The Flow Country

The peatlands of Caithness and Sutherland

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Contents

13 The definition of nature conservation requirements

The background purpose of the NCC's survey is to provide a factual basis for a nature conservation programme in the Caithness and Sutherland peatlands, in conjunction with surveys of birds and fresh waters. The information-base reported in the preceding chapters was planned to allow the evaluation of scientific interest in terms of range of variation in peatland hydromorphology, structure, vegetation and flora. The principles and criteria for nature conservation evaluation follow those developed within the NCC for the assessment and selection of important areas (Ratcliffe 1977, 1986a), taking both a Great Britain and an international perspective. One of the crucial aspects of judging the conservation value of the Caithness and Sutherland peatlands is, indeed, that the frame of reference should be knowledge of other peatlands, not only in the rest of this country but across the world.

In the selection of areas of outstanding importance for nature conservation, two major principles have previously been applied. The first is the choice of areas to give an adequate representation of reference points across the whole field of variation in ecosystems, and the second is the identification of a minimum standard of importance, above which every area qualifies for selection. The main criteria used to assess the comparative value of areas of similar ecological character and to define standards of quality are -

- Extent
- Diversity
- Naturalness
- Rarity
- Fragility
- Typicalness
- Position in an ecological/geographical unit

In addition the concept of "non-recreatability" is useful as an integrating measurement of nature conservation value.

Three especially important factors affect the nature conservation assessment of the Caithness and Sutherland peatlands and definition of particular areas within them.

The first factor is that not only is this a very large total expanse, but also much of it is continuous and of such a character that, over extensive areas, natural discontinuities which can be used in the delineation of particular blocks are often few in number. This means that in many places the boundaries between particular mire complexes are somewhat subjective, in as much as a moderate slope or a line of rock outcrops or a road may suggest that a boundary could reasonably be drawn along such a feature, but absolute confidence in such a boundary would depend on a more detailed study of peat depth and water movement.

The second factor is that this is not only one of the most extensive mosaics of natural and semi-natural ecosystems remaining in Britain, but also a globally rare type with high international importance (Chapter 3).

The third factor is that 17% of the total extent, including many important individual mire units, has already been lost (or is programmed to be lost) through afforestation and that this activity has affected 33 out of the 41 major river catchments (Stroud *etal.* 1987).

Evaluation and selection procedure

Previous attempts to assess the range and quality of peatland sites across a geographical region or province have often used various attribute-scoring methods to make overall comparisons between sites. Table 5 presents a synopsis of the factors regarded as important by a number of authors in the assessment of peatlands in various parts of the UK.

Not all the factors in Table 5 are applicable to blanket bog evaluation. For example, Leach & Corbett (1987) were concerned solely with raised mires in Northern Ireland, in which the presence of a lagg fen and the extent of undamaged dome are both factors of considerable importance, but these seldom occur in blanket bogs. A feature of Greig's (1975) and Charter's (1985a, 1985b) surveys is the use of formal scoring methods to evaluate the quality of individual mire units. This method is attractive in that the final ordered table enables priorities to be placed on subsequent action programmes, but the system assumes that attributes are additive, that the arbitrary 'weighting' of their value is appropriate and that an accumulation of factors represents an increasing level of nature conservation interest.

Penford (1985) reviews the problems of drawing up a ranked evaluation table, pointing out the large degree of subjective variability which is inherent in assigning scores to features which cannot practicably be quantified. Although some sites were clearly highlighted by the use of such a scoring system in her study, she concludes that "it would be unwise to base site selection on an evaluation such as this". Her two main objections are, first, that the cumulative scoring has the effect of compounding subjective errors, thereby inviting criticism of the final scoring, and, secondly, that sites not possessing

Factor	Charter (1984)	Leach & Corbett (1987)	Greig (1975)
Sphagnum cover	■	■	■
Structural elements	■		
Other "bog typics"	■	■	■
Size of site	■		
Presence of surface patterning	■	■	
Position of the water table	■		
Damage	■	■	■
• burning	■		
• drainage	■		
• afforestation	■		
• trampling	■		
• erosion	■		
Other notable features			
• mire morphology	■		
• extent of lagg fen		■	
• % size of remaining dome		■	

Table 5

Synopsis of the factors regarded as important in the assessment of peatlands in studies carried out in various parts of the United Kingdom.

all the features in abundance do not score highly, yet they may have particular features which are, of themselves, sufficient to warrant complete protection. In addition, she points out that such an evaluation does not cater for areas where a large proportion of the sites may be of high quality in a wider geographical context. The system tends to encourage an assumption that attention should be focused on, say, the top 25% of sites in the evaluation table, but in a wider context perhaps 75% would be regarded as essential to a conservation programme.

Both criticisms are particularly relevant to the Caithness and Sutherland survey, the former because of the varied sources of survey information used in the analysis. The latter point is perhaps best illustrated by the example of ladder fens, which do not possess many of the usual criteria for "high quality mire" but are of considerable importance in a national and even international context. In a ranked evaluation table, such sites would almost certainly not fall within the top 25%. Moreover, a ranking system based on detailed samples taken only from the two Districts would highlight the gradient of quality within the Flow Country but could not be used to evaluate the difference in quality between the peatlands of Caithness and Sutherland and of other parts of Britain.

While scoring procedures are useful in ranking similar sites in order of value, they do not measure the degree of difference between sites or give an absolute value. They therefore give little help in the crucial decisions about site selection, whether in choice of a representative series or in definition of minimum standards.

These various weaknesses of a numerical approach suggested that a less elaborate method of evaluation should be applied to the data from Caithness and Sutherland, particularly as a number of consistently recorded and essentially simple features were readily identifiable throughout. These are itemised later in this chapter.

The NCC's approach

The method adopted was a semi-quantitative one based on the analysis of site types described in Chapter 12. The 15 site types and the bioclimatic zones (Chapter 4) provide a computer-based matrix for the field of ecological variation in Caithness and Sutherland peatlands which has to be represented in the selection of sites (Table 6). This particular approach and the survey as a whole have produced information directly comparable with that obtained by the NCC's surveys of peatlands elsewhere in Britain, so that valid comparisons between the Flow Country and other regions can be made.

Although the site types described in Chapter 12 are all fairly distinctive, considerable variation exists within each type as a result of topographic and climatic factors. Thus western examples of northern boreal types have significantly greater quantities of *Molinia* or *Myrica*, for example. On the other hand, it is clear that most types have a fairly well-defined centre of distribution, within which the largest

	Site type						Bioclimatic zones							
		01H1A3	OIHIBI	01H1B2	01H1B3	01H2B1	01H2B2	01H2B3	01H3B1	01H3B2	01H3B3	PA3	PA2	PA1
Type 1	Ladder fens													
Type 2	Flushed bog			13		147		5						
Type 3	Low-relief western' bog			115	15		19	29						
Type 4	Low-relief northern boreal bog			66		41	505				165			
Type 5	*Eriophorum vaginatum* 'eastern' bog	40		12		20	19	15	26	129	637			
Type 6	*Molinia-Sphagnum-Menyanthes* bog		197		16		46							
Type 7	Hyperoceanic patterned bog		302		23									
Type 8	Central watershed bog													
Type 9	'Eastern' watershed bog													
Type 10	*Racomitrium* watershed bog						202			46				
Type 11	Damaged northern boreal bog													
Type 12	Microbroken bog								19					
Type 13	Regenerating erosion complex													
Type 14	Severely damaged *Trichophorum* bog		206							166	161			
Type 15	Plateau erosion, with *Erica cinerea*		2799	96	156									
	Site type	40	3504	289	223	61	938			341	963			
								44	50 :					

		02H1A3	02H1B1	02H1B2	02H1B3	021					02PA3	02PA2	02PB3	02PB2	Totals
Type 1	Ladder fens			286			27								313
Type 2	Flushed bog	140	23	252			42	35							657
Type 3	Low-relief 'western' bog			77											255
Type 4	Low-relief northern boreal bog		36	341			434		80						1668
Type 5	*Eriophorum vaginatum* 'eastern' bog	497	900	826			1299		645						5065
Type 6	*Molinia-Sphagnum-Menyanthes* bog		158	178	32		447	12							1086
Type 7	Hyperoceanic patterned bog			238			60							28	651
Type 8	Central watershed bog	146	145	471			470	35		162					1429
Type 9	'Eastern' watershed bog						2540		600						3140
Type 10	*Racomitrium* watershed bog			1232		61	588								2129
Type 11	Damaged northern boreal bog	56		40			641								737
Type 12	Microbroken bog						13								32
Type 13	Regenerating erosion complex	352	837	944			93								2226
Type 14	Severely damaged *Trichophorum* bog	61	174	244			264								1276
Type 15	Plateau erosion, with *Erica cinerea*	5382	628	40							230				9331
		6634	2901	5169	32	61	6918	82	1325	162	230			28	29995

Table 6

Total areas (ha x 100) of site types within each bioclimatic zone.

number of 'typical' examples can be expected. Table 6 shows the scatter of site types across the range of bioclimatic zones for the region. In particular, it highlights the major zones for any given site type, as well as indicating the site types which best characterise each of the bioclimatic zones. Within the hyperoceanic region, the zones H1/B1, H1/B2 and H2/B2 represent major centres of distribution for particular site types, whilst H1/A3, H1/B2 and H2/B2 are important centres for site types within the euoceanic region.

The approach most appropriate to the selection of exemplary areas of any peatland type involves the selection of a single example from each bioclimatic zone containing that site type. Where a bioclimatic zone contained many examples, the largest site was selected. Figures 51-64 illustrate the distribution of each site type, with emphasis on the largest examples in each bioclimatic zone. This approach has the advantage that the complete geographical/ climatic gradient of each site type can be represented and the selection process is evenly spread throughout the region instead of focusing on particular parts. A fairly high proportion of ground so identified is already recognised as being of high quality for nature conservation, having been described in *A Nature Conservation Review* (Ratcliffe 1977) as "key" national sites or subsequently recognised as having SSSI quality.

In addition, some of the blanket bog features are of sufficient importance for all examples to require protection. This expresses the selection principle of *minimum standards*, above which all examples qualify, and is used as a necessary second approach to complement the series of *exemplary sites.* The criteria of rarity, naturalness and fragility together identify certain general attributes as highly localised, declining and endangered as British habitats. In most cases, their present occurrence represents a much reduced remnant of former distribution and extent. These features are quaking mire, *Sphagnum* cover, rare species and combinations of other species indicating lack of disturbance; they are not peculiar to any one site type and so may elevate the value of any example based on the criterion of size already applied. Site types 1, 2, 3, 4, 7, 8, 9, 11 and 15 qualify under these criteria for selection in their entirety.

There follows a synopsis of the nature conservation value and the selection requirements for all 15 site types. A further section spells out in greater detail the special features within the field of mire variation that require complete protection.

Conservation value and need, according to site types

Site type 1: Ladder fens (see Figure 51)

Conservation status

Maximum protection of all examples. The type has been identified as internationally important by the International Mire Conservation Group.

Site type 2: Flushed bog and valley mire transition (see Figure 52)

Conservation status

Very high. All undamaged examples should be protected. This is a rich mire type characterised by several important conservation features. First, it is frequently associated with quaking mire. Secondly, it is one of the major types within which *Vaccinium oxycoccos* occurs. It also reveals a number of relationships between ladder fens, valley mires and ombrotrophic patterns.

Site type 3: Low-relief 'western' blanket bog (see Figure 53)

Conservation status

High. All examples should be protected. A very small number of sites were recorded. All these would need to be protected to meet normal site selection criteria, In addition, the association of this type with quaking mire and the richness of its vegetation, which forms important links with the Inner and Outer Isles, make the type particularly significant.

Site type 4: Low-relief northern boreal blanket bog (see Figure 54)

Conservation status

Maximum protection for all examples. Although the type cannot be described as rich, it represents one of the rarest mire communities in Britain, provides a phytogeographical link with continental mires and is an important source of undamaged quaking mire. Its concentration within the main area of forestry activity is obviously a major source of concern, and the possible loss already of one of the most easterly outliers simply serves to highlight the problem.

Site type 5: *Ehophorum vaginatum* 'eastern' blanket bog (see Figure 55)

Conservation status

Representative, except for examples of *Sphagnum pulchrum* mire, which require maximum protection. As this is the major type within the region, as well as an important link with mire types further south, it is necessary to ensure that sufficient examples are protected to maintain the range of variation.

Site type 6: *Molinia-Sphagnum-Menyanthes* blanket bog (see Figure 56)

Conservation status

High/representative. Although this type is not striking in its floristics, the combination of vegetation and surface pattern is one which is relatively infrequent outside Sutherland. Sufficient examples should certainly be protected to ensure that its full range of forms is maintained, but there is an argument on national and international grounds for ensuring that a rather larger range of examples is protected.

Site type 7: Hyperoceanic patterned blanket bog (see Figure 57)

Conservation status

Maximum protection required. There are few examples, not only in Caithness and Sutherland but throughout the rest of Britain.

Site type 8: Central watershed blanket bog (see Figure 58)

Conservation status

Maximum protection required. This is one of three major types which characterise the Caithness and Sutherland peatlands and are found, almost certainly, nowhere else in Europe (and therefore, probably, the world). The other two are Site types 4 and 9.

Site type 9: 'Eastern' watershed blanket bog (see Figure 59)

Conservation status

Maximum protection required. All examples (the few remaining) require complete protection because they represent the only known examples of the type.

Site type 10: *Racomitrium* watershed blanket bog (see Figure 60)

Conservation status

High/representative. The type does not support any vegetation communities which are unique to Caithness and Sutherland. However, it is important for the patterns adopted by its microtopes, which show an extreme form of watershed pool development. Such patterns have an extremely localised distribution in Britain. In terms of mire hydromorphology, therefore, a wide range of examples should be protected.

Site type 11: Damaged northern boreal blanket bog (see Figure 61)

Conservation status

High. Although damaged, the type is important for the light it sheds on the distribution of *Betula nana* on British mire systems. In addition, many of these sites have every likelihood of recovery if burning and trampling are reduced. They therefore represent an important additional component within the whole distribution of Caithness and Sutherland northern boreal blanket bog.

Site type 12: Microbroken blanket bog
(A distribution map is not included.)

Conservation status

Microbroken ground has little intrinsic value. However, it plays a significant part in maintaining the hydrology of more important mire systems when it forms an adjoining unit.

Site type 13: Regenerating erosion complex
(see Figure 62)

Conservation status

Representative. The widespread nature of this type in high-level mires means that sufficient examples should be protected to maintain the range of geographical variation displayed within the two Districts.

Site type 14: Severely damaged *Trichophorum* blanket bog (see Figure 63)

Conservation status

Representative. Like microbroken mire, the type is generally only important as 'connective' land between other more important areas. However, the type is somewhat different in coastal Caithness and this is probably of value as a geographical variant which should be represented in the programme of protection.

Site type 15: Plateau erosion, with *Erica cinerea* (see Figure 64)

Conservation status

High. The status of erosion, in terms of its natural or anthropogenic origins, has yet to be determined (see Chapter 5). Clearly erosion is often made more severe by human agency, but all high-level plateaux are characterised by this type and it is likely that some of the closest links with Scandinavian northern boreal mires are to be found here. It is therefore essential that as wide a range of this type as possible should be protected, particularly as these areas are likely to be of greatest value for research into erosion and its origins.

Conservation value and need, according to special features

Quaking mire

Quaking mire is the very softest type of ground, where the normally solid ridges feel extremely unstable and large areas of the surface may quake under a person's body-weight. Whilst the high water content of any peat means that it is normally possible to make the ground shake slightly, quaking mire literally quakes with every footfall, and the ridges are so soft that crossing such an area is hazardous. The surface layers are typically almost completely unhumified, often to depths of 20-30 cm, and the catotelm as a whole is close to the liquid limit in water content of the peat (Hobbs 1986). This phenomenon is usually associated with an abundance of the *Sphagna* typical of a low-relief microtopography. It seems to be associated with the least damaged mires or parts of mires. Such areas can therefore be taken to display a high degree of "naturalness".

It is important to distinguish here between whole blanket bog units and individual elements of microtopography or certain minerotrophic basin mires. Al hollows typically quake, but, though generally indicating high quality, they do not represent a quaking mire unit or mesotope. Many mires have certain elements which are extremely soft, but these are usually only individual hollows or pools. "Quaking mire" refers to sites which have large areas of uninterrupted quaking, ombrotrophic surface, so that the whole or most of the catotelm is in an almost liquid state. Whilst the surface of some basin mires can also be extremely hazardous, this is usually a result of their basic structure, where a thin skin of vegetation floats on an underlying lens of water - the *Schwingmoore* typical of such sites as the kettle-hole mires of the north-west Midlands (e.g. Moore & Bellamy 1974).

On a national scale quaking mire is rare, especially in blanket bogs, and has been regarded as an important attribute for the selection of SSSIs on the criterion of "rarity". Only 19 current SSSIs possess examples of quaking mire, although a number of early accounts of peatland systems attest to its former widespread occurrence (Cromertie 1711; Gorham 1953b). There are 43 recorded examples in Sutherland and Caithness, and the region holds a large percentage of the British total of this rare habitat. Figure 65 shows the distribution of quaking mire in the region.

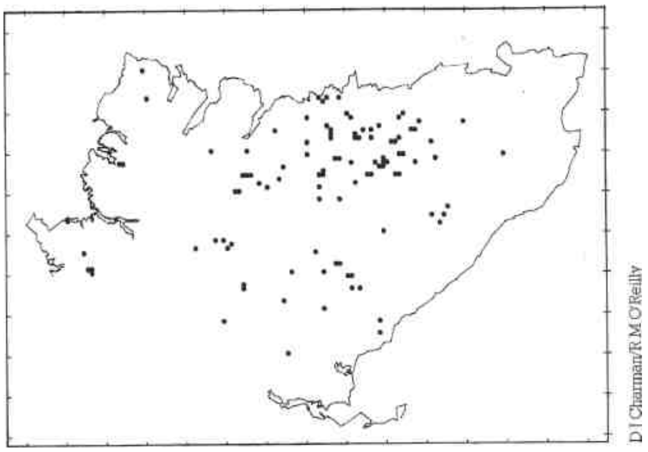

Figure 65 Surveyed peatland sites which were found to contain substantial areas of quaking mire.

Sphagnum cover

Sphagnum is a sensitive genus, being especially adversely affected by fire, lowering of the water table (Ivanov 1981; Clymo & Hayward 1982), trampling by livestock or humans (Slater & Agnew 1977) and pollution (Ferguson *et al.).* Agricultural reclamation, afforestation and pollution have removed *Sphagnum* from large parts of its former range in Britain. This means that its occurrence and abundance are a good indication of "naturalness". Abundant, healthy *Sphagnum* over a high proportion of the surface is a sign that the mire is still in an actively growing, rather than moribund, state and that its nature conservation interest is likely to be maintained over the foreseeable future, if it is not disturbed. It is a feature also rating highly under the criterion of "fragility", since it is so easily damaged by human interference. The species associated with active bog growth are *Sphagnum papillosum, S. magellanicum, S. rubellum, S. subnitens, S. cuspidatum* and *S. auriculatum.* Some others, notably *S. recurvum, S. tenellum* and *S. compactum* are often indicators of disturbance or drying, especially when present in abundance.

This is another factor which has been used in the past as an indicator of sites of SSSI quality, increasingly so because the number of *Sphagnum*-rich mires in Britain has declined rapidly since the turn of the century (e.g. Nature Conservancy Council 1982, pp. 8-9).

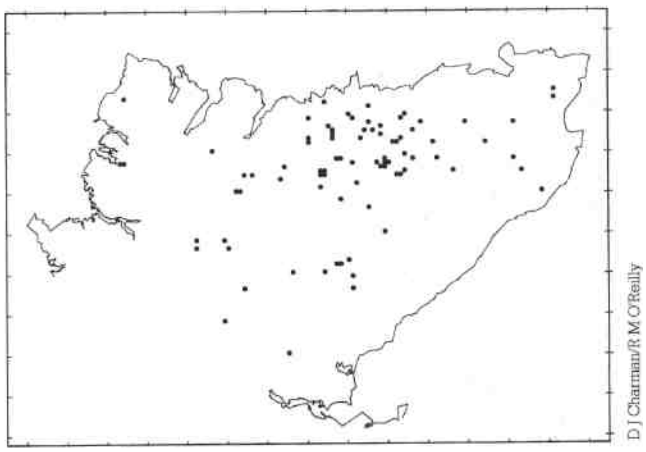

Figure 66 Surveyed peatland sites which were found to possess a high cover of *Sphagnum,*

Caithness and Sutherland hold peatland of considerable value in terms of *Sphagnum* cover, with large proportions of the area possessing high-scoring sites. The region probably contains the bulk of the *Sphagnum-dominated* bogs remaining in Britain. Figure 66 shows the distribution of *Sphagnum-dominated* bogs within Caithness and Sutherland. The scale of the map means that sites which are closer together than 1 km are plotted as a single point.

It is worth stressing that low cover of *Sphagnum* does not always indicate drying and disturbance of the bog surface. Some studies (Moore 1977; Walker 1961) of stratigraphy of Highland and Irish blanket bogs reveal a low content of *Sphagnum* in the peat down to a considerable depth, showing that it may sometimes, and quite naturally, be only a minor component of the active bog surface. This has to be allowed for in evaluation of peatland interest.

Indicator species

The use of particular species for site assessment is well established (e.g. Greig 1975; Charter 1985a, 1985b), either indirectly as indicators of presence or absence of damage or directly for their value in their own right (e.g. as rare species). The species used here are selected for both reasons. Their national and regional importance and distribution are discussed in Chapter 11.

Sphagna

Sphagnum imbricatum and *S. fuscum* are the two species regarded as most characteristic of mires in good condition in western and northern Britain. *S. imbricatum* features prominently in plant remains in sub-surface peat and was much more widespread in the past. The reasons for this decline are not known fully (Tallis 1964c). Both species are conspicuous dry hummock formers on mire surfaces and may therefore be susceptible to fire (McVean & Lockie 1969; Slater & Slater 1978). Frequently they are in a degenerate state, and the possibility that atmospheric pollution is a factor in *Sphagnum* decline has stimulated considerable recent research (e.g. Lee 1981; see also Chapter 5).

S. pulchrum is a national rarity and, while the reasons for its restricted distribution are not known, its continuing decline is a direct result of straightforward habitat destruction, particularly of lowland raised and blanket mires in western Britain. Its Wigtownshire stations on Moss of Cree and Kilquhockadale Flow have been destroyed by afforestation.

The total number of *Sphagnum* species present has been used in some other studies for quality assessment, on the assumption that more diverse sites are more valuable than uniform sites. However, only those species characteristic of intact ombrotrophic mire should be used, as adjacent fen systems and damage features may contain species which should be excluded from additive scoring of this kind.

Other bryophytes

The presence of the rare moss *Dicranum bergeri* is regarded as an important indication of lack of damage to mire surfaces.

Higher plants

Higher plants which can be positively scored to measure mesotope value, on the basis of their restricted distributions, at least as bog plants are *Vaccinium oxycoccos* and *V. microcarpum, Rhynchospora fusca* and *R. alba, Arctostaphylos uva-ursi, Betula nana, Carex limosa* and *C. pauciflora, Sparganium angustifolium, Drosera intermedia and D. anglica.* However, the majority of these species are associated with high *Sphagnum* cover and are relatively common within the region, so they were not used in the final selection of mire complexes.

Only *Rhynchospora fusca* and *Sphagnum pulchrum* were considered to be sufficiently rare, both nationally and within the region, to merit their use as selection criteria for particular blanket bog complexes. The remainder of the species were used to evaluate sites, but were not themselves used as selection criteria.

The quite extraordinary aspect of Caithness and Sutherland is the large extent of ground which meets the various criteria listed above. In other parts of Britain such selection standards would tend to identify small units within an otherwise lower-quality matrix of peatland habitat.

The cumulative selection of conservation areas

The combined distribution of mire complexes identified for protection from the site type/ bioclimatic zone matrix is shown in Figure 67. This area (189,104 ha) represents the range of best examples for each site type, together with those site types of which all examples should be protected on grounds of national rarity, but also includes areas already lost to forestry. Many mire complexes are shown to contain both exemplary and rare site types.

This selection is based on an assessment, by computer analysis, of those mire complexes for which there is quadrat information. Supplementary information on the occurrence of quaking mire, *Sphagnum* cover and the presence of rare species is available for all sites covered by the survey, so that a list of individual mire units (as distinct from site types) with these attributes is easily accessible through the survey data-base. These were plotted onto 1:50,000 maps, together with their supporting hydrological boundaries. This results in a larger area of rare mire types being shown than in Figure 67. However, some of the highly rated sites have been

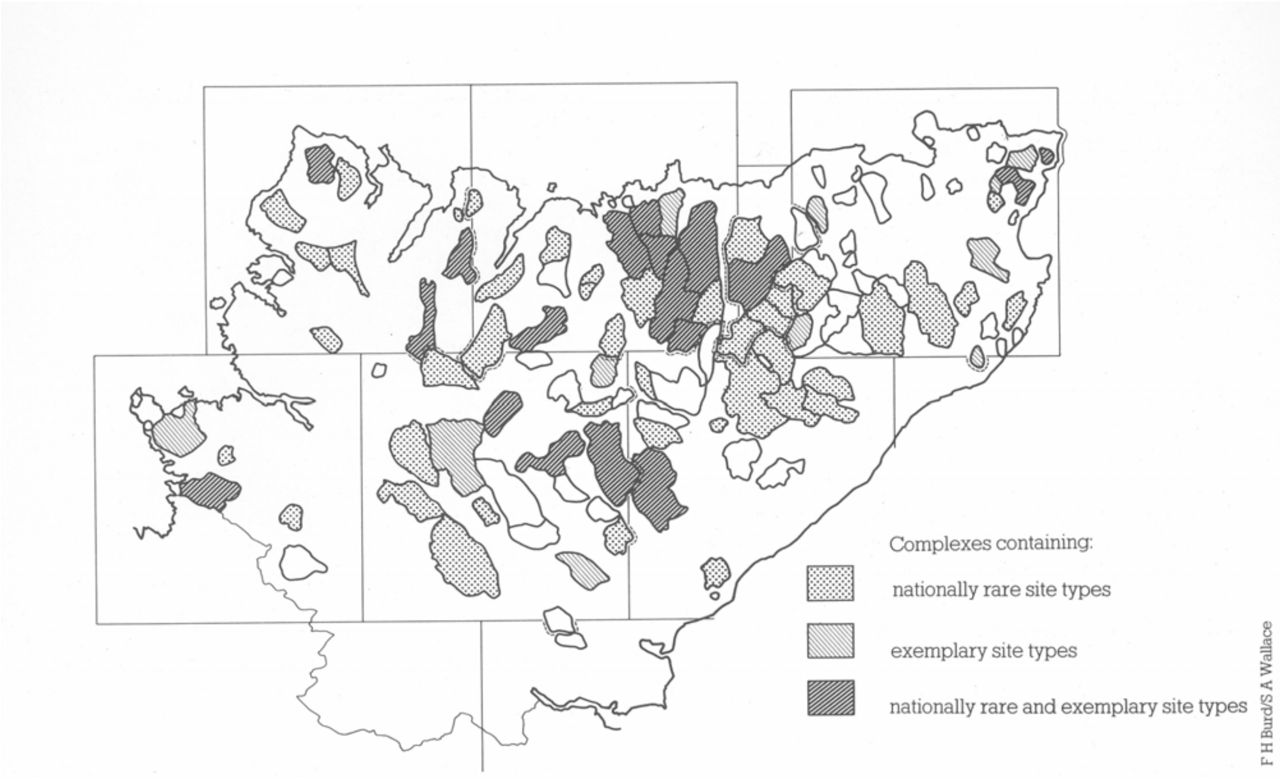

Figure 67 Distribution of mire complexes identified for protection because they contain exemplary and/or nationally rare site types. Some of the areas have been afforested since they were surveyed or are currently programmed for afforestation.

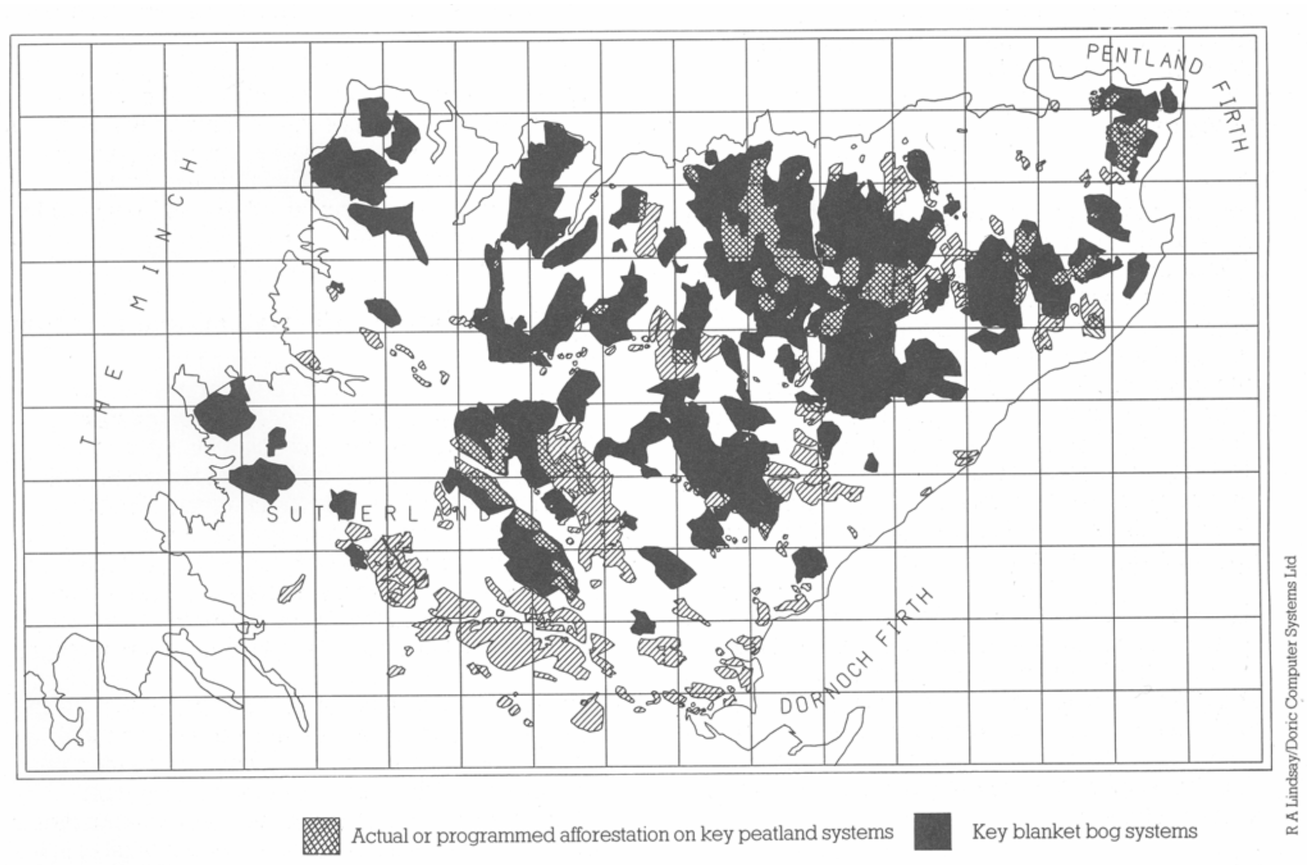

Figure 68 Distribution of "key" (Nature Conservation Review status) peatland systems identified for protection either because they contain exemplary or nationally rare site types or because they support bog vegetation exceeding the criterion of quality which requires all examples to be protected. Existing or proposed peatland SSSIs are also included within this distribution. Key peatland areas which have been afforested since they were surveyed or are now programmed for afforestation are shown cross-hatched; other forestry is shown single-hatched.

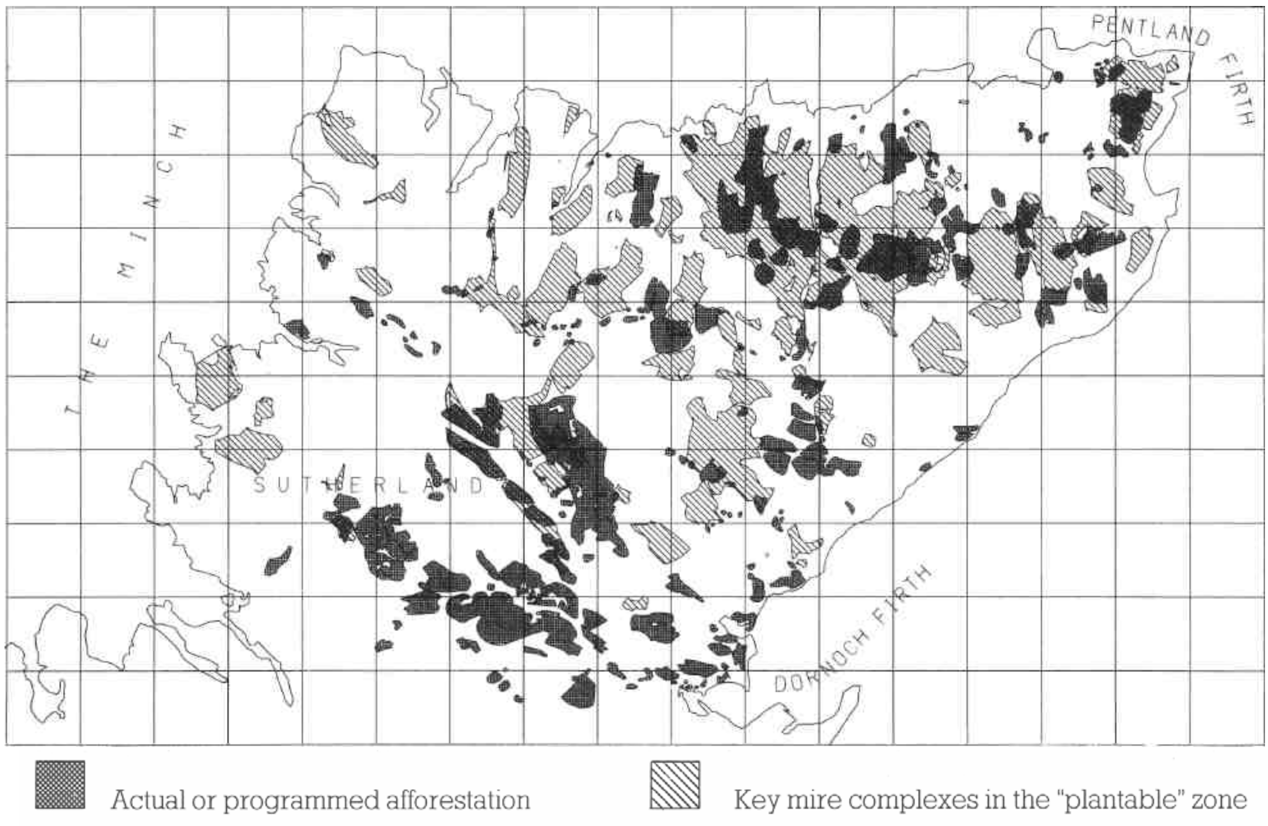

Figure 69 The extent of "key" blanket bog systems which lie within the "plantable" zone. Land which is classed as "unplantable" by the Forestry Commission has been removed. Land shown with single-hatching is therefore key peatland habitat within which further losses through afforestation may occur.

lost since they were surveyed and require substitutes for representation. The combined area of key mire systems, including peatland SSSIs, is shown in Figure 68 (with afforested areas and those programmed for planting superimposed). The total area of important surveyed peatland vegetation remaining outside afforested areas is 195,063 ha. Not all of this land is in conflict with forestry, however, because some ground is classed as "unplantable" by the Forestry Commission. The total area of important peatland vegetation lying within the area defined as "plantable" by the Forestry Commission is 128,584 ha (see Figure 69).

Finally, the selection requirement has to be assessed against the area of blanket bog in the region already lost to afforestation and the international importance of this peatland class. Apart from the overall reduction in blanket bog extent and the destruction of or damage to high-quality sites, an important aspect of this impact is the way it has fallen widely but haphazardly across the whole peatland area. At least 33 out of the 41 major river catchments within the region now contain at least some afforestation. The effect has been to cause a marked fragmentation of many major blocks of once continuous peatland and to destroy the visual integrity of the total blanket bog landscape in many places. It was this visual character, of a continuous tundra-like physiognomy, that was once so striking and unique a feature of the main flow areas. In parts of the region where this character of intact peatland landscapes still persists, including the associated range of freshwater systems, it is important that it be maintained as far as possible. Because of the propensity of afforestation for affecting the mechanics and chemistry of peats and waters in parts of a catchment well away from the planted ground, it is also important to maintain the integrity of those catchments which have no forest and to avoid further planting on ground draining into highly valued mire systems.

To take account of this need, five major blocks of still continuous peatland have been identified, based on the occurrence of important exemplary and special feature sites but with the addition of connecting ground which is necessary to their continuity. These blocks, which are an important component of the whole conservation programme, should be regarded as particularly sensitive to any further afforestation within their boundaries because even small plantations can have an impact out of all proportion to their size, particularly in an area which was previously almost completely unafforested.

These blocks are indicated in only a general way in Figure 70 because boundaries of landscape units are less clearly definable than, say, the limits of a hydrological catchment.

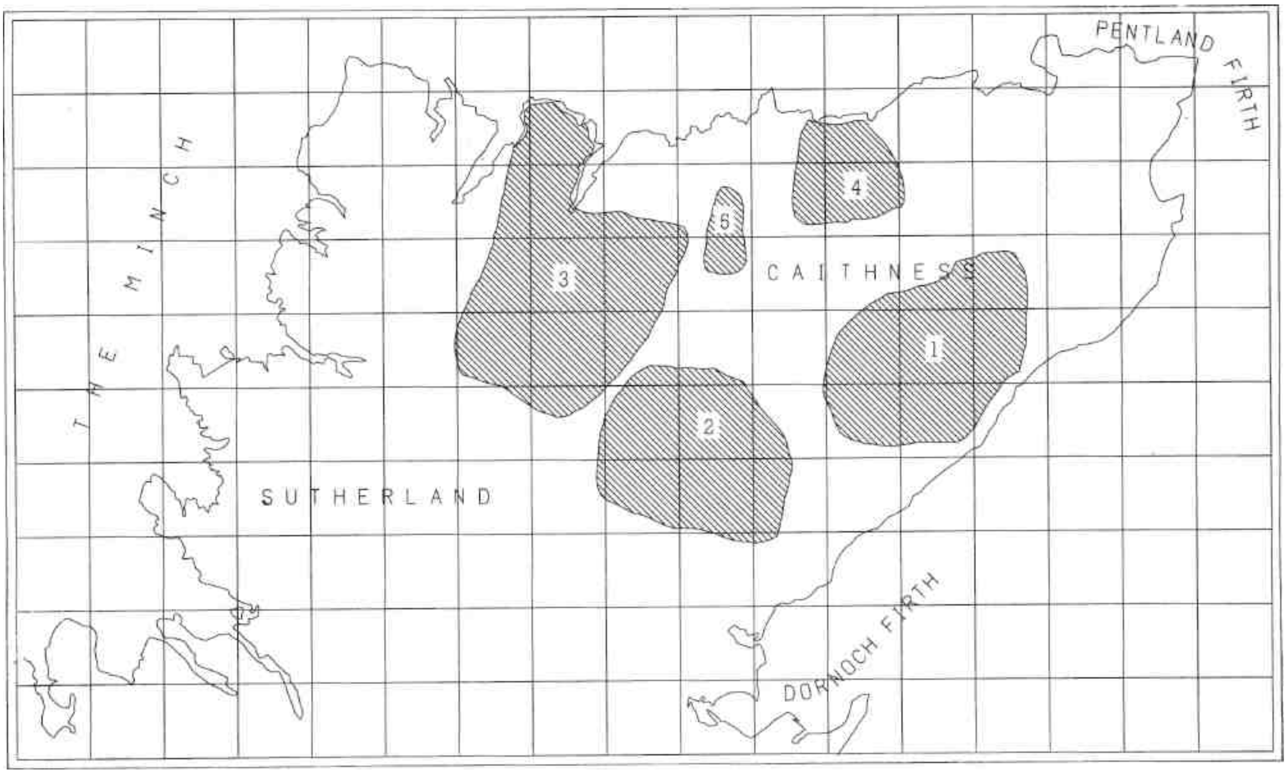

Figure 70 Generalised areas of landscape which are peat-dominated but which currently have a low proportion of afforestation. These landscape units are important as control catchments for fisheries and acid rain research and should therefore be regarded as particularly sensitive to further afforestation.

1 South of the River Thurso - Berriedale - Knockfin

2 Brora - Loch Choire - Borrobol - Black Water

3 A'Mhoine - Ben Loyal - Beinn Stumanadh - Strathnaver - Pole Hill - Ben Klibreck - Ben Hee - Loch Hope

4 Melvich Bay - Trantlemore - Loch Caluim - Reay

5 The catchment of the Allt Lon a'Chuil (between Strathnaver and the Rimsdale Burn)

Part III The freshwater habitats of Caithness and Sutherland

14 Recent surveys of aquatic flora and fauna

Caithness and Sutherland contain approximately 30,000 ha of open water (Highland Regional Council statistic), comprising many hundreds of lochs and stream systems. Since 1979 botanical surveys have been carried out by the NCC on four rivers - the Forss Water and the Rivers Oykel, Wick and Inver - and over 350 lochs in Caithness and Sutherland. 117 lochs and rivers were surveyed for invertebrates in 1985 by the Caithness Biological Records Centre (Spirit 1987). In 1986 the Freshwater Biological Association was commissioned by the NCC to carry out invertebrate surveys of the River Oykel in Sutherland and the Burn of Latheronwheel and the. Forss Water in Caithness. In 1987, 43 sites were surveyed for water beetles by Dr G N Foster, the national recorder for aquatic Coleoptera (Foster 1987). The following information is based mainly on these recent surveys and on records held by the Biological Records Centre at Monks Wood Experimental Station of the Institute of Terrestrial Ecology.

Aquatic vegetation

The NCC has recently produced classifications of the vegetation of rivers (Holmes, 1983) and standing waters (M A Palmer in prep.) throughout Great Britain. Both these classifications reflect the nutrient status of aquatic systems.

Nutrient-poor (oligotrophic) waters are typified by species such as alternate water-milfoil *Myriophyllum alterniflorum,* bulbous rush *Juncus bulbosus,* shoreweed *Littorella uniflora,* water lobelia *Lobelia dortmanna,* floating bur-reed *Sparganium angustifolium*, bog pondweed *Potamogeton polygonifolius* and broad-leaved pondweed *Potamogeton natans.* Nutrient-poor rivers are often dominated by mosses and liverworts rather than higher plants. Lakes and pools floored by peat are usually highly acidic (dystrophic) and often contain few plants apart from *Sphagnum* species, bulbous rush and bogbean *Menyanthes trifoliata.*

Moderately nutrient-rich (mesotrophic) waters typically lack *Potamogeton polygonifolius* and *Sparganium angustifolium.* Mesotrophic lakes are likely to have a more diverse *Potamogeton* flora than oligotrophic sites and often contain perfoliate pondweed *Potamogeton perfoliatus* and various-leaved pondweed P. *gramineus.* Mesotrophic rivers contain proportionally fewer mosses and liverworts and more higher plants than oligotrophic rivers. Mesotrophic and oligotrophic waters occur predominantly in the north and west of Britain.

There are a number of vegetation types typical of nutrient-rich (eutrophic) waters, some dominated by floating plants such as duckweeds *Lemna* species and yellow water-lily *Nuphar lutea,* others by submerged species such as spiked water-milfoil *Myriophyllum spicatum,* fennel pondweed *Potamogeton pectinatus* and (in rivers) the river water-crowfoot *Ranunculus penicillatus* var. *calcareus.* A final category of "mixed" lake has a peculiar and unusual mixture of species typical of oligotrophic and eutrophic .conditions, normally occurring as a result of acid inflows to a calcareous basin. Eutrophic systems are found predominantly in lowland Britain, especially in the south and east.

Figures 71 to 73 illustrate the distribution of the various standing water and river types in Caithness and Sutherland, based on botanical survey data collected recently by the NCC and categorised according to its Great Britain classifications. A wide range of vegetation types is represented, but the mesotrophic and eutrophic end of the spectrum is largely confined to areas away from deep peat (Figures 71-72). The two river systems surveyed in Sutherland are relatively uniform throughout their length, whereas those in Caithness show a downstream progression from nutrient-poor to more nutrient-rich conditions. A few lochs in Caithness and on Durness Limestone in north-west Sutherland belong to the nationally rare "mixed" lake type (Figure 72). Most of the lochs examined in the area covered by blanket bog are oligotrophic or dystrophic (Figure 73).

Rare and uncommon plants

Table 7 lists the 10 species of nationally scarce plants which have been recorded in the last four years in water bodies either in the blanket bog of Caithness and Sutherland or in catchments influenced by

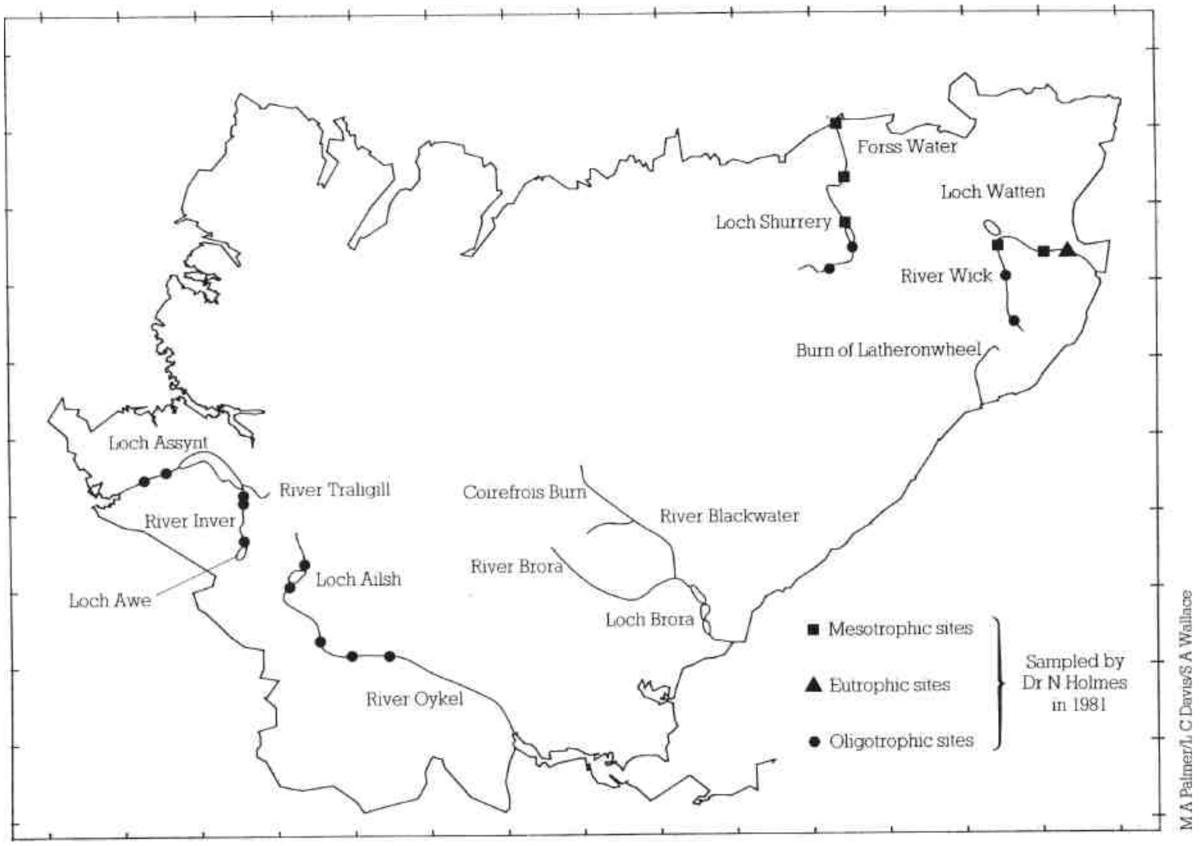

Figure 71 Surveyed river sites in Caithness and Sutherland.

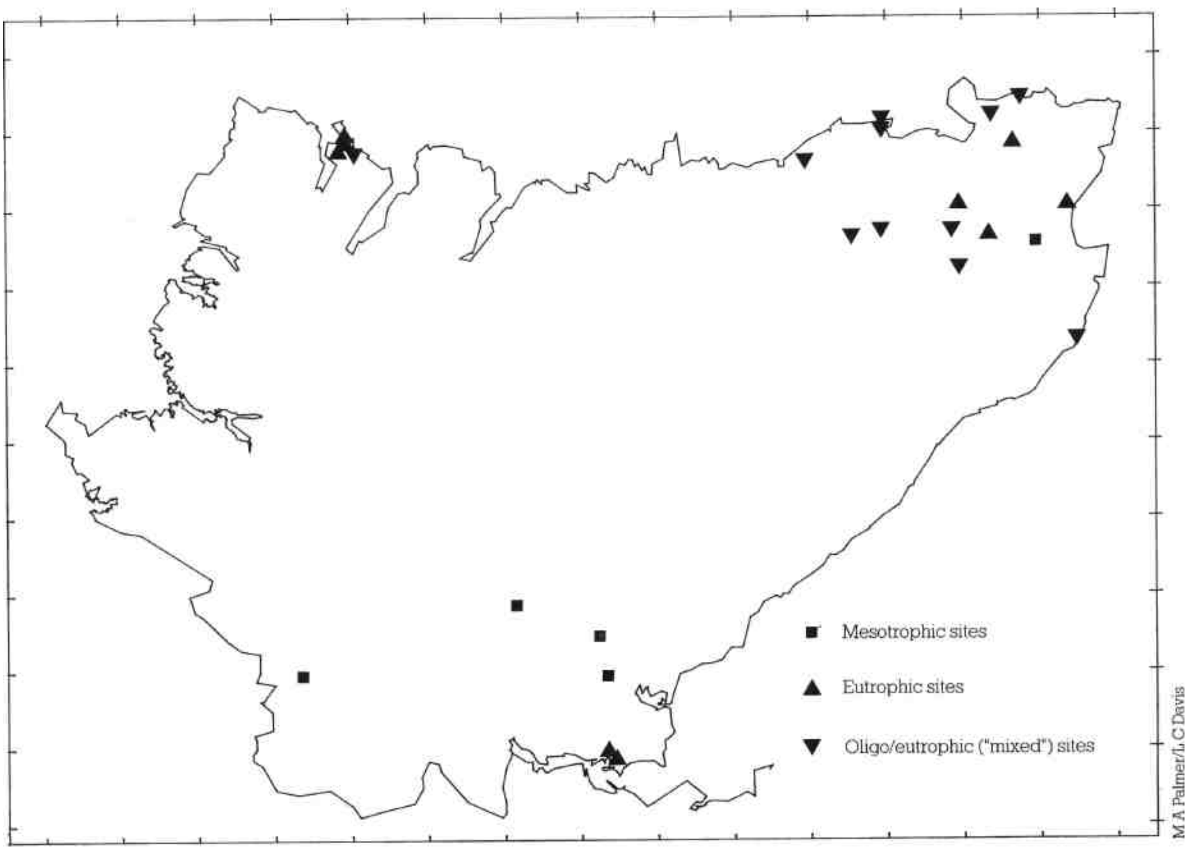

Figure 72 Lochs of richer nutrient status in Caithness and Sutherland.

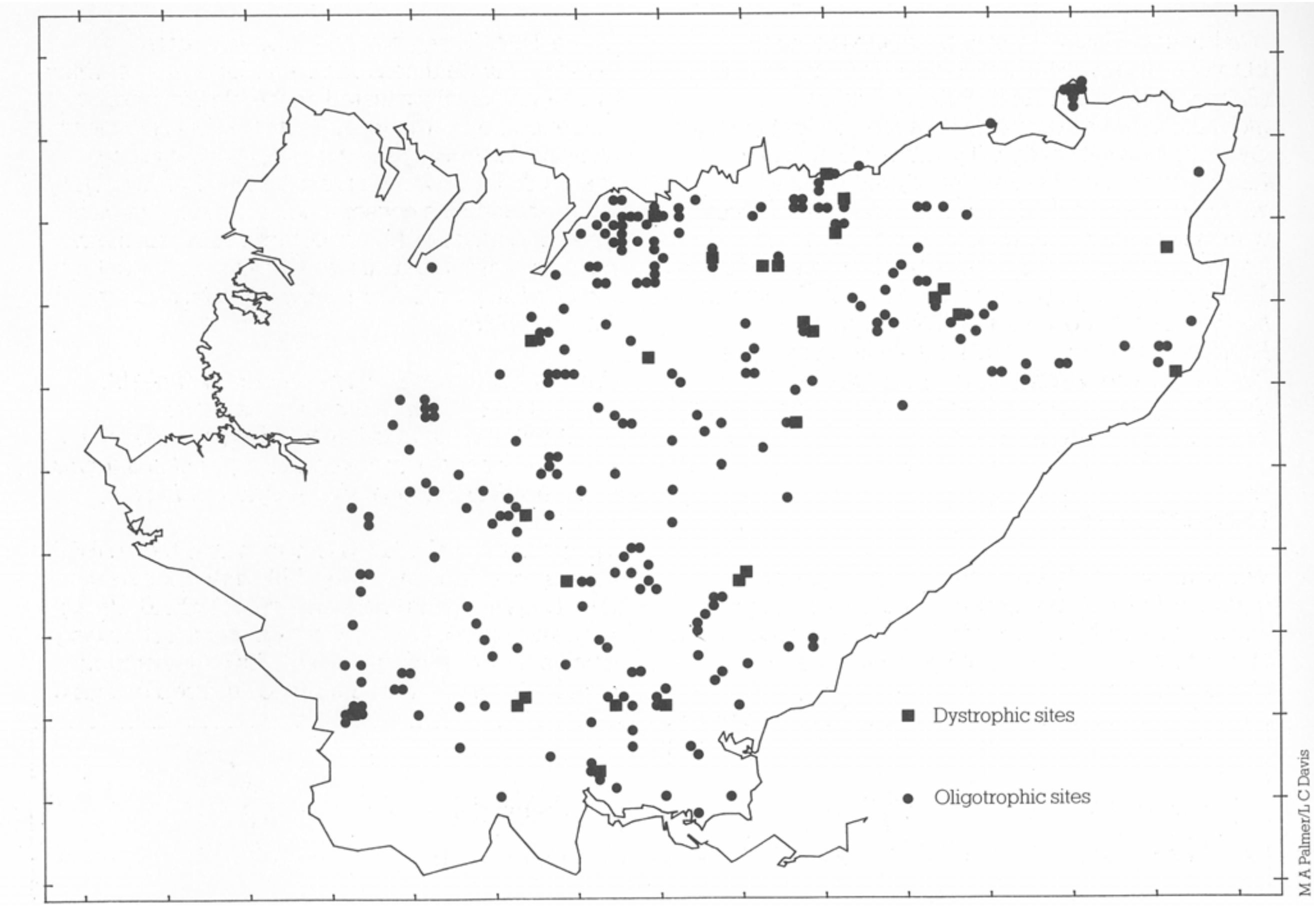

Figure 73 Distribution of nutrient-poor lochs in Caithness and Sutherland.

	No. of 10 km squares in Great Britain*	Records 1984–1987 Caithness	Sutherland	Comments
Callitriche hermaphroditica	80	+	+	
Carex aquatilis	46	+	+	
Deschampsia setacea	41	–	+	
Hammarbya paludosa	67	–	+	
Isoetes setacea	60	–	+	
Lycopodiella inundata	55	–	+	
Nuphar pumila	24	–	+	
Pilularia globulifera	71	–	+	IUCN Red Data Book – vulnerable category
Potamogeton filiformis	48	+	Durness Lochs only	
Potamogeton praelongus	81	+	+	

* 1930 onwards for flowering plants.
1950 onwards for ferns.
Includes new sites discovered in 1987.

Table 7

Nationally scarce plant species recorded recently from Caithness and Sutherland waters which are on or influenced by deep peat.

blanket bog. Nationally scarce species occur in between 16 and 100 10 km squares in Great Britain (Palmer & Newbold 1983). Pillwort *Pilularia globulifera*, which occurs in the valley of the River Oykel, is internationally vulnerable (Council of Europe 1983). Least water-lily *Nuphar pumila* is a very uncommon plant (Figure 74), which hybridises with the common yellow water-lily *Nuphar lutea*, itself rare in northern Scotland. Several species in Table 7, notably autumnal water-starwort *Callitriche hermaphroditica*, slender-leaved pondweed *Potamogeton filiformis* and long-stalked pondweed *Potamogeton praelongus*, are more typical of slightly alkaline or neutral waters than of acidic, markedly nutrient-poor sites.

Invertebrates

Whilst the invertebrate communities of waters in northern Scotland are generally less diverse than those of lowland England, they are often of great interest because of their relict arctic-alpine characteristics.

Table 8 lists 21 notable invertebrate species occurring in Caithness and Sutherland waters which are either actually situated on the blanket mire or influenced by it. Not included in the list is the native crayfish *Austropotamobius pallipes*, whose only known Scottish location is a loch near Durness, lying on limestone. The conservation of this species is of great importance since elsewhere in Britain many native crayfish populations are being wiped out by the crayfish plague fungus *Aphanomyces astaci* (Marren 1986).

The most noteworthy of the species in Table 8 are the freshwater pearl mussel *Margaritifera margaritifera*, the blue hawker dragonfly *Aeshna caerulea*, a caddis fly *Nemotaulius punctatolineatus* and a small diving beetle *Oreodytes alpinus.*

The pearl mussel is listed as vulnerable by the IUCN (Wells, Pyle & Collins 1983). Although it occurs in a few rivers in Wales and south-west England, strong populations are restricted to a few cool, fast-flowing, calcium-poor rivers in Scotland. River systems on peat in Caithness and Sutherland with populations of

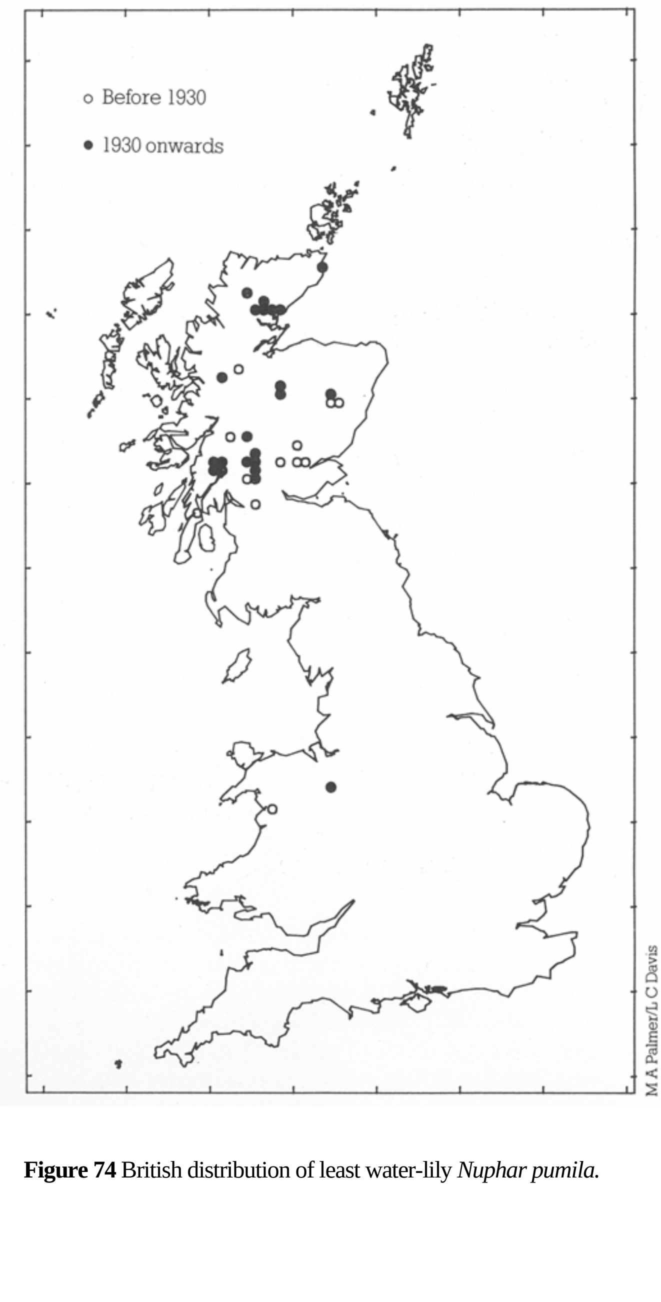

Figure 74 British distribution of least water-lily *Nuphar pumila.*

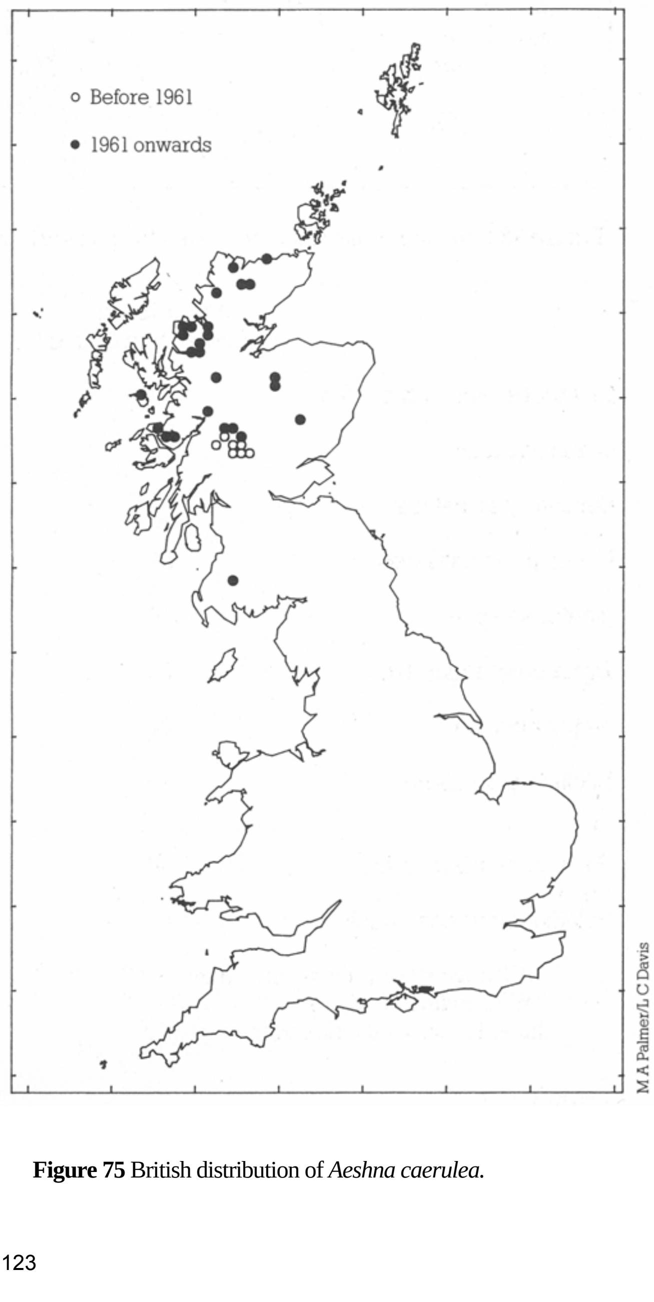

Figure 75 British distribution of *Aeshna caerulea.*

	Caithness	Sutherland	Comments
Molluscs			
Margaritifera margaritifera	+	+	IUCN Red Data Book - vulnerable category
Sphaerium lacustre	+	-	Rare in northern Scotland
Crustaceans			
Gammarus pulex	+	-	Rare in northern Scotland
Stoneflies			
Capnia bifrons	+ (Forss)	-	Rare but widespread in Great Britain
Dragonflies			
Aeshna caerulea	-	+	Nationally scarce; confined in Great Britain to north-west Scotland
Cordulegaster boltonii	-	+	Threatened in parts of Europe
Sympetrum nigrescens	+	+	Largely confined in Great Britain to north-west Scotland
Caddisflies			
Nemotaulius punctatolineatus	+	-	British Red Data Book - rare category
Polycentropus kingi	+(Latheronwheel)	-	Uncommon but widespread in Great Britain
Beetles			
Coelambus novemlineatus	+	+	Nationally scarce
Deronectes latus	+	+	Nationally scarce
Dytiscus lapponicus	+	-	Nationally scarce
Gyrinus minutus	+	+	Nationally scarce
Gyrinus opacus	+	+	Scarce in Great Britain and Europe
Hydraena rufipes	+	-	Nationally scarce
Hydroporus longicornis	+	+	Nationally scarce
Ilybius aenescens	+	+	Nationally scarce
Ochthebius bicolon	+ (Forss)	-	Nationally scarce
Ochthebius exsculptus	+(Forss)	-	Nationally scarce
Oreodytes alpinus	+	+	British Red Data Book - rare category
Potamonectes griseostriatus	+	+	Nationally scarce

Table 8

Notable invertebrate species recorded recently in Caithness and Sutherland waters which are on or influenced by deep peat.

pearl mussel are listed in Table 9. A recent severe decline in this species has been attributed to pollution, habitat modification and over-fishing for pearls (Young & Williams 1983), The mussel is parasitic in its larval stage on the gills of fish, mainly salmonids, so changes in water quality which make a river unsuitable for these will affect mussel Populations. *Margaritifera margaritifera* has recently been recommended by the NCC for addition to

Caithness	
Berriedale	Few, small mussels present. Only known site in Caithness.
Sutherland	
Borgie	Small numbers of small mussels remain.
Brora	Populations of mussels present.
Helmsdale	Overfishing has reduced the population.
Naver	Mussels common in some places.

Table 9

Catchments on peat with populations of pearl mussel *Margaritifera margaritifera* recorded since 1970.

Schedule 5 of the Wildlife and Countryside Act 1981 and for protection under the Bern Convention (see Chapter 18). At its session of July 1987 the European Parliament adopted a resolution that the habitats of the pearl mussel must be designated as protected sites.

Ten species of dragonfly have recently been recorded from the lochs, pools and streams of the Flow Country. This represents only a quarter of the British dragonfly fauna, a consequence of the natural decline in dragonfly diversity with increasing latitude. *Aeshna caerulea* (Figure 75) is a circumboreal species confined in Britain to acid pools and seepages in Scotland.

The caddisfly *Nemotaulius punctatolineatus* (Figure 76) was discovered breeding in inland *dubh lochain* in Blar nam Faoileag, a peatland SSSI in Caithness, in 1985 (Spirit 1987). This species is included in the Insect Red Data Book (Shirt 1987) and has previously been found in Britain only near Aviemore, in its adult stage.

The beetle *Oreodytes alpinus,* another Red Data Book species (Shirt 1987), was first discovered alive

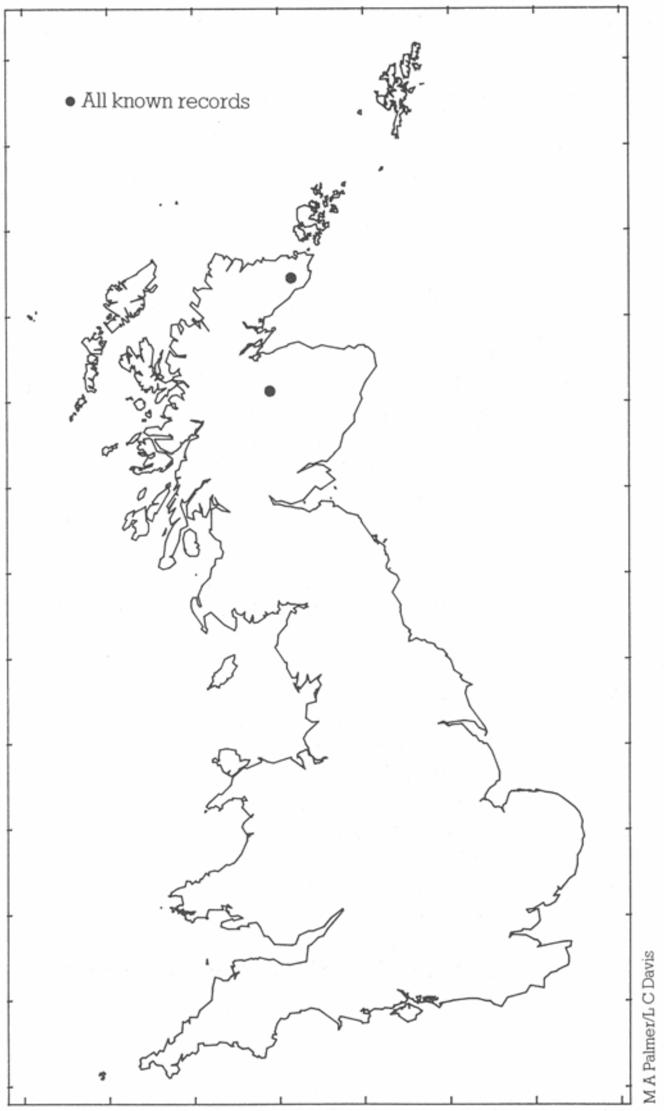

Figure 76 British distribution of *Nemotaulius punctatolineatus.*

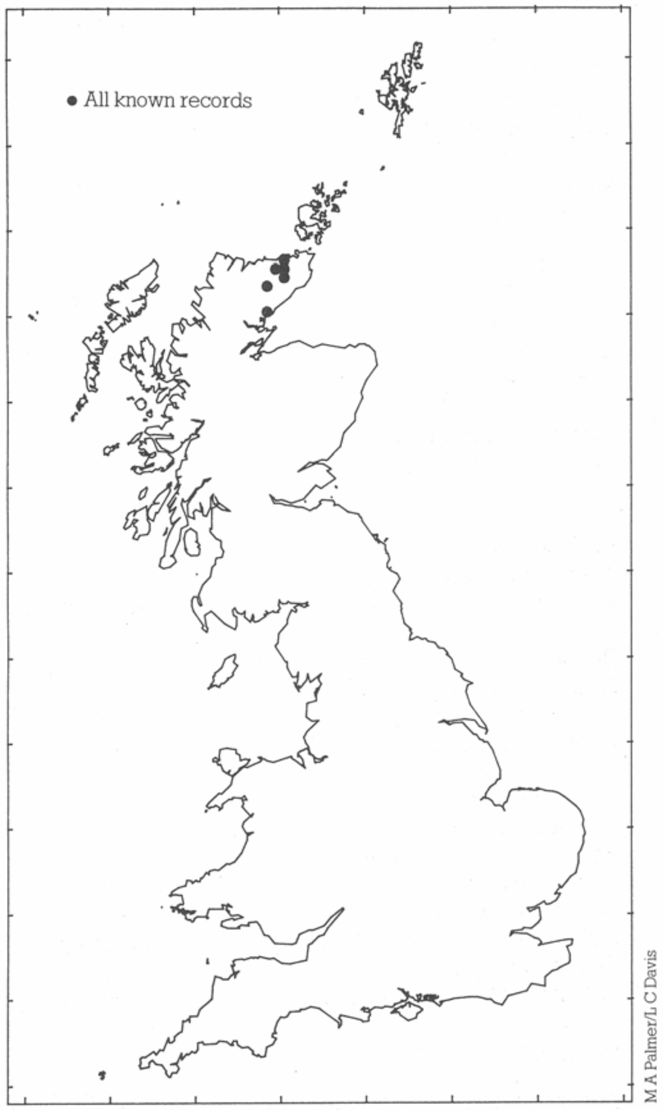

Figure 77 British distribution of *Oreodytes alpinus.*

in Britain in 1985 (Foster & Spirit 1986). It was known previously in Britain only as a sub-fossil in glacial deposits. It also occurs in northern Scandinavia and Siberia and has now been recorded from two sandy lochs in Sutherland and several in Caithness (Foster 1987 and Figure 77). On the blanket bog itself, the most favourable type of area for water beetles is a lochan-studded plateau with a range of pools of varying size containing diverse vegetation. Such areas exist at the Flows of Leanas (ND 2648), the Knockfin Heights (NC 9133) and Druim na h-Uamha Moire (NC 2328). The whirligig beetle *Gyrinus opacus*, which is uncommon in Europe as well as Britain, occurs at these sites. This beetle appears to need highly specialised conditions, preferring eroding lochans without inflows or outflows but with deep water relatively free of loose, floating peaty material (Foster 1987). *Gyrinus opacus* and a scarce diving water beetle, *Dytiscus lapponicus*, which was first found in Caithness in 1985 (Spirit 1987), are also relict arctic-alpine species, confined (apart from one Welsh record for the latter) to Scotland (Figures 78 and 79).

Rivers sampled		BMWP scores			
	Sampling stations	Spring	Summer	Autumn	Seasons combined
Forss Water	1 2	124 182	154 117	181 206	236 245
Burn of Latheronwheel	1 2	160 165	121 112	144 116	184 203
River Oykel	1 2	146 181	144 120	70 42	206 202

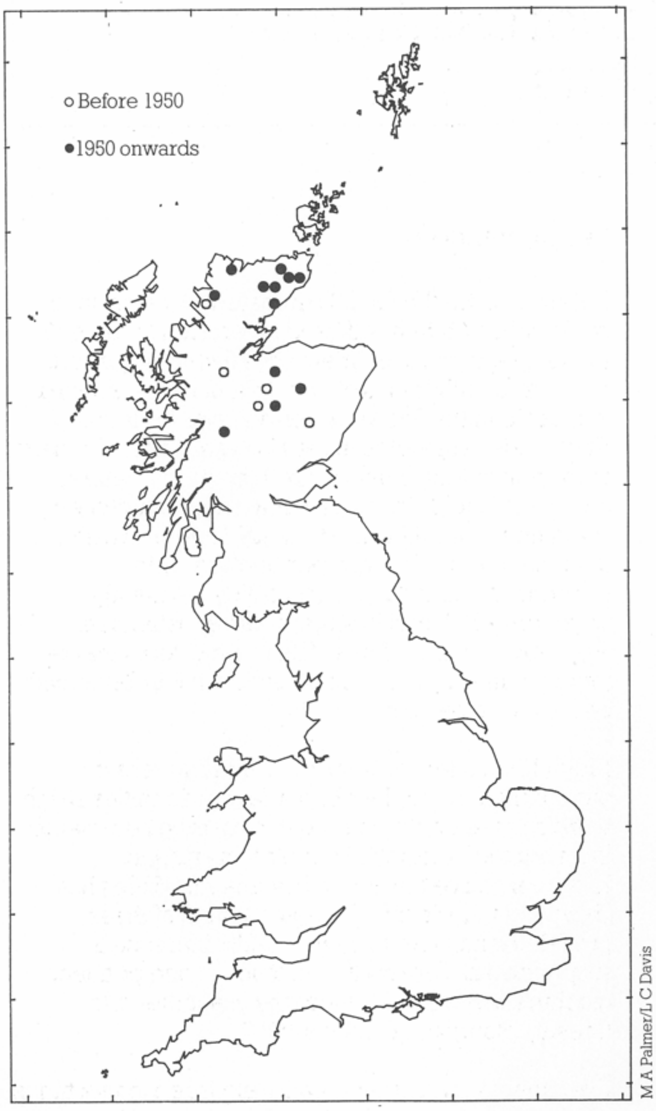

Figure 78 British distribution of *Gyrinus opacus.*

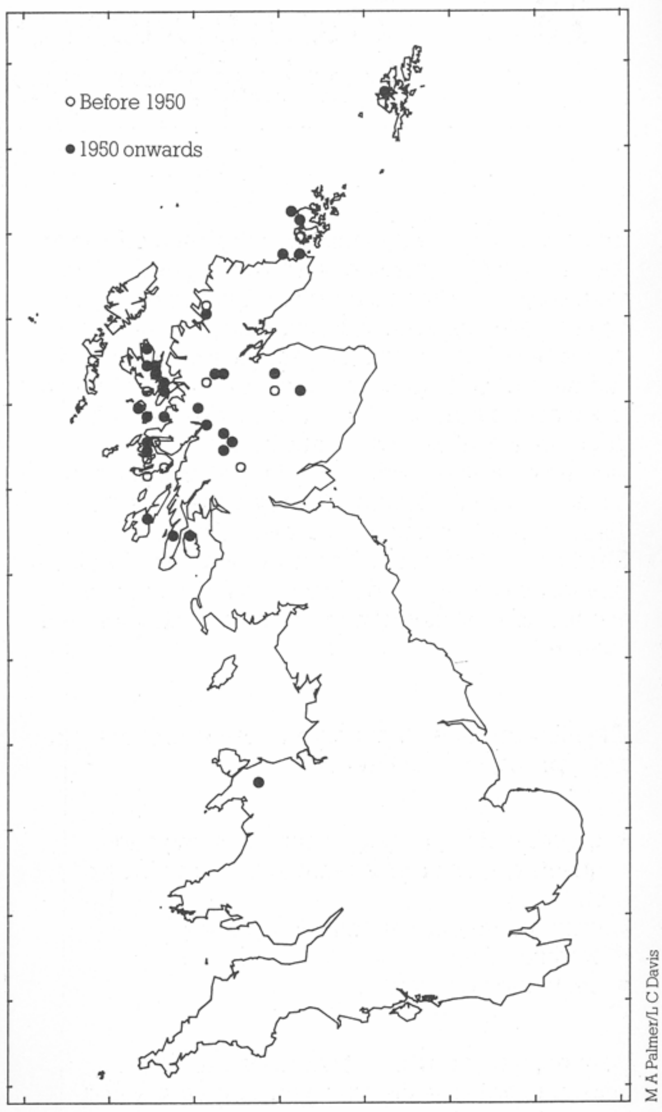

Figure 79 British distribution of *Dytiscus lapponicus.*

A survey of the invertebrate fauna of the Forss Water, Burn of Latheronwheel and River Oykel by the Freshwater Biological Association in 1986 showed that these rivers all contain a diverse fauna, typical of clear, upland rivers. Several uncommon insects were found (Table 8). The Biological Monitoring Working Party (BMWP) scores for sites on these rivers are given on page 125.

The BMWP score is calculated by allotting scores to a range of invertebrate families, according to their sensitivity to pollution, and totalling the scores for the families present in a sample. BMWP scores above 120 are unusual (National Water Council 1981), so it is clear that the rivers surveyed in Caithness and Sutherland are of high quality, especially the Forss Water.

Fisheries

Caithness and Sutherland have important freshwater fisheries, and rivers such as the Helmsdale, Shin, Thurso and Naver are famous for their game fishing. There have however recently been declines in catches on the Helmsdale and other rivers.

15 The impacts of afforestation on freshwater habitats

Afforestation of blanket mire has profound effects on the ecology of associated freshwater systems. The most evident harm occurs when small-scale pool systems are obliterated during ploughing and drainage or natural watercourses are straightened and deepened to form collecting drains. Even where associated freshwater habitat is not destroyed by direct means, it usually suffers fundamental modification. The evidence linking afforestation with changes in aquatic fauna illustrates one aspect of these indirect effects. For instance, Egglishaw, Gardiner & Foster (1986) have demonstrated a close relationship between declines in salmon catches and the afforestation of nursery stream catchments in Scotland.

The most important impacts on freshwater flora and fauna probably result from -

- physical changes (e.g. in run-off timing and quantity; erosion and sedimentation; degree of shading);
- nutrient enrichment (eutrophication);
- acidification;
- pesticide application.

Planting, tree growth and harvesting all have different effects on the hydrology, chemistry and biota of the freshwater system, and each phase can cause profound and destabilising change to the ecosystem.

Physical changes

Run-off

Drainage of peat soils immediately prior to afforestation frequently produces a "flashy" storm response, giving higher flood flows in streams and a reduction in times to peak (Robinson 1980). Later in the cycle, closed canopy forest intercepts much of the rainfall, which can cause a reduction in total run-off of 20-30%, as compared with conditions measured on open moorland (Hornung & Newson 1986), thereby creating prolonged droughts on the forest floor. Many stream invertebrates are adapted to restricted ranges of current velocity and cease to feed or are washed away during extreme spates. Salmonid eggs and fry are also likely to be washed out in such conditions. In streams which dry up or become sluggish, fish will be unable to breed successfully and the invertebrate faunas will be severely reduced or their community structures changed.

Sedimentation

Robinson & Blythe (1982) estimated that a drained peatland catchment suffered an erosion level of 120 tonnes per square kilometre in a five-year period, compared with losses of only 15 tonnes per square kilometre in the five year period prior to draining. Thus, sediment yields in the five years after drainage were equivalent to nearly half a century's natural sediment load. In that Northumberland catchment, draining resulted in an additional level of erosion amounting to 1.05 tonnes per hectare, with concentrations of suspended solids frequently exceeding 500 mg/1 in stream water. Battarbee, Appleby, Odell & Flower (1985) reported a marked increase in sediment accumulation in four lakes with partly afforested catchments.

Mills (1980) offered useful guidelines to reduce sedimentation. Unploughed streamside buffer strips were suggested as a means of capturing sediments in an unmodified belt of vegetation and soil. However, research at Llanbrynmair in Wales has shown that the careful implementation of these guidelines failed to prevent a 246% increase in suspended stream sediment loads in one peatland catchment and a 479% increase in another after forestry ploughing (Francis 1987).

Even mature catchments can yield three to five times the volume of stream bed-load discharged from grassland (Newson 1980), probably because herb growth is suppressed and log-jams result in changes to stream-courses. During felling operations significant increases in suspended sediment yields have been measured (Leeks & Roberts 1986). The construction of forestry roads can also exacerbate sedimentation.

Hobbs (1986) points to the phenomenon of "rebound" when a load is removed from a peat body. This arises because the natural shape of the peat mass is distorted by the weight of any load placed on it. Thus, as the timber crop grows, it gains weight and acts as a considerable load, depressing the natural shape of the peat body. The extent of distortion varies with the general degree of humification in the original peat and also, clearly, the weight attained by the trees. When the trees are removed at harvesting, the rebound of the mire surface to something approaching its original shape can be significant and can also occur over a considerable period of time. There is thus the additional problem, at harvesting, of drain 'rejuvenation' caused by small but steady increases in surface gradients further contributing to increased run-off, scouring and sedimentation.

High concentrations of suspended solids limit light penetration, thus reducing the rate of photosynthesis by aquatic plants. This, together with the settlement of silt on leaves, can kill submerged vegetation in streams and lakes. Blanketing of the stream bed reduces substrate diversity and makes conditions unsuitable for invertebrates adapted to life in stony lakes and gravelly reaches of streams. Filter-feeding molluscs such as the pearl mussel close their shells for prolonged periods in silty water. Their feeding and breathing mechanisms are impaired by heavy silt loads (Ellis 1936).

The gills of fish become inflamed at suspended solids loadings of only 100-270 mg/1 (Alabaster & Lloyd 1980). Turbid water may reduce a fish's foraging efficiency. Egg survival is impaired in silt-laden streams because the gravelly spawning sites of salmonid fish become occluded by sediment, which reduces the oxygen supply. Alabaster & Lloyd (1980) have therefore suggested an upper safe limit of 25-80 mg/1 suspended solids for salmonid fisheries. Such values are very frequently exceeded in watercourses draining afforested areas.

Shading

Dense shading of coniferous forest streams and pools prevents the growth of marginal vegetation. Reedswamp and shrubs are lost, whereas they would normally tend to stabilise banks, provide niches for invertebrates and give cover for fish. The diversity of both fauna and habitat is therefore reduced. A closed canopy can reduce the light reaching a stream bed to 10% of that in open environments (Smith 1980), an effect which has profound implications for aquatic plants and invertebrate community structures. Although aquatic invertebrate biomass may not be affected by afforestation, diversity can be reduced (Harriman & Morrison 1982). The biomass of invertebrates falling into the water from the surrounding land, another food source for salmonid fish, does, however, appear to be lower in coniferous forest than in deciduous woodland or moorland (S J Ormerod *et al.* unpublished).

Shading by coniferous forest has a strong moderating influence on stream temperature, and this affects the growth, distribution and life cycles of invertebrates and fish. Welsh stream water in a forested catchment was recorded as on average 2°C cooler in the summer and up to 1°C warmer in the winter than water in moorland catchments (Roberts & James 1972). Simulations of annual growth, based on water temperatures in Wales, have predicted that a 10-gramme fish would attain a weight 15% lower in an afforested than in a moorland stream (Ormerod, Mowle & Edwards 1986).

Nutrient enrichment

Afforestation on nutrient-poor soils is accompanied by the application of fertilisers containing rock phosphate. Often potassium is also applied, and sometimes nitrogen in the form of urea. Quite apart from the effects of fertiliser application, ploughing and felling can cause mobilisation of nutrients and lead to increased concentrations in drainage water.

Harriman (1978) estimated that 15% of the phosphorus in fertiliser applied to an afforested peatland was lost to streamwater. Malcolm & Cuttle (1983) measured nutrient losses to drainwater after fertilising unplanted drained peat. 16% of the phosphorus was lost over three years and they estimated that 25-30% would be lost to drainwater in five or six years. Experience at the Black Esk reservoir in north-east Dumfriesshire suggests that after an aerial application of rock phosphate to the catchment the raw water phosphorus increased from 0.002 mg/1 to 0.06 mg/1 over a six-month period and stabilised at 0.04 mg/1 (Parr 1984). The 30-fold increase in phosphorus concentrations at this reservoir over the first six months following application was possibly due in part to the drift of phosphate directly into watercourses. However, the stabilised figure (a 20-fold increase) seems to reflect a longer-term leaching of fertiliser from soils.

When rock phosphate was applied to forests in the Cree catchment in Galloway during frosty weather, ensuing thaw and rain produced a river load of 321 kg of elemental phosphorus in one day, 25 times the normal level (Coy 1979). Even when fertiliser is applied in warmer conditions, rock phosphate releases phosphorus so slowly that the surface peat may retain a high proportion of this element for a lengthy period. When subsurface layers are frozen or saturated, rain or snow-melt will rapidly transport surface water to drains and natural streams.

Other eutrophication effects may stem from rapid oxidation and mineralisation of peat rather than applied fertiliser. Duxbury & Peverly (1978) reported significant losses of nitrogen after drainage of organic soils. Forest clearance can also affect water quality. In New Hampshire, for two years after clear-felling, nitrate-nitrogen concentrations in streams exceeded the level of 11.3 mg/1 recommended by the World Health Organisation for drinking water (Likens, Bormann, Johnson, Fisher & Pierce 1970).

Nutrient enrichment of lakes in afforested catchments has led to blooms of planktonic and filamentous algae, especially nitrogen-fixing blue-green species and diatoms (Richards 1984). Dense algal blooms can lead to suppression of aquatic vegetation, loss of plant and invertebrate species diversity and sometimes fish-kills, owing to algal toxins or deoxygenation. Rivers and streams subject to enrichment will also experience enhanced productivity, which can manifest itself in an increase in epilithon (the film of bacteria, algae and other micro-organisms coating the surface of stones) and in populations of animals such as some mayfly species which graze the epilithon. Leaves decompose rapidly in nutrient-rich waters, so invertebrates which live on fine, decomposing organic matter will benefit. Filter-feeders, including biting blackflies (Simuliidae) which can be serious pests, and detritivores such as worms may increase in numbers, whereas "shredders", such as many of the stoneflies (Plecoptera), which live on coarse organic material, are disadvantaged (Hildrew, Townsend, Francis & Finch 1984). The eutrophication of lakes and streams can therefore cause fundamental changes in their flora and fauna.

Acidification

There is strong evidence that conifer plantations on upland, base-poor soils enhance the acidification of surface waters and increase concentrations of metals such as aluminium. In Wales, for example, streams draining forest blocks have a mean pH (hydrogen ion concentration) which is 0.5 to 1.0 units lower than similar streams draining moorland and aluminium concentrations 0.1 to 0.4 mg/1 higher (Stoner, Gee & Wade 1984).

Coniferous tree crops increase the concentration of acidifying sulphur and chlorine compounds in soils and run-off by efficient "scavenging" from oceanic or polluted air (Bergkvist 1986; Reuss & Johnson 1986). Ammonia and compounds of nitrogen and oxygen (NO_x) are also efficiently captured by conifer needles and can contribute to the acidity of run-off, although they do not necessarily accumulate in soils. Further, a considerable proportion of incoming water passes over acidic bark as stem-flow. Enhancement of acidity by coniferous forest is partly related to the level of atmospheric pollution, which is relatively low in Caithness and Sutherland. However, as explained in Chapter 5, the peatlands of Caithness and Sutherland are very sensitive to acid deposition.

Ploughing and drainage cause the oxidation and mineralisation of previously anaerobic organic and inorganic soil components, resulting in the production of further hydrogen ions (Cresser & Edwards 1987). Trees also release hydrogen ions during the uptake of cations such as ammonium. Peats are not well buffered and can be expected to discharge more hydrogen ions than most mineral soils. All these processes may contribute to the increase in acidity of the water draining from afforested areas of blanket bog.

Aluminium is a major component of the mineral ash of peats (Gorham 1953a; Cuttle 1983). This originates both from mineral soil-water in peat and from atmospheric inputs (Peirson, Cawse, Salmon & Cambray 1973). However, such considerations may be almost irrelevant, because ploughing and draining almost always expose some aluminium-rich mineral soil to run-off. Owing to undulations in the bedrock and drifts below the peat, mineral soil is frequently exposed by ploughing as shallow as 45 cm. Drains at either 60 cm or 90 cm will, in the vast majority of cases, connect with patches of mineral soil, especially near mire margins and natural watercourses.

There is a close relationship between water chemistry and the composition of aquatic plant and animal communities. Many of the rarer aquatic plants, for instance *Potamogeton praelongus* and *Callitriche hermaphroditica,* are restricted to waters • with a fairly narrow range of pH (Newbold & Palmer 1979). Such species are unlikely to survive in acidified waters. Invertebrate density may be higher in acidic streams draining coniferous forest than in their counterparts draining moorland, but diversity is reduced (Ormerod *et al.* 1986). Crustaceans (e.g. *Gammarus species),* mayflies and some caddisflies are intolerant of pH 5.7 or lower and of aluminium concentrations of more than 0.1 mg/1. These groups are often scarce in forest streams.

Low pH and high aluminium concentrations damage the gills offish. Data from over 100 sites in upland Wales (Welsh Water Authority unpublished) indicate that salmonid densities are closely correlated with these factors. A review of the effects on fish of acidification associated with conifer forests is contained in *Nature Conservation and Afforestation in Britain* (Nature Conservancy Council 1986). The following examples are cited (pp. 40-41) -

- after afforestation, there has been a reduction in the catches of salmonids in the River Fleet in Galloway (Drakeford 1979,1982);

- in the upper Tywi, trout are absent from many streams in afforested areas and the number of invertebrate species is less than half that in unafforested areas (Stoner *et al.* 1984);

- after afforestation there has been a decline in salmonids on Plynlimon (Newson 1985);

- salmon eggs and young trout translocated to plantation streams in the Loch Ard (Harriman & Morrison 1982) and upper Tywi areas (Stoner *et al.* 1984) respectively showed much poorer survival than in moorland streams;

- the failure to stock the Rivers Camddwr and Tywi above the Llyn Brianne reservoir with salmon and sea trout has been attributed to afforestation (Stoner & Gee 1985).

Common frog *Rana temporaria* tadpoles, like fish, are sensitive to low pH and high aluminium concentrations (Cummins 1986). Dippers *Cinclus cinclus* have declined since afforestation was carried out along the River Irfon in Wales. This bird is also scarce in other Welsh streams with pH levels below 5.7 and aluminium concentrations above 0.1 mg/1, probably because the invertebrate food is in short supply (Ormerod *et al.* 1986).

Pesticide application

Organophosphorus insecticides such as Fenitrothion have been used in Scotland against pine beauty moth *Panolis flammea* in lodgepole pine forests. After one dose, applied by aerial spraying, concentrations in rivers reached 18—48 jug/1 and aquatic invertebrates were affected, as was obvious from the large numbers observed to be drifting downstream (Morrison & Wells 1981). The adult and flying stages of aquatic insects are also susceptible to such pesticides, and the use of these chemicals near the few lochs known to harbour the rare caddisfly *Nemotaulius punctatolineatus* and the rare water beetle *Oreodytes alpinus* could endanger the survival of these species in Britain. Adult dragonflies are especially vulnerable to pesticides because many hunt some way from the water in sheltered situations and are drawn in large numbers to forested areas adjacent to their breeding grounds.

16 Selection of freshwater habitats for nature conservation

Principles and criteria for selection

The conservation of freshwater habitats requires different emphases, compared with the treatment of terrestrial habitats. Basic to any measures for the protection of rivers and lakes is the need to consider the catchments concerned, for, if adverse changes occur that affect water here, they may nullify attempts to safeguard the confines of the open water bodies. A practical factor is that many of the lochs and rivers in Caithness and Sutherland remain unsurveyed, though it is possible to assign most of these to their broad ecological type by comparison with those for which there is adequate information. The principles of selection are again to give an adequate representation of the range of variation and to ensure that all major examples of rare freshwater types are chosen for protection. The criterion of naturalness is extremely important, in the sense of lack of pollution or disturbance to the hydrological regime. Because oligotrophic and dystrophic water bodies are naturally species-poor, diversity is not necessarily the most significant factor, and the important point is that fresh waters should be assessed according to the characteristics of their type (see Chapter 14).

Oligotrophic and dystrophic lakes and rivers are associated with acidic rock and peat-covered catchments in many parts of Britain and show considerable uniformity. While highly characteristic of the Caithness and Sutherland peatland catchments, they are less notable in their own right either nationally or internationally than the blanket bog systems themselves. They are, nevertheless, important and integral components of the total ecosystem complex, especially as bird habitats (Stroud *et al.* 1987), and it is essential to ensure that they are well represented within the peatland areas identified as important to nature conservation. This representation should include the full range of bioclimatic zones throughout which the open water habitats occur (see Chapter 4). The particular purpose of the freshwater survey has been to indicate the extra biological interest contained within the freshwater systems incidentally included within the peatland conservation areas and to identify further nationally important examples which need protection *in addition*, especially on grounds of catchment safeguard.

Choice of nationally important freshwater sites

Morgan & Britton, *in A Nature Conservation Review* (Ratcliffe 1977), list a series of freshwater sites throughout Great Britain which are nationally important for wildlife conservation. The following five are in Caithness and Sutherland -

Caithness:

Burn of Latheronwheel - eutrophic stream on sandstone
Loch Watten - eutrophic loch on sandstone

Sutherland:

Durness Lochs - four lochs on limestone
Loch Stack and River Laxford - oligotrophic waters, within an acidic rock and peat catchment
Loch Mhaolach-Coire and River Traligill - eutrophic loch and limestone river, with some blanket bog in the catchment.

Figure 80 shows lochs in Caithness and Sutherland notified for their intrinsic value, as distinct from their incidental occurrence as 'bonus' features in association with blanket bog. Apart from the NCR lochs listed above, there are only four lochs notified specifically for freshwater interest. These are three eutrophic lochs - Loch Scarmclate, Loch Heilen and Loch of Wester - and the oligotrophic Loch Glutt, all of them in Caithness.

The recent surveys of rivers and lochs have indicated that three other areas qualify as nationally important (NCR quality) freshwater sites. These are the Forss Water in Caithness, a cluster of three small lochs - Lochs Dola, Craggie and Tigh na Creige - in south-east Sutherland and Loch Brora, also in Sutherland.

The Forss Water is an outstanding example of an unspoilt river showing a transition from oligotrophy to mesotrophy. At the transition lies Loch Shurrery, which is a Site of Special Scientific Interest because of its fen habitat and birds. Several lochs in the catchment contain the rare relict water beetle *Oreodytes alpinus*.

Data from 1124 recently surveyed standing water sites throughout Britain are now held on computer by the NCC. Only 17(1.5%) of these sites have 20 or more species of submerged and floating aquatic plants. Loch Dola, one of the few mesotrophic lochs in northern Scotland, is the fourth richest site in the data-base and the richest in Caithness and Sutherland, with 24 species. Seven additional species are present in the nearby oligotrophic waters Lochs Craggie and Tigh na Creige. These three lochs also contain the nationally scarce *Callitriche hermaphroditica* and *Potamogeton praelongus*. If emergent aquatic plants as well as floating and submerged species are included in the

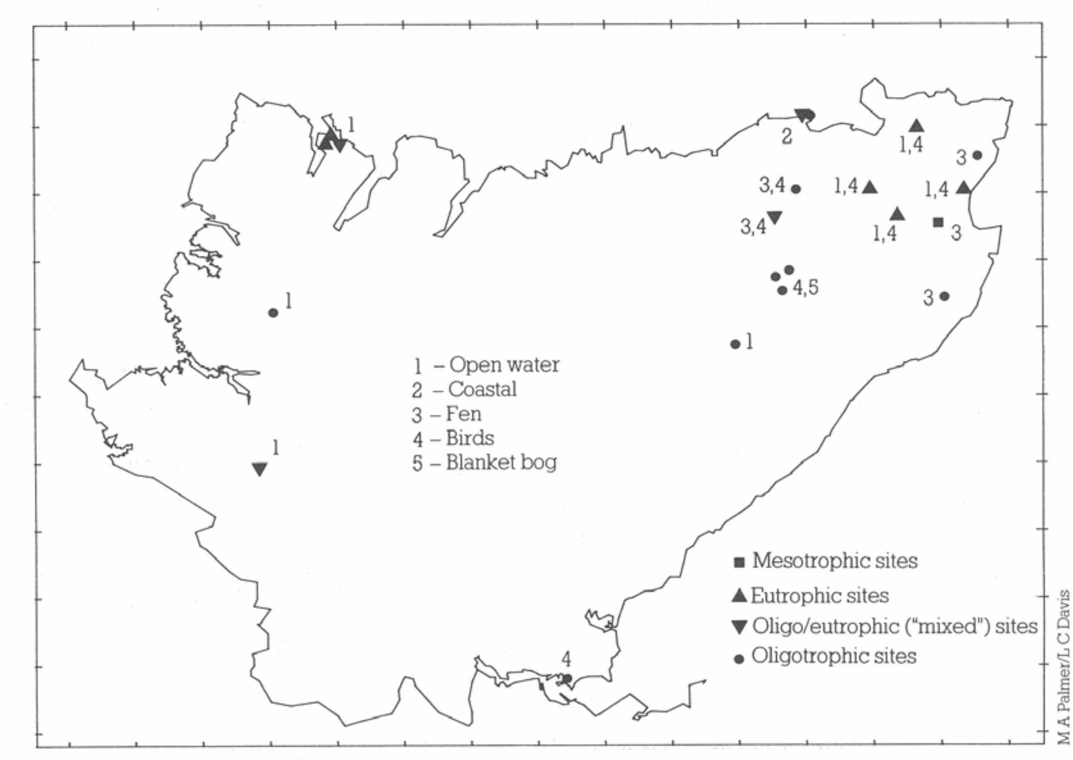

Figure 80 Existing SSSIs which are selected primarily or partly for their freshwater interest.

analysis, Loch Dola is the 13th richest site known to the NCC in Britain.

Loch Brora, despite its oligotrophic nature, has 21 species of open water plants and is the 16th richest of the 1124 sites for submerged and floating species. However, because of its interesting margins, Loch Brora is the 12th richest site in the national data-base if emergent plants are also considered. The loch contains two nationally scarce species, water sedge *Carex aquatilis* and least water-lily *Nuphar pumila. Oreodytes alpinus* is also abundant in Loch Brora. The unspoilt oligotrophic rivers upstream of the loch contain healthy populations of the pearl mussel; therefore there is considerable intrinsic interest in the catchment as well as in the loch itself.

Figure 81 shows the extent of the catchments of the existing NCR sites and of the three recently discovered sites which qualify for NCR status because of their freshwater interest. The figure shows that most of the land in the two largest catchments is of national importance either for peatland habitat or for wading birds (Stroud *et al.* 1987), and this combination of interests adds to its importance for wildlife.

Protection of nationally important freshwater sites

To give full protection to these eight nationally important sites, no further afforestation should be carried out in their catchments. This is particularly important in the areas most sensitive to acidification, which are the headwaters of the Forss Water, the Brora catchment and Loch Stack and its outflow.

Since 1980, at least 90 km of the upper reaches of rivers in Wales have been downgraded in the river quality classification scheme because acidification has made them unsuitable for salmonid fish (Welsh Water Authority pers, comm.). In order to safeguard fisheries, the Welsh Water Authority has drawn up interim guidelines for acceptable levels of afforestation in river catchments lying in areas sensitive to acidification (Welsh Water Authority 1987). The guidelines recommend that, where the mean annual water hardness is less than 12 mg/1 $CaC0_3$, plantations should not exceed 10% of the total river catchment subject to acidification (i.e. the catchment upstream of the point on the river having a mean annual hardness of 15 mg/1). Planting should be confined to small catchments drained by first-order streams having a negligible effect on the receiving watercourse. Wet deposited acidity over most of Wales is 0.03 g H^+/m^2/year or less, as it is in Caithness and Sutherland (United Kingdom Review Group on Acid Rain 1987; Warren Spring Laboratory 1987), so extrapolation of these guidelines to northern Scotland seems appropriate.

Data for total hardness of the Forss Water upstream of Loch Shurrery and for the River Brora above Loch Brora are not available. However, the Highland River Purification Board has measured hardness on the Lower Oykel, a river similar to the Brora. The mean hardness for 1986/87 on the River Oykel (at NC 4101) was 11.6 mg/1. Water analyses carried out in 1987, in connection with the NCC's loch survey, showed hardness in Loch Brora to be 11.76 mg/1 and that of Glas Loch Beag, in the headwaters of the River

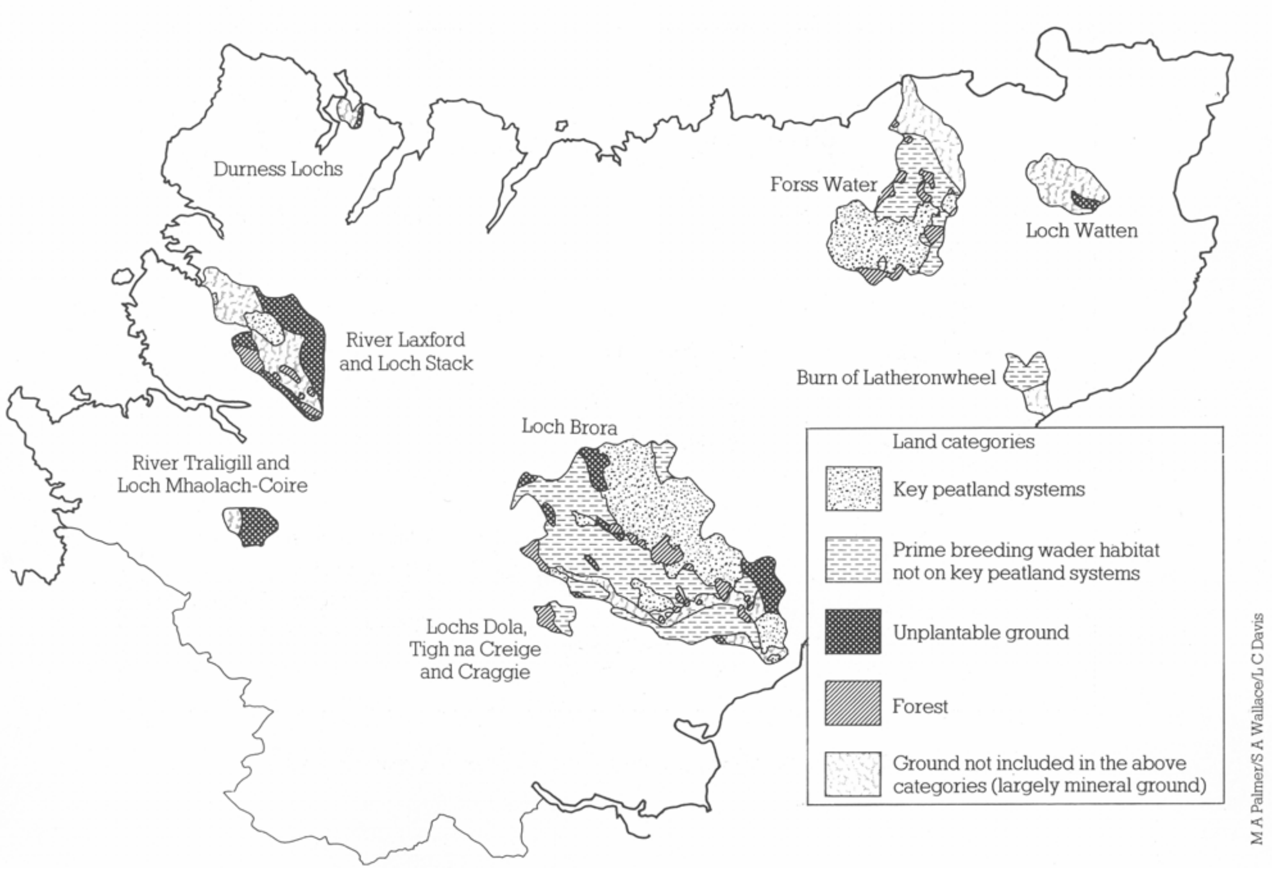

Figure 81 Catchments of nationally important freshwater sites.

Brora, to be 6.32 mg/1. Loch nan Clach Geala, near the headwaters of the Forss Water, had a hardness of only 5.94 mg/1.

Existing plantings are approaching 10% of the catchments of Loch Stack, the Brora and the Forss Water. Much of the catchment of Lochs Dola, Craggie and Tigh na Creige has already been afforested or is planned for planting. Hardness of these loch waters ranged from 15.9 to 18.56 mg/1 in 1987, so they are better buffered than Loch Brora. However, effects such as eutrophication and increased sedimentation could be extremely damaging in this catchment, even if acidification is less of a threat. The potential degradation of one of the richest aquatic plant communities in Britain lends urgency to the need for tight protection in the River Brora catchment, as this is still relatively free of afforestation.