Maitland, P. S. 1972. *A key to the freshwater fishes of the British Isles, with notes on their distribution and ecology.* (Scientific publications no. 27.) Windermere: Freshwater Biological Association.

Maitland, P. S. 1979. *Synoptic limnology. The analysis of British freshwater ecosystems.* Cambridge: Institute of Terrestrial Ecology.

Maitland, P. S. 1985. Criteria for the selection of important sites for freshwater fish in the British Isles. *Biol. Conserv,* **31,** 335-353.

Maizels, J. K. 1985. The physical background of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 7-22. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Moon, H. P. 1938. Importance of the substratum to the invertebrate animals on which fish feed. *Ann. Rep. Avon. biol. Res.*, 6th, 36-40.

Pennak, R. W. 1971. Towards a classification of lotic habitats. *Hydrobiologia,* **38,** 321-324. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Pugh, K. B. 1985. The chemistry of the River Dee. In: The biology and management of the River Dee, edited by D. Jenkins, 34-41.

Ratcliffe, D. A., ed. 1977. *A nature conservation review: the selection of biological sites of national importance to nature conservation in Britain.* 2v. Cambridge: Cambridge University Press.

Ricker, W. E. 1934. An ecological classification of certain Ontario streams. *Univ. Toronto Stud. biol. Ser.,* **37,** 1-114.

Scottish Development Department. 1976. *Towards cleaner water 1975.* Edinburgh: HMSO.

Scottish Development Department. 1983. *Water pollution control in Scotland: recent developments.* Edinburgh: SDD.

Warren, J. S. 1985. The hydrology of the River Dee. In: *The biology and management of the River Dee,* edited by D. Jenkins, 23-28. (ITE symposium no. 14.) Abbots Ripton: Institute of Terrestrial Ecology.

Water Data Unit. 1982. *Surface water: United Kingdom 1974-76.* London: HMSO.

Wright, J. F., Moss, D., Armitage, P. D. & Furse, M. T. 1984. A preliminary classification of running-water sites in Great Britain based on macro-invertebrate species and the prediction of community type using environmental data. *Freshwater Biol.,* **14,** 221-256.

Concluding comments

C H GIMINGHAM
Department of Plant Science, University of Aberdeen

1 Introduction

It will be evident from the collected papers that the conference effectively combined presentation of scientific studies of the River Dee and its surroundings with discussions of practical problems relating to management. The assembled information ranges across a wide spectrum of disciplines, and the views expressed represent a considerable variety of interests. Much of the success of the symposium derived from the way in which scientists and historians, landowners and engineers, managers and sportsmen, conservationists and 'recreationists', foresters and agriculturists were all drawn into a discussion on the past, present and future of what, by common agreement, was regarded as a resource of unique value.

There is little point in rehearsing here the contents of the various contributions; however, it may be useful in these concluding comments to touch on the extent to which the symposium achieved its objectives, and to present some of the views expressed in the final discussions, particularly as regards future action. The stated aims were 'To assess existing knowledge of the river system and to identify gaps in knowledge, to assess the interests of people in the river system and possible conflicts between these interests, and to consider the current management of the system'.

2 The scientific assessment

An impressive array of scientific observations and data was presented, extending from the geomorphological evolution of the river system and its bed, to features of the flow and chemical composition of the water, the aquatic and riverside vegetation, and the invertebrate and vertebrate fauna. While in the course of time changes of land use in the catchment, modifications of the course of the river, management of its banks and extraction of its water have all had their effects, the fact remains that the Dee has been much less influenced by such activities than most other British rivers of equivalent size. The water quality remains virtually undiminished throughout its length, pollution is minimal, quickly diluted and dispersed, and the river is oligotrophic from source to sea. These features, together with the 'alpine' type of flow regime, confer upon it genuine distinction in scientific terms. Furthermore, although the pure acidic and nutrient-poor water does not encourage a highly diverse or species rich fauna and flora, there are nonetheless numerous components of special interest, and in several cases rarity. The landscape through which the river flows is of spectacular beauty and charm, and in terms of ecological and natural history interest ranks highly. During the symposium, a very positive, affirmative answer was given to the question 'Is the River Dee of exceptional value scientifically, and is it sufficiently important to merit efforts to ensure its conservation?'

Detailed attention to this question led to the conclusion that the river and its catchment are, indeed, of national importance in conservation terms.

The scientific assessment also involved consideration of the history of the river system and the nature of the processes at work at the present time. Past changes in the course of the river, with the creation of terraces, abandoned channels, islands and other features, have greatly enhanced the diversity of habitats and consequently of the fauna and flora. However, increasing use of the floodplain in the lower reaches of the valley for agriculture and other purposes has led to a variety of measures designed to control or regulate natural processes such as flooding or bank erosion. The implications of these measures are often difficult to predict, and their ecological consequences may be unknown.

This highlighted the incompleteness of the scientific assessment, which, though extensive, revealed many gaps. For example, while flow rates have been monitored at several stations over a considerable period of years and correlated with climatic fluctuations, little is known of whether the changes represent long-term trends, or may be cyclic in nature. In view of the apparent increased incidence of periods of low flow in recent years, this kind of information is needed to answer the question as to whether these are caused by changes in the hydrology of the river, or by changes in climate.

There are, also, few data on current rates of bank erosion, or of the wider effects of control measures. The sources and higher reaches of the river have received relatively little attention, and there are conspicuous gaps in the documentation of the flora and fauna. In particular, there is much detail still to be added to the description of the often rich and varied plant communities of the river banks, while the invertebrate fauna would also repay more intensive sampling. Of the larger animals, little is known of the small mammals (eg water voles and water shrews) or of the sorts of places where otters have their young, while the status and distribution of the coarse fish are insufficiently investigated. Apart from the straightforward documentation, more attention to the ecology of the plant and animal populations of the river would help to establish some important points which remain obscure, for example the effects upon them of past losses of deciduous woodland which formerly fringed the river throughout much of its length, and the changes which might be expected if it were to be restored in selected locations.

3 Assessment of interests and demands upon the river and its catchment

The symposium drew attention to the fact that the river and its surroundings are of social and economic importance in a widely ranging variety of ways. Past patterns of agriculture and forestry in the area have, perhaps, had rather little direct effect, except where they have brought about replacement of deciduous trees by conifers, or by fields close to the river banks. Eutrophication from agricultural fertilizers, however, has evidently not been a major problem. The 2 main demands upon the river itself concern, first, water abstraction, chiefly to supply the needs of Aberdeen city, and, second, fishing. Demands for water have risen over the years at an increasing pace, to a point at which they may conflict with the interests of fishing at times when the river is low. The importance of the Dee as a salmon river was undisputed, and was regarded as conferring upon it national, if not international, significance. Understandably, this is an aspect of major concern to the landowners through whose estates the river flows.

People appreciate the river and its surroundings for a variety of other reasons. Its varied scenery has a wide appeal and positive economic value as a tourist attraction, while the banks provide opportunities for informal recreation and the river itself for canoeing. Certain conflicts were identified among these demands, but in general these were regarded as of minor significance and capable of solution by consultation between the parties concerned. However, there is no doubt that the pressures are increasing and the dangers inherent in uncontrolled access to this amenity are real.

4 Rates of change — cause for concern?

Most of the papers in the symposium were concerned with establishing the scientific importance of the river and its surroundings, and identifying the values placed upon it by the community. Having recognized it as a unique asset, the question arose as to whether it can confidently be expected that its special qualities will survive substantially undiminished, in the absence of measures designed to conserve them. While there was a fair degree of optimism, it was also felt that in view of the rapidity of environmental change at present, even in sparsely populated areas, it would be a mistake to be complacent. What was important was to be aware of, and in a position to monitor, changes that may be taking place.

In certain respects, valuable monitoring is already being carried out. Rainfall is measured at a number of stations, and both flow and chemical composition are recorded regularly at selected sites along the whole length of the river. Biological monitoring is also conducted on a regular basis. Statistics are available on the salmon catches over a period of at least 30 years. However, in the course of discussion, it became evident that in a number of respects the research base for detecting potentially damaging changes is inadequate or lacking. Reference was made, for example, to the need to follow the effects on soil or water of changes of land use in the catchment affecting the balance between livestock and arable farming, or between agriculture and forestry, which may be initiated by alterations in EEC policies or other social changes. The possibility that further extensive afforestation in the catchment might affect its hydrology was evidently very much a matter of debate. Emphasis was therefore placed on the need to obtain actual measurements of the effects of plantation on evapotranspiration in this area. This would require a substantial research input. Similarly, the extent to which fertilizer applications during the establishment of plantations might lead to elevated concentrations of certain nutrients (notably phosphorus) in the river water is relatively unexplored. This factor was thought unlikely to be of significance because it would apply only where the water drains entirely through peat. Care is normally taken to ensure that drainage water must pass through mineral material, which extracts the excess phosphorus. However, this is a topic which merits further investigation with a view to checking whether or not recommended practice is always followed.

Another urgent problem may be the effects of acid rain. The North East River Purification Board, recognizing the possibility of damaging consequences, has initiated monthly monitoring at a number of sites in the upper reaches of the river system, and has identified a small number of locations which may be especially at risk in respect of the ability of the river water to buffer changes in acidity. However, the Board has neither the capacity nor the funds to undertake the intensive research necessary for continual monitoring, in order to detect what might be infrequent but heavy pollution 'events' (eg acid snow). It was argued that here there is a major research programme waiting to be undertaken if resources could be obtained, and a framework set up to promote collaboration between different organizations. Furthermore, apart from the question of acid rain, there was evidently a need for much more information, both chemical and biological, from the upper sections of the river system.

With the greatly increased abstraction of water from the river and new 'bed intakes', the point was made that, while flow is recorded at various stations along the river, management requires detailed knowledge of conditions at the point of intervention. Attempts to reconcile measurements from different gauging stations show that significant losses and gains may occur unexpectedly, possibly as a result of exchanges with the gravels of the floodplain. This again represents a potential cause of change in the system about which there is insufficient information.

The conditions of flow in the river, especially at times of low flow, affect the movement of salmon. While there has been effective co-operation between the Water Services of the Grampian Regional Council and various salmon fishing interests, knowledge of variation in the fish populations of the river is limited to the statistics of the catches. The Dee salmon constitutes such an important resource, which is susceptible to change induced by a variety of causes, that it was felt to be a matter of urgency to rectify this situation and seek means to conduct a much more thorough examination of the ecology of salmon in the Dee, along lines which have been successfully developed in other rivers.

5 A proposal for action

The river is a changing system; it has altered a great deal in the past and will continue to alter in the future. It was recognized that there is no merit in trying to preserve the river exactly as it is at present. However, while most other rivers have lost much or all of their original character, the Dee has not suffered to the same extent. It is therefore a strong contender for conservation as an example of an oligotrophic river. A good deal has already been achieved by informal consultation between interested groups. However, members of the symposium felt strongly that there should be moves towards a more integrated type of management, not imposing arbitrary rules but promoting communication and understanding of the varying attributes of the river which people appreciate, and the several demands made upon it. Landowners, managers, naturalists, and representatives of water authorities, fishing and recreational interests all expressed their sympathy with conservation objectives and their willingness to collaborate to promote these and to remove any sources of conflict. (An encouraging example of such collaboration was the successful establishment of an 'otter haven' on the river.) The need for public understanding and support, and the desirability of education to that end, were also stressed.

It became evident that there was a considerable body of opinion in favour of setting up an advisory group, which would provide the opportunity for all interests to interact and work towards the integration of management activities. Such a group could also focus attention on the gaps in knowledge and understanding of the processes at work in the river and its catchment, and seek resources to encourage the necessary research. It was felt that it would be most appropriate for a group of this kind to have a formal link with the local authority and its planning department, and it was decided to explore this proposal further.

Appendix I

LIST OF PARTICIPANTS

Mr C O Badenoch, Nature Conservancy Council, Galahill House, Barr Road, *Galashiels*, TD1 3HX.

Mr R Balharry, Nature Conservancy Council, Wynne-Edwards House, 17 Rubislaw Terrace, *Aberdeen*, AB1 1XE.

Dr N G Bayfield, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Dr M V Bell, Institute of Marine Biochemistry, St Fittick's Road, Torry, *Aberdeen*, AB1 3RA.

Mr H L Black, North of Scotland College of Agriculture, Agriculture College Office, 21 Evan Street, *Stonehaven*, AB3 2EQ.

Mrs M Borthwick, Department of Physical Planning, Grampian Regional Council, Woodhill House, Ashgrove Road West, *Aberdeen*, AB9 2LU.

Mr I D Brown, Director of Water Services, Grampian Regional Council, Woodhill House, Ashgrove Road West, *Aberdeen*, AB9 2LU.

Mr R N Campbell, Tigh-Ur, Killiecrankie, by *Pitlochry*, Perthshire, PH16 5NP.

Dr R N B Campbell, Institute of Terrestrial Ecology, Bush Estate, *Penicuik*, Midlothian, EH 26 0QB.

Mr J W H Conroy, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Miss S M M Cooper, Rector, Aboyne Academy, Bridgeview Road, *Aboyne*, Aberdeenshire, AB3 5JN.

Dr G Dalton, North of Scotland College of Agriculture, School of Agriculture, 581 King Street, *Aberdeen*, AB9 1UD.

Mr M B Davidson, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr R Dennis, Royal Society for the Protection of Birds, RSPB Highland Office, *Munlochy*, Ross & Cromarty, IV8 8ND.

Mr D Dunkley, Department of Agriculture and Fisheries for Scotland, 6 California Street, *Montrose*, Angus, DD10 8DN.

Dr E Farr, North of Scotland College of Agriculture, School of Agriculture, 581 King Street, *Aberdeen*, AB9 1UD.

Mr J A Forster, Careers Advisory Office, University of Aberdeen, University Office, Regent Walk, *Aberdeen*, AB9 1FX.

Major H F B Foster, Park House, Drumoak, *Banchory*, Kincardineshire, AB3 3AD.

Mr I Fozzard, Forth River Purification Board, Causewayhead Old School, Alloa Road, *Stirling*, FK9 5NP.

Mr W Gardner, 3 Mill of Dinnet, Dinnet, *Aboyne*, Aberdeenshire, AB3 5LA.

Professor C H Gimingham, Department of Botany, University of Aberdeen, St Machar Drive, *Aberdeen*, AB9 2UD.

Miss J Green, Nature Conservancy Council, Wynne-Edwards House, 17 Rubislaw Terrace, *Aberdeen*, AB1 1XE.

Dr D Groman, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr H A Hawkes, 154 Orphanage Road, Erdington, *Birmingham*, B24 0AA.

Mr & Mrs J Hepburn, Badcall Bay, Scourie, by *Lairg*, Sutherland, IV27 4TH.

Mr A Holden, Ach-na-Sithe, Manse Road, Moulin, *Pitlochry*, Perthshire.

Dr N T H Holmes, Nature Conservancy Council, Northminster House, *Peterborough*, PE1 1UA.

Mr J M M Humphrey, Estate Office, Dinnet, *Aboyne*, Aberdeenshire, AB3 5LL.

Dr D Jenkins, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Mr W Kellas, 138 Gray Street, *Aberdeen*, AB1 6JU.

Dr J B Kenworthy, Department of Botany, University of Aberdeen, St Machar Drive, *Aberdeen*, AB9 2UD.

Dr H Kruuk, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Mr J A Lewis, 80 Beaconsfield Place, *Aberdeen*, AB2 4AJ.

Mr D Litten, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr F Little, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr C I Lumsden, Laramie, Muiresk Drive, *Turriff*, Aberdeenshire, AB5 7BB.

Mr G Macdonald, Environmental Education Resource Base, Ballater Outdoor Centre, School Lane, *Ballater*, Aberdeenshire, AB3 5RJ.

Mr T D Macdonald, Scottish Development Department, Pentland House, 47 Robbs Loan, *Edinburgh*, EH14 1TY.

Professor A D McIntyre, Department of Agriculture and Fisheries for Scotland, Marine Laboratory, PO Box 101, Victoria Road, Torry, *Aberdeen*, AB9 8DB.

Dr P S Maitland, Institute of Terrestrial Ecology, Bush Estate, *Penicuik*, Midlothian, EH26 0QB.

Dr Judith K Maizels, University of Aberdeen, Department of Geography, St Mary's, High Street, *Old Aberdeen*, AB9 2UF.

Mr P R Marren, Nature Conservancy Council, Foxhold House, Thornford Road, Crookham Common, *Newbury*, Berkshire, RG15 8EL.

Mr N G Marr, Kincardine & Deeside District Council, Carlton House, Arduthie Road, *Stonehaven*, AB3 2DP.

Dr M Marquiss, Institute of Terrestrial Ecology, Bush Estate, *Penicuik*, Midlothian, EH26 0QB.

Mr E M Matthew, Nature Conservancy Council, Wynne-Edwards House, 17 Rubislaw Terrace, *Aberdeen*, AB1 1XE.

Mr J F Mellanby, Grampian Regional Council, Woodhill House, Ashgrove Road West, *Aberdeen*, AB9 2LU.

Dr J Miles, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Dr G R Miller, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Professor H G Miller, Department of Forestry, University of Aberdeen, St Machar Drive, *Aberdeen*, AB9 2UU.

Miss K Miller, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr R C Milligan, Shell UK Exploration and Production, 1 Altens Farm Road, Nigg, *Aberdeen*, AB9 2HY.

Mr James M Mitchell, Messrs A J Tulloch, Commercial Quay, *Aberdeen*, AB1 2PH.

Dr E A Needham, Hayes McCubbin Macfarlane, 11 Rubislaw Terrace, *Aberdeen*, AB1 1XE.

Dr C Newbold, Nature Conservancy Council, Northminster House, *Peterborough*, PE1 1UA.

Dr I Newton, Institute of Terrestrial Ecology, Monks Wood Experimental Station, Abbots Ripton, *Huntingdon*, Cambs, PE17 2LS.

Mr I A Nicholson, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Mr A H Nicol, Estates Office, Ballogie, *Aboyne*, Aberdeenshire, AB3 5DT.

Mr R M G O'Brien, Education Department, Grampian Regional Council, Moray Divisional Education Offices, Academy Street, *Elgin*, IV30 1LL.

Mr J Oswald, 3 Bush Cottages, Glen Tanar, *Aboyne*, Aberdeenshire, AB3 5EU.

Dr R P Owen, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr J Parkin, Nature Conservancy Council, New Kinord House, Dinnet, *Aboyne*, Aberdeenshire, AB3 5LQ.

Mr I S Paterson, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Mr A M Pelham-Burn, Knappach, *Banchory*, Kincardineshire, AB3 3JS.

Mr N Picozzi, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Dr J D Pirie, Department of Natural Philosophy, University of Aberdeen, *Aberdeen*, AB9 2UE.

Dr K B Pugh, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Professor P A Racey, Department of Zoology, University of Aberdeen, Tillydrone Avenue, *Aberdeen*, AB9 2TN.

Mr D Rice, Countryside Commission for Scotland, Battleby, Redgorton, *Perth*, PH1 3EW.

Mr K Robertson, Laird's Cast, Inchmarlo Road, *Banchory*, Kincardineshire, AB3 3RR.

Mr P I Rothwell, Nature Conservancy Council, Wynne-Edwards House, 17 Rubislaw Terrace, *Aberdeen*, AB1 1XE.

Mr J A Ruxton, Department of Water Services, Grampian Regional Council, Woodhill House, Ashgrove Road West, *Aberdeen*, AB9 2LU.

Mr S H Ali Al-Thanoon, Department of Botany, University of Aberdeen, St Machar Drive, *Aberdeen*, AB9 2UD.

Mr J R Scott, Secretary, Aberdeen Harbour Board, 16 Regent Quay, *Aberdeen*, AB1 2AE.

Mr W M Shearer, Department of Agriculture and Fisheries for Scotland, Freshwater Fisheries Laboratory, 6 California Street, *Montrose*, Angus, DD10 8DW.

Dr R G J Shelton, Department of Agriculture and Fisheries for Scotland, Freshwater Fisheries Laboratory, Faskally, *Pitlochry*, Perthshire, PH16 5LB.

Mr I R Smith, Institute of Terrestrial Ecology, Bush Estate, *Penicuik*, Midlothian, EH26 0QB.

Dr J S Smith, Department of Geography, University of Aberdeen, St Mary's, High Street, *Old Aberdeen*, AB9 2UF.

Dr J Speakman, Department of Zoology, University of Aberdeen, Tillydrone Avenue, *Aberdeen*, AB9 2TN.

Dr B W Staines, Institute of Terrestrial Ecology, Hill of Brathens, *Banchory*, Kincardineshire, AB3 4BY.

Mr M Stephenson, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr B L Strachan, Mill of Strachan, Strachan, by *Banchory*, Kincardineshire, AB3 3NS.

Mr G G M Taylor, Forestry Commission, East (Scotland) Conservancy, 6 Queen's Gate, *Aberdeen*, AB9 2NQ.

Dr J Treasurer, Hospital Services Administrator, Woodend General Hospital, Eday Road, *Aberdeen*, AB9 2YS.

Mr G Tuley, Forestry Commission, Kirkton of Durris, *Banchory*, Kincardineshire, AB3 3BP.

Mr J S Warren, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Mr R D Watson, North East Mountain Trust, 396 King Street, *Aberdeen*, AB2 3BY.

The Hon D N Weir, c/o Highland Wildlife Park, *Kincraig*, Kingussie, Inverness-shire, PH21 1ND.

Dr B B Willetts, Department of Engineering, University of Aberdeen, Marischal College, *Aberdeen*, AB9 1AS.

Dr W Williams, Nature Conservancy Council, Wynne-Edwards House, 17 Rubislaw Terrace, *Aberdeen*, AB1 1XE.

Miss E Woodward, Department of Physical Planning, Grampian Regional Council, Woodhill House, Ashgrove Road West, *Aberdeen*, AB9 2LU.

Mrs R Worsman, North East River Purification Board, Woodside House, Persley, *Aberdeen*, AB2 2UQ.

Dr R A D Wright, Shell UK Exploration and Production, 1 Altens Farm Road, Nigg, *Aberdeen*, AB9 2HY.

Dr M R Young, Department of Zoology, University of Aberdeen, Tillydrone Avenue, *Aberdeen*, AB9 2TN.

Appendix II

LIST OF PLANT AND ANIMAL SPECIES REFERRED TO IN THE TEXT WITH BOTH THEIR COMMON ENGLISH NAME AND THEIR LATIN BINOMIAL

1 Plants (common English names are rarely used either for algae, lichens, liverworts and mosses, or for most invertebrates. These species have therefore only been included in the lists of Latin names)

1.1 Listed by common English name

Alder	*Alnus glutinosa*
Alternate water-milfoil	*Myriophyllum alterniflorum*
Amphibious bistort	*Polygonum amphibium*
Annual meadow-grass	*Poa annua*
Ash	*Fraxinus excelsior*
Aspen	*Populus tremula*
Bay willow	*Salix pentandra*
Beech	*Fagus sylvatica*
Bell heather	*Erica cinerea*
Bilberry	*Vaccinium myrtillus*
Bird cherry	*Prunus padus*
Bistort	*Polygonum crispus*
Bistort	*Polygonum natans*
Bistort	*Polygonum pectinatus*
Bistort	*Polygonum perfoliatus*
Bitter vetch	*Lathyrus montanus*
Bittersweet	*Solanum dulcamara*
Blinks	*Montia fontana*
Blue water-speedwell	*Veronica anagallis-aquatica*
Bog pondweed	*Potamogeton polygonifolius*
Bog stitchwort	*Stellaria alsine*
Bottle sedge	*Carex rostrata*
Bracken	*Pteridium aquilinum*
Bramble	*Rubus fruticosus*
Branched bur-reed	*Sparganium erectum*
Broad-leaved pondweed	*Potamogeton natans*
Brooklime	*Veronica beccabunga*
Broom	*Sarothamnus scoparius*
Brown bent	*Agrostis canina*
Bugle	*Ajuga reptans*
Bulbous rush	*Juncus bulbosus*
Burnet-saxifrage	*Pimpinella saxifraga*
Bur-reed	*Sparganium* spp.
Bush vetch	*Vicia sepium*
Butterbur	*Petasites hybridus*
Buttercup	*Ranunculus calcareus*
Canadian waterweed	*Elodea canadensis*
Canary-grass	*Phalaris canariensis*
Carnation sedge	*Carex panicea*
Cat's-ear	*Hypochoeris radicata*
Celery-leaved buttercup	*Ranunculus scleratus*
Clover	*Trifolium* spp.
Cock's-foot	*Dactylis glomerata*
Colt's-foot	*Tussilago farfara*
Common bent	*Agrostis tenuis*
Common bistort	*Polygonum bistorta*
Common comfrey	*Symphytum officinale*
Common dog-violet	*Viola riviniana*
Common duckweek	*Lemna minor*
Common figwort	*Scrophularia nodosa*
Common knapweed	*Centaurea nigra*
Common marsh-bedstraw	*Galium palustre*
Common nettle	*Urtica dioica*
Common ragwort	*Senecio jacobaea*
Common rock-rose	*Helianthemum chamaecistus*
Common sedge	*Carex nigra*
Common spike-rush	*Eleocharis palustris*
Common valerian	*Valeriana officinalis*
Common water-crowfoot	*Ranunculus aquatilis*
Common water-starwort	*Callitriche stagnalis*
Common wintergreen	*Pyrola minor*
Common yellow-sedge	*Carex demissa*
Cottongrass	*Eriophorum* spp.
Creeping bent	*Agrostis stolonifera*
Creeping buttercup	*Ranunculus repens*
Creeping yellow-cress	*Rorippa sylvestris*
Crested dog's-tail	*Cynosurus cristatus*
Cuckooflower	*Cardamine pratensis*
Curled pondweed	*Potamogeton crispus*
Deergrass	*Trichophorum cespitosum*
Devil's-bit scabious	*Succisa pratensis*
Dog's mercury	*Mercurialis perennis*
Douglas fir	*Pseudotsuga menziesii*
Downy birch	*Betula pubescens*
Eared willow	*Salix aurita*
European larch	*Larix decidua*
Eyebright	*Euphrasia officinalis*
False oat-grass	*Arrhenatherum elatius*
Fescue	*Festuca* spp.
Field forget-me-not	*Myosotis arvensis*
Field horsetail	*Equisetum arvense*
Fine-leaved sheep's-fescue	*Festuca tenuifolia*
Floating bur-reed	*Sparganium angustifolium*
Floating club-rush	*Scirpus fluitans*
Floating sweet-grass	*Glyceria fluitans*
Fool's water-cress	*Apium nodiflorum*
Forget-me-not	*Myosotis palustris*
Foxglove	*Digitalis purpurea*
Germander speedwell	*Veronica chamaedrys*
Glaucous sedge	*Carex flacca*
Globeflower	*Trollius europaeus*
Goat willow	*Salix caprea*
Goldenrod	*Solidago virgaurea*
Goldilocks buttercup	*Ranunculus auricomus*
Gorse	*Ulex europaeus*
Grand fir	*Abies grandis*
Great willowherb	*Epilobium hirsutum*
Great wood-rush	*Luzula sylvatica*
Great yellow-cress	*Rorippa amphibia*
Greater bird's-foot-trefoil	*Lotus uliginosus*
Greater pond-sedge	*Carex riparia*
Green water-cress	*Nasturtium officinale*
Green-ribbed sedge	*Carex binervis*
Grey willow	*Salix cinerea*
Hairy sedge	*Carex hirta*
Hairy St John's-wort	*Hypericum hirsutum*
Hard rush	*Juncus inflexus*
Harebell	*Campanula rotundifolia*
Hazel	*Corylus avellana*
Heath bedstraw	*Galium saxatile*
Heath rush	*Juncus squarrosus*
Heath speedwell	*Veronica officinalis*
Heather	*Calluna vulgaris*
Hedge woundwort	*Stachys sylvatica*
Hemlock water-dropwort	*Oenanthe crocata*
Herb-Robert	*Geranium robertianum*
Hogweed	*Heracleum sphondylium*
Horned pondweed	*Zannichellia palustris*
Imperforate St John's-wort	*Hypericum maculatum*
Indian balsam	*Impatiens glandulifera*
Japanese larch	*Larix leptolepis*
Jointed rush	*Juncus articulatus*
Lady's bedstraw	*Galium verum*
Lady's mantle	*Alchemilla glabra*

Lady's mantle	*A. filicaulis* subsp. *vestita*
Lady's mantle	*A. xanthochlora*
Large bitter-cress	*Cardamine amara*
Leopard's-bane	*Doronicum pardalianches*
Lesser clubmoss	*Selaginella selaginoides*
Lesser spearwort	*Ranunculus flammula*
Lesser stitchwort	*Stellaria graminea*
Lodgepole pine	*Pinus contorta*
Long-stalked yellow-sedge	*Carex lepidocarpa*
Lupin	*Lupinus* spp.
Mackay's horsetail	*Equisetum* x *trachyodon*
Maiden pink	*Dianthus deltoides*
Marsh foxtail	*Alopecurus geniculatus*
Marsh horsetail	*Equisetum palustre*
Marsh-marigold	*Caltha palustris*
Marsh violet	*Viola palustris*
Marsh woundwort	*Stachys palustris*
Mat-grass	*Nardus stricta*
Meadow buttercup	*Ranunculus acris*
Meadow-grass	*Poa* spp.
Meadow oat-grass	*Helictotrichon pratense*
Meadow vetchling	*Lathyrus pratensis*
Meadowsweet	*Filipendula ulmaria*
Melancholy thistle	*Cirsium heterophyllum*
Monkeyflower	*Mimulus guttatus*
Moss campion	*Silene acaulis*
Mountain sorrel	*Oxyria digyna*
Mouse-ear hawkweed	*Hieracium pilosella*
Noble fir	*Abies procera*
Nootka lupin	*Lupinus nootkatensis*
Northern bedstraw	*Galium boreale*
Northern dock	*Rumex longifolius*
Northern marsh-orchid	*Dactylorhiza purpurella*
Northern rock-cress	*Cardaminopsis petraea*
Norway spruce	*Picea abies*
Orpine	*Sedum telephium*
Osier	*Salix viminalis*
Oval sedge	*Carex ovalis*
Oxeye daisy	*Leucanthemum vulgare*
Pedunculate oak	*Quercus robur*
Perennial rye-grass	*Lolium perenne*
Perforate St John's-wort	*Hypericum perforatum*
Pignut	*Conopodium majus*
Polypody	*Polypodium vulgare*
Primrose	*Primula vulgaris*
Procumbent pearlwort	*Sagina procumbens*
Purple moor-grass	*Molinia caerulea*
Quaking-grass	*Briza media*
Ragged-robin	*Lychnis flos-cuculi*
Red currant	*Ribes rubrum*
Reed canary-grass	*Phalaris arundinacea*
Reed sweet-grass	*Glyceria maxima*
Remote sedge	*Carex remota*
Ribwort plantain	*Plantago lanceolata*
River water-crowfoot	*Ranunculus fluitans*
Rosebay willowherb	*Chamerion angustifolium*
Rough horsetail	*Equisetum hyemale*
Rowan	*Sorbus aucuparia*
Scots pine	*Pinus sylvestris*
Scurvygrass	*Cochlearia* spp.
Sea campion	*Silene maritima*
Selfheal	*Prunella vulgaris*
Sessile oak	*Quercus petraea*
Sharp-flowered rush	*Juncus acutiflorus*
Sheep's-fescue	*Festuca ovina*
Shoreweed	*Littorella uniflora*
Sibbaldia	*Sibbaldia procumbens*
Silver birch	*Betula pendula*
Sitka spruce	*Picea sitchensis*
Slender St John's-wort	*Hypericum pulchrum*
Smith's pepperwort	*Lepidium heterophyllum*
Smooth meadow-grass	*Poa pratensis*
Sneezewort	*Achillea ptarmica*
Soft rush	*Juncus effusus*
Spear mint	*Mentha spicata*
Spignel	*Meum athamanticum*
Spiked water-milfoil	*Myriophyllum spicatum*
Star sedge	*Carex echinata*
Starwort	*Callitriche hamulata*
Sweet Cicely	*Myrrhis odorata*
Sweet vernal-grass	*Anthoxanthum odoratum*
Sycamore	*Acer pseudoplatanus*
Tall fescue	*Festuca arundinacea*
Thrift	*Armeria maritima*
Toad rush	*Juncus bufonius*
Tormentil	*Potentilla erecta*
Tufted hair-grass	*Deschampsia cespitosa*
Tufted vetch	*Vicia cracca*
Unbranched bur-reed	*Sparganium emersum*
Water avens	*Geum rivale*
Water chickweed	*Myosoton aquaticum*
Water clubmoss	*Selaginella aquaticus*
Water figwort	*Scrophularia auriculata*
Water forget-me-not	*Myosotis scorpioides*
Water horsetail	*Equisetum fluviatile*
Water mint	*Mentha aquatica*
Water sedge	*Carex aquatilis*
Western hemlock	*Tsuga heterophylla*
White willow	*Salix alba*
Wild angelica	*Angelica sylvestris*
Wild basil	*Clinopodium vulgare*
Wild pansy	*Viola tricolor*
Wild strawberry	*Fragaria vesca*
Wild thyme	*Thymus drucei*
Wood avens	*Geum urbanum*
Wood club-rush	*Scirpus sylvaticus*
Wood crane's-bill	*Geranium sylvaticum*
Wood horsetail	*Equisetum sylvaticum*
Wood meadow-grass	*Poa nemoralis*
Wood-rush	*Luzula* spp.
Wych elm	*Ulmus glabra*
Yellow-cress	*Rorippa palustris*
Yellow-cress	*Rorippa lacustris*
Yellow iris	*Iris pseudacorus*
Yellow pimpernel	*Lysimachia nemorum*
Yellow rattle	*Rhinanthus minor*
Yellow saxifrage	*Saxifraga aizoides*

1.2 Listed by Latin binomial

Abies grandis	Grand fir
Abies procera	Noble fir
Acer pseudoplatanus	Sycamore
Achillea ptarmica	Sneezewort
Agrostis canina	Brown bent
Agrostis stolonifera	Creeping bent
Agrostis tenuis	Common bent
Ajuga reptans	Bugle
Alchemilla glabra	Lady's mantle
Alchemilla filicaulis subsp. *vestita*	Lady's mantle
Alchemilla xanthochlora	Lady's mantle
Alnus glutinosa	Alder
Alopecurus geniculatus	Marsh foxtail
Amblystegium fluviatile	(Moss)
Amblystegium riparium	(Moss)
Angelica sylvestris	Wild angelica
Anomobryum filiforme	(Moss)
Anthelia julacea	(Liverwort)
Anthoxanthum odoratum	Sweet vernal-grass
Aphanizomenon flos-aquae	(Alga)
Apium nodiflorum	Fool's water-cress
Armeria maritima	Thrift
Arrhenatherum elatius	False oat-grass
Atrichum tenellum	(Moss)
Aulacomnium palustre	(Moss)
Barbula recurvirostra	(Moss)

Betula pendula	Silver birch
Betula pubescens	Downy birch
Blasia pusilla	(Liverwort)
Blindia acuta	(Moss)
Brachythecium mildeanum	(Moss)
Brachythecium plumosum	(Moss)
Brachythecium rivulare	(Moss)
Brachythecium rutabulum	(Moss)
Briza media	Quaking-grass
Bryum alpinum	(Moss)
Bryum argenteum	(Moss)
Bryum pallens	(Moss)
Bryum pseudotriquetrum	(Moss)
Calliergon cuspidatum	(Moss)
Calliergon giganteum	(Moss)
Callitriche hamulata	Starwort
Callitriche stagnalis	Common water-starwort
Calluna vulgaris	Heather
Caltha palustris	Marsh-marigold
Campanula rotundifolia	Harebell
Cardamine amara	Large bitter-cress
Cardamine pratensis	Cuckooflower
Cardaminopsis petraea	Northern rock-cress
Carex aquatilis	Water sedge
Carex binervis	Green-ribbed sedge
Carex demissa	Common yellow-sedge
Carex echinata	Star sedge
Carex flacca	Glaucous sedge
Carex hirta	Hairy sedge
Carex lepidocarpa	Long-stalked yellow-sedge
Carex nigra	Common sedge
Carex ovalis	Oval sedge
Carex panicea	Carnation sedge
Carex remota	Remote sedge
Carex riparia	Greater pond-sedge
Carex rostrata	Bottle sedge
Centaurea nigra	Common knapweed
Cephalozia bicuspidata	(Liverwort)
Chamaesiphon spp.	(Algae)
Chamerion angustifolium	Rosebay willowherb
Chiloscyphus polyanthos	(Liverwort)
Cinclidotus fontinaloides	(Moss)
Cirsium heterophyllum	Melancholy thistle
Cladophora aegagropila	(Alga)
Cladophora glomerata	(Alga)
Climacium dendroides	(Moss)
Clinopodium vulgare	Wild basil
Cochlearia spp.	Scurvygrass
Collema fluviatile	(Lichen)
Conocephalum conicum	(Liverwort)
Conopodium majus	Pignut
Corylus avellana	Hazel
Cynosurus cristatus	Crested dog's-tail
Dactylis glomerata	Cock's-foot
Dactylorhiza purpurella	Northern marsh-orchid
Dermatocarpon fluviatile	(Lichen)
Deschampsia cespitosa	Tufted hair-grass
Dianthus deltoides	Maiden pink
Dichodontium flavescens	(Moss)
Dichodontium pellucidum	(Moss)
Dicranella palustris	(Moss)
Dicranella rufescens	(Moss)
Didymosphenia geminata	(Alga)
Digitalis purpurea	Foxglove
Doronicum pardalianches	Leopard's-bane
Drepanocladus revolvens	(Moss)
Eleocharis palustris	Common spike-rush
Elodea canadensis	Canadian waterweed
Enteromorpha spp.	(Algae)
[*Ephydatia fluviatilis*	(Sponge)]
Epilobium hirsutum	Great willowherb
Equisetum arvense	Field horsetail
Equisetum fluviatile	Water horsetail
Equisetum hyemale	Rough horsetail
Equisetum palustre	Marsh horsetail
Equisetum sylvaticum	Wood horsetail
Equisetum x trachyodon	Mackay's horsetail
Erica cinerea	Bell heather
Eriophorum spp.	Cottongrass
Euphrasia officinalis	Eyebright
Fagus sylvatica	Beech
Festuca arundinacea	Tall fescue
Festuca ovina	Sheep's-fescue
Festuca tenuifolia	Fine-leaved sheep's-fescue
Filipendula ulmaria	Meadowsweet
Fissidens viridulus	(Moss)
Fontinalis antipyretica	(Moss)
Fontinalis squamosa	(Moss)
Fragaria vesca	Wild strawberry
Fraxinus excelsior	Ash
Galium boreale	Northern bedstraw
Galium palustre	Common marsh-bedstraw
Galium saxatile	Heath bedstraw
Galium verum	Lady's bedstraw
Geranium robertianum	Herb-Robert
Geranium sylvaticum	Wood crane's-bill
Geum rivale	Water avens
Geum urbanum	Wood avens
Glyceria fluitans	Floating sweet-grass
Glyceria maxima	Reed sweet-grass
Gymnostomum aeruginosum	(Moss)
Helianthemum chamaecistus	Common rock-rose
Helictotrichon pratense	Meadow oat-grass
Heracleum sphondylium	Hogweed
Hieracium pilosella	Mouse-ear hawkweed
Hildenbrandia rivularis	(Alga)
Hygrobiella laxifolia	(Liverwort)
Hygrohypnum luridum	(Moss)
Hygrohypnum ochraceum	(Moss)
Hygrohypnum smithii	(Moss)
Hylocomium splendens	(Moss)
Hyocomium armoricum	(Moss)
Hypericum hirsutum	Hairy St John's-wort
Hypericum maculatum	Imperforate St John's-wort
Hypericum perforatum	Perforate St John's-wort
Hypericum pulchrum	Slender St John's-wort
Hypochoeris radicata	Cat's-ear
Hypnum cupressiforme	(Moss)
Impatiens glandulifera	Indian balsam
Iris pseudacorus	Yellow iris
Juncus acutiflorus	Sharp-flowered rush
Juncus articulatus	Jointed rush
Juncus bufonius	Toad rush
Juncus bulbosus	Bulbous rush
Juncus effusus	Soft rush
Juncus inflexus	Hard rush
Juncus squarrosus	Heath rush
Jungermannia cordifolia	(Liverwort)
Larix decidua	European larch
Larix leptolepis	Japanese larch
Lathyrus montanus	Bitter vetch
Lathyrus pratensis	Meadow vetchling
Lemanea fluviatilis	(Alga)
Lemna minor	Common duckweed
Lepidium heterophyllum	Smith's pepperwort
Leucanthemum vulgare	Oxeye daisy
Littorella uniflora	Shoreweed
Lolium perenne	Perennial rye-grass
Lotus uliginosus	Greater bird's-foot-trefoil
Lunularia cruciata	(Liverwort)
Lupinus nootkatensis	Nootka lupin
Luzula sylvatica	Great wood-rush
Lychnis flos-cuculi	Ragged-robin
Lysimachia nemorum	Yellow pimpernel
Marchantia polymorpha	(Liverwort)
Marsupella emarginata	(Liverwort)

Mentha aquatica	Water mint
Mentha spicata	Spear mint
Mercurialis perennis	Dog's mercury
Meum athamanticum	Spignel
Mimulus guttatus	Monkeyflower
Mnium hornum	(Moss)
Molinia caerulea	Purple moor-grass
Montia fontana	Blinks
Myosotis arvensis	Field forget-me-not
Myosotis palustris	Forget-me-not
Myosotis scorpioides	Water forget-me-not
Myosoton aquaticum	Water chickweed
Myriophyllum alterniflorum	Alternate water-milfoil
Myriophyllum spicatum	Spiked water-milfoil
Myrrhis odorata	Sweet Cicely
Nardia compressa	(Liverwort)
Nardus stricta	Mat-grass
Nasturtium officinale	Green water-cress
Nostoc parmelioides	(Alga)
Oenanthe crocata	Hemlock water-dropwort
Oligotrichum hercynicum	(Moss)
Oxyria digyna	Mountain sorrel
Pellia endiviifolia	(Liverwort)
Pellia epiphylla	(Liverwort)
Petasites hybridus	Butterbur
Phalaris arundinacea	Reed canary-grass
Phalaris canariensis	Canary-grass
Philonotis fontana	(Moss)
Phormidium spp.	(Algae)
Picea abies	Norway spruce
Picea sitchensis	Sitka spruce
Pimpinella saxifraga	Burnet-saxifrage
Pinus contorta	Lodgepole pine
Pinus sylvestris	Scots pine
Plagiomnium rostratum	(Moss)
Plantago lanceolata	Ribwort plantain
Poa annua	Annual meadow-grass
Poa nemoralis	Wood meadow-grass
Poa pratensis	Smooth meadow-grass
Pogonatum nanum	(Moss)
Polygonum amphibium	Amphibious bistort
Polygonum bistorta	Common bistort
Polygonum crispus	Bistort
Polygonum natans	Bistort
Polygonum pectinatus	Bistort
Polygonum perfoliatus	Bistort
Polypodium vulgare	Polypody
Polytrichum commune	(Moss)
Polytrichum juniperinum	(Moss)
Populus tremula	Aspen
Potamogeton crispus	Curled pondweed
Potamogeton natans	Broad-leaved pondweed
Potamogeton polygonifolius	Bog pondweed
Potentilla erecta	Tormentil
Prasiola crispa	(Alga)
Preissia quadrata	(Liverwort)
Primula vulgaris	Primrose
Prunella vulgaris	Selfheal
Prunus padus	Bird cherry
Pseudotsuga menziesii	Douglas fir
Pteridium aquilinum	Bracken
Pyrola minor	Common wintergreen
Quercus petraea	Sessile oak
Quercus robur	Pedunculate oak
Racomitrium aciculare	(Moss)
Racomitrium aquaticum	(Moss)
Ranunculus acris	Meadow buttercup
Ranunculus aquatilis	Common water-crowfoot
Ranunculus auricomus	Goldilocks buttercup
Ranunculus calcareus	Buttercup
Ranunculus flammula	Lesser spearwort
Ranunculus fluitans	River water-crowfoot
Ranunculus repens	Creeping buttercup
Ranunculus scleratus	Celery-leaved buttercup
Rhinanthus minor	Yellow rattle
Rhizomnium punctatum	(Moss)
Rhodochorton violaceum	(Alga)
Rhynchostegium riparioides	(Moss)
Ribes rubrum	Red currant
Rorippa amphibia	Great yellow-cress
Rorippa lacustris	Yellow-cress
Rorippa palustris	Yellow-cress
Rorippa sylvestris	Creeping yellow-cress
Rubus fruticosus	Bramble
Rumex longifolius	Northern dock
Sagina procumbens	Procumbent pearlwort
Salix alba	White willow
Salix aurita	Eared willow
Salix caprea	Goat willow
Salix cinerea	Grey willow
Salix pentandra	Bay willow
Salix viminalis	Osier
Sarothamnus scoparius	Broom
Saxifraga aizoides	Yellow saxifrage
Scapania gracilis	(Liverwort)
Scapania undulata	(Liverwort)
Schistidium agassizii	(Moss)
Schistidium alpicola	(Moss)
Scirpus fluitans	Floating club-rush
Scirpus sylvaticus	Wood club-rush
Scorpidium scorpioides	(Moss)
Scrophularia auriculata	Water figwort
Scrophularia nodosa	Common figwort
Sedum telephium	Orpine
Selaginella aquaticus	Water clubmoss
Selaginella selaginoides	Lesser clubmoss
Senecio jacobaea	Common ragwort
Sibbaldia procumbens	Sibbaldia
Silene acaulis	Moss campion
Silene maritima	Sea campion
Solanum dulcamara	Bittersweet
Solenostoma cordifolium	(Liverwort)
Solenostoma triste	(Liverwort)
Solidago virgaurea	Goldenrod
Sorbus aucuparia	Rowan
Sparganium angustifolium	Floating bur-reed
Sparganium emersum	Unbranched bur-reed
Sparganium erectum	Branched bur-reed
Sphagnum spp.	(Moss)
Stachys palustris	Marsh woundwort
Stachys sylvatica	Hedge woundwort
Stellaria alsine	Bog stitchwort
Stellaria graminea	Lesser stitchwort
Stephanodiscus spp.	(Algae)
Stigeoclonium tenue	(Alga)
Succisa pratensis	Devil's-bit scabious
Symphytum officinale	Common comfrey
Tetraspora spp.	(Algae)
Thamnobryum alopecurum	(Moss)
Thuidium tamariscinum	(Moss)
Thymus drucei	Wild thyme
Tolypothrix penicillata	(Alga)
Trichophorum cespitosum	Deergrass
Trifolium spp.	Clover
Trollius europaeus	Globeflower
Tsuga heterophylla	Western hemlock
Tussilago farfara	Colt's-foot
Ulex europaeus	Gorse
Ulmus glabra	Wych elm
Urtica dioica	Common nettle
Vaccinium myrtillus	Bilberry
Valeriana officinalis	Common valerian
Vaucheria sessilis	(Alga)
Veronica anagallis-aquatica	Blue water-speedwell
Veronica beccabunga	Brooklime
Veronica chamaedrys	Germander speedwell

Veronica officinalis	Heath speedwell
Verrucaria praetermissa	(Lichen)
Verrucaria spp.	(Lichen)
Vicia cracca	Tufted vetch
Vicia sepium	Bush vetch
Viola palustris	Marsh violet
Viola riviniana	Common dog-violet
Viola tricolor	Wild pansy
Zannichellia palustris	Horned pondweed

2 Animals

2.1 Vertebrates

2.1.1 Listed by common English name

Adder	*Vipera berus*
Barnacle goose	*Branta leucopsis*
Bean goose	*Anser fabalis*
Black grouse	*Lyrurus tetrix*
Black-headed gull	*Larus ridibundus*
Brook lamprey	*Lampetra planeri*
Brown bear	*Ursus arctos*
Brown hare	*Lepus capensis*
Brown long-eared bat	*Plecotus auritus*
Brown rat	*Rattus norvegicus*
Brown trout	*Salmo trutta*
Buzzard	*Buteo buteo*
Canada goose	*Branta canadensis*
Capercaillie	*Tetrao urogallus*
Charr	*Salvelinus* spp.
Chub	*Leuciscus cephalus*
Common frog	*Rana temporaria*
Common gull	*Larus canus*
Common sandpiper	*Tringa hypoleucos*
Common scoter	*Melanitta nigra*
Common seal	*Phoca vitulina*
Common tern	*Sterna hirundo*
Common toad	*Bufo bufo*
Coot	*Fulica atra*
Curlew	*Numenius arquata*
Dace	*Leuciscus leuciscus*
Daubenton's bat	*Myotis daubentoni*
Dipper	*Cinclus cinclus*
Dunlin	*Calidris alpina*
Eel	*Anguilla anguilla*
Eider	*Somateria mollissima*
Great crested newt	*Triturus cristatus*
Flounder	*Platichthys flesus*
Gadwall	*Anas strepera*
Goldeneye	*Bucephala clangula*
Goosander	*Mergus merganser*
Grasshopper warbler	*Locustella naevia*
Grayling	*Thymallus thymallus*
Great black-backed gull	*Larus marinus*
Great crested grebe	*Podiceps cristatus*
Greenshank	*Tringa nebularia*
Grey wagtail	*Motacilla cinerea*
Greylag goose	*Anser anser*
Gudgeon	*Gobio gobio*
Hen harrier	*Circus cyaneus*
Heron	*Ardea cinerea*
Herring gull	*Larus argentatus*
Kingfisher	*Alcedo atthis*
Lapwing	*Vanellus vanellus*
Long-tailed duck	*Clangula hyemalis*
Mallard	*Anas platyrhynchos*
Marsh harrier	*Circus aeruginosus*
Mink	*Mustela vison*
Minnow	*Phoxinus phoxinus*
Moorhen	*Gallinula chloropus*
Mountain hare	*Lepus timidus*
Mute swan	*Cygnus olor*
Natterer's bat	*Myotis nattereri*
Noctule	*Nyctalus noctula*
Osprey	*Pandion haliaetus*
Otter	*Lutra lutra*
Oystercatcher	*Haematopus ostralegus*
Palmate newt	*Triturus helveticus*
Parti-coloured bat	*Vespertilio murinus*
Partridge	*Perdix perdix*
Perch	*Perca fluviatilis*
Pheasant	*Phasianus colchicus*
Pied wagtail	*Motacilla alba*
Pike	*Esox lucius*
Pink-footed goose	*Anser brachyrhynchus*
Pintail	*Anas acuta*
Pipistrelle bat	*Pipistrellus pipistrellus*
Pochard	*Aythya ferina*
Rabbit	*Oryctolagus cuniculus*
Rainbow trout	*Salmo gairdneri*
Red deer	*Cervus elaphus*
Red grouse	*Lagopus lagopus scoticus*
Red-breasted merganser	*Mergus serrator*
Redshank	*Tringa totanus*
River lamprey	*Lampetra fluviatilis*
Roach	*Rutilus rutilus*
Roe deer	*Capreolus capreolus*
Ruffe	*Gymnocephalus cernua*
Salmon	*Salmo salar*
Sand eel	*Ammodytes marinus*
Sand martin	*Riparia riparia*
Scaup	*Aythya marila*
Sea lamprey	*Petromyzon marinus*
Sprat	*Sprattus sprattus*
Sea trout	*Salmo trutta*
Sedge warbler	*Acrocephalus schoenobaenus*
Shelduck	*Tadorna tadorna*
Shoveler	*Anas clypeata*
Slow worm	*Anguis fragilis*
Smelt	*Osmerus eperlanus*
Smew	*Mergus albellus*
Smooth newt	*Triturus vulgaris*
Snow goose	*Anser caerulescens*
Starling	*Sturnus vulgaris*
Stone loach	*Noemacheilus barbatulus*
Swallow	*Hirundo rustica*
Teal	*Anas crecca*
Three-spined stickleback	*Gasterosteus aculeatus*
Tufted duck	*Aythya fuligula*
Viviparous lizard	*Lacerta vivipara*
Water rail	*Rallus aquaticus*
Water shrew	*Neomys fodiens*
Water vole	*Arvicola terrestris*
White-fronted goose	*Anser albifrons*
Whooper swan	*Cygnus cygnus*
Wigeon	*Anas penelope*
Wolf	*Canis lupus*

2.1.2 Listed by Latin binomial

Acrocephalus schoenobaenus	Sedge warbler
Alcedo atthis	Kingfisher
Ammodytes marinus	Sand eel
Anas acuta	Pintail
Anas clypeata	Shoveler
Anas crecca	Teal
Anas penelope	Wigeon
Anas platyrhynchos	Mallard
Anas strepera	Gadwall
Anguilla anguilla	Eel
Anguis fragilis	Slow worm
Anser albifrons	White-fronted goose
Anser anser	Greylag goose
Anser brachyrhynchus	Pink-footed goose
Anser caerulescens	Snow goose
Anser fabalis	Bean goose
Ardea cinerea	Heron
Arvicola terrestris	Water vole

Aythya ferina	Pochard
Aythya fuligula	Tufted duck
Aythya marila	Scaup
Branta canadensis	Canada goose
Branta leucopsis	Barnacle goose
Bucephala clangula	Goldeneye
Bufo bufo	Common toad
Buteo buteo	Buzzard
Calidris alpina	Dunlin
Canis lupus	Wolf
Capreolus capreolus	Roe deer
Cervus elaphus	Red deer
Cinclus cinclus	Dipper
Circus aeruginosus	Marsh harrier
Circus cyaneus	Hen harrier
Clangula hyemalis	Long-tailed duck
Cygnus cygnus	Whooper swan
Cynus olor	Mute swan
Esox lucius	Pike
Fulica atra	Coot
Gallinula chloropus	Moorhen
Gasterosteus aculeatus	Three-spined stickleback
Gobio gobio	Gudgeon
Gymnocephalus cernua	Ruffe
Haematopus ostralegus	Oystercatcher
Hirundo rustica	Swallow
Lacerta vivipara	Viviparous lizard
Lagopus lagopus scoticus	Red grouse
Lampetra fluviatilis	River lamprey
Lampetra planeri	Brook lamprey
Larus argentatus	Herring gull
Larus canus	Common gull
Larus marinus	Great black-backed gull
Larus ridibundus	Black-headed gull
Lepus capensis	Brown hare
Lepus timidus	Mountain hare
Leuciscus cephalus	Chub
Leuciscus leuciscus	Dace
Locustella naevia	Grasshopper warbler
Lutra lutra	Otter
Lyrurus tetrix	Black grouse
Melanitta nigra	Common scoter
Mergus albellus	Smew
Mergus merganser	Goosander
Mergus serrator	Red-breasted merganser
Motacilla alba	Pied wagtail
Motacilla cinerea	Grey wagtail
Mustela vison	Mink
Myotis daubentoni	Daubenton's bat
Myotis nattereri	Natterer's bat
Neomys fodiens	Water shrew
Noemacheilus barbatulus	Stone loach
Numenius arquata	Curlew
Nyctalus noctula	Noctule
Oryctolagus cuniculus	Rabbit
Osmerus eperlanus	Smelt
Pandion haliaetus	Osprey
Perca fluviatilis	Perch
Perdix perdix	Partridge
Petromyzon marinus	Sea lamprey
Phasianus colchicus	Pheasant
Phoca vitulina	Common seal
Phoxinus phoxinus	Minnow
Pipistrellus pipistrellus	Pipistrelle bat
Platichthys flesus	Flounder
Plecotus auritus	Brown long-eared bat
Podiceps cristatus	Great crested grebe
Rallus aquaticus	Water rail
Rana temporaria	Common frog
Rattus norvegicus	Brown rat
Riparia riparia	Sand martin
Rutilus rutilus	Roach
Salmo gairdneri	Rainbow trout
Salmo salar	Salmon
Salmo trutta	Brown trout
Salmo trutta	Sea trout
Salvelinus spp.	Charr
Somateria mollissima	Eider
Sprattus sprattus	Sprat
Sterna hirundo	Common tern
Sturnus vulgaris	Starling
Tadorna tadorna	Shelduck
Tetrao urogallus	Capercaillie
Thymallus thymallus	Grayling
Tringa hypoleucos	Common sandpiper
Tringa nebularia	Greenshank
Tringa totanus	Redshank
Triturus cristatus	Great crested newt
Triturus helveticus	Palmate newt
Triturus vulgaris	Smooth newt
Ursus arctos	Brown bear
Vanellus vanellus	Lapwing
Vespertilio murinus	Parti-coloured bat
Vipera berus	Adder

2.2 Invertebrates

2.2.1 Listed by common English family name

Kentish glory moth	*Endromis versicolora*

2.2.2 Listed by Latin binomial

Agabus spp.	(Beetles)
Agapetus spp.	(Caddis flies)
Allogamus auricollis	(Caddis fly)
Anabolia nervosa	(Caddis fly)
Ancylus fluviatilis	(Water snail)
Aphinemura sulcicollis	(Stonefly)
Asellus aquaticus	(Water slater)
Asellus meridianus	(Water slater)
Atherix ibis	(Two-winged fly)
Athripsodes spp.	(Caddis flies)
Baetis muticus	(Mayfly)
Baetis pumilus	(Mayfly)
Baetis rhodani	(Mayfly)
Baetis scambus	(Mayfly)
Baetis vernus/tenax	(Mayfly)
Brachycentrus subnubilus	(Caddis fly)
Brachyptera putata	(Stonefly)
Brachyptera risi	(Stonefly)
Brychius elevatus	(Beetle)
Caenis rivulorum	(Mayfly)
Capnia bifrons	(Stonefly)
Centroptilum luteolum	(Mayfly)
Ceratopogonidae	(Two-winged flies)
Chironomidae	(Two-winged flies)
Chloroperla torrentium	(Stonefly)
Chloroperla tripunctata	(Stonefly)
Clinocera spp.	(Two-winged flies)
Crenobia alpina	(Flatworm)
Dicranota spp.	(Two-winged flies)
Dinocras cephalotes	(Stonefly)
Diura bicaudata	(Stonefly)
Drusus annulatus	(Caddis fly)
Ecclisopteryx guttulata	(Caddis fly)
Ecdyonurus dispar	(Mayfly)
Ecdyonurus torrentis	(Mayfly)
Ecdyonurus venosus	(Mayfly)
Elaeophila spp.	(Two-winged flies)
Elmis aenea	(Riffle beetle
Enchytraeidae	(Segmented worms)
Endromis versicolora	Kentish glory moth
Ephemera danica	(Mayfly)
Ephemerella ignita	(Mayfly)
Ephemerella notata	(Mayfly)
Erpobdella octoculata	(Leech)
Esolus parallelepipedus	(Beetle)

Gammarus pulex	(Water shrimp)
Gammarus zaddachi	(Water shrimp)
Gerris costai	(Water bug)
Glossiphonia complanata	(Leech)
Glossosoma spp.	(Caddis flies)
Goera pilosa	(Caddis fly)
Halesus radiatus/digitatus	(Caddis fly)
Haliplus spp.	(Beetles)
Helobdella stagnalis	(Leech)
Helophorus spp.	(Beetles)
Hemerodromia spp.	(Two-winged flies)
Heptagenia sulphurea	(Mayfly)
Hexatoma spp.	(Two-winged flies)
Hydraena gracilis	(Beetle)
Hydropsyche angustipennis	(Caddis fly)
Hydropsyche contubernalis	(Caddis fly)
Hydropsyche instabilis	(Caddis fly)
Hydropsyche pellucidula	(Caddis fly)
Hydropsyche siltalai	(Caddis fly)
Hydroptilidae	(Caddis flies)
Isoperla grammatica	(Stonefly)
Lasiocephala basalis	(Caddis fly)
Lepidostoma hirtum	(Caddis fly)
Leptophlebia marginata	(Mayfly)
Leuctra fusca	(Stonefly)
Leuctra geniculata	(Stonefly)
Leuctra hippopus	(Stonefly)
Leuctra inermis	(Stonefly)
Limnephilus spp.	(Caddis fly)
Limnius volckmari	(Beetle)
Limnophora spp.	(Two-winged flies
Lumbricidae	(Segmented worms)
Lumbriculidae	(Segmented worms)
Lymnaea peregra	(Water snail)
Naididae	(Segmented worms)
Nemoura avicularis	(Stonefly)
Nemoura cambrica	(Stonefly)
Nemoura cinerea	(Stonefly)
Odontocerum albicorne	(Caddis fly)
Oreodytes sanmarki	(Beetle)
Oulimnius tuberculatus	(Beetle)
Paraleptophlebia submarginata	(Mayfly)
Pedicia spp.	(Two-winged flies)
Perla bipunctata	(Stonefly)
Perlodes microcephala	(Stonefly)
Philopotamus montanus	(Caddis fly)
Physa fontinalis	(Water snail)
Pisidium spp.	(Water pea mussels)
Planorbis albus	(Water snail)
Planorbis contortus	(Water snail)
Platambus maculatus	(Beetle)
Plectrocnemia conspersa	(Caddis fly)
Polycelis felina	(Flatworm)
Polycelis tenuis/nigra	(Flatworm)
Polycentropus flavomaculatus	(Caddis fly)
Potamonectes depressus/ elegans	(Beetle)
Potamophylax cingulatus	(Caddis fly)
Potamophylax latipennis	(Caddis fly)
Potamopyrgus jenkinsi	(Water snail)
Protonemura meyeri	(Stonefly)
Protonemura montana	(Stonefly)
Protonemura praecox	(Stonefly)
Psychodidae	(Two-winged flies)
Rhithrogena semicolorata	(Mayfly)
Rhyacophila dorsalis	(Caddis fly)
Rhyacophila obliterata	(Caddis fly)
Sericostoma personatum	(Caddis fly)
Sialis fuliginosa	(Alderfly)
Sialis lutaria	(Alderfly)
Sigara concinna	(Water bug)
Silo pallipes	(Caddis fly)
Simulidae	(Two-winged flies)
Simulium monticola	(Two-winged fly)
Simulium reptans	(Two-winged fly)
Sphaerium corneum	(Water pea mussel)
Sphaerium spp.	(Water pea mussels)
Stenophylax lateralis/sequax	(Caddis fly)
Taeniopteryx nebulosa	(Stonefly)
Taphrophila spp.	(Two-winged flies)
Theromyzon tessulatum	(Leech)
Tipula spp.	(Two-winged flies)
Trocheta bykowskii	(Leech)
Tubificidae	(Segmented worms)
Wormaldia spp.	(Caddis flies)

ISBN 0904282 88 0
ISSN 0263-8614