Late summer habitat selection by breeding waterfowl in northern Scotland

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The majority of lochs and water courses were visited in an area of northern Scotland during July 1988. The breeding waterfowl of these waters were recorded along with details of environmental parameters at each site, including water quality. In a correspondance analysis, three axes accounted for 72% of the variance, with conductivity, pH and other measures of habitat type all highly represented. Site analysis showed that different species had distinct habitat preferences. Waterfowl of most restricted distribution on the peatlands (namely Black-throated Diver and Common Scoter) showed strong preferences for lochs with islands and with high pH/conductivity, Red-throated Divers tended to occur on mid-range water quality lochs, Teal selected acidic, base-poor waters and Mallard showed little selectivity in their use of peatland waters. Some implications of peatland afforestation are discussed with respect to breeding waterfowl communities.

The mild, wet, oceanic climate of northern Scotland has resulted in extensive tracts of blanket bog, particularly in Caithness and Sutherland. These peatlands support northern bird communities not encountered elsewhere and are of considerable conservation importance in world terms (Stroud *et al.* 1987, Lindsay *et al.* 1988). Extensive surveys of the breeding bird fauna of the peatlands have taken place in recent years, with particular emphasis on the nesting wading birds (e.g. Reed *et al.* 1983). The waterbodies of the area also support a range of breeding waterfowl species which are rare and/or declining in Britain or which show high breeding densities in the north of Scotland. In particular, the peatlands support nationally important numbers of breeding Red-throated Diver *Gavia stellata*, Black-throated Diver *G. arctica*, Greylag Goose *Anser anser*, Wigeon *Anas penelope* and Common Scoter *Melanitta nigra* (Stroud *et al.* 1987).

Extensive afforestation of the peatlands from the early 1980s threaten the existence of the bogland biotopes by altering the water-table and modifying drainage and run-off patterns. The growth of trees also leads to the ultimate extinction of the open moorland flora and fauna (NCC 1986). However, the ecological effects of ploughing and planting also affect freshwater systems by increasing sediment load (Robinson & Blyth 1982, Burt *et al.* 1983, Batterbee *et al.* 1985, Francis & Taylor 1989), increasing nutrient status (through run-off e.g. Hornung & Newson 1986 or fertiliser loss e.g. Harriman 1978), and increasing acidification (Stoner & Gee 1985). These features have already been demonstrated to have a detrimental effect on existing invertebrate and fish faunas (Milner *et al.* 1981) as well as aquatic plants (Barko & Smart 1983) and consequently are highly likely to affect aquatic birds dependent on freshwaters. In addition, the provision of cover is likely to increase densities of potential nest predators of wetland birds (e.g. Andren *et al.* 1985).

In order to establish the nature and extent of breeding waterfowl communities in the peatlands of Caithness and Sutherland, an extensive ground survey was carried out in July 1988. This paper summarises the findings of the survey, describes the breeding waterfowl of the area and examines patterns of habitat selection for individual species.

Study Area and Methods

Attempts were made to visit all lochs and major water-courses in the peatland complex within 17 National Grid 10 km squares, shown in Figure 1, during the period 9 to 30

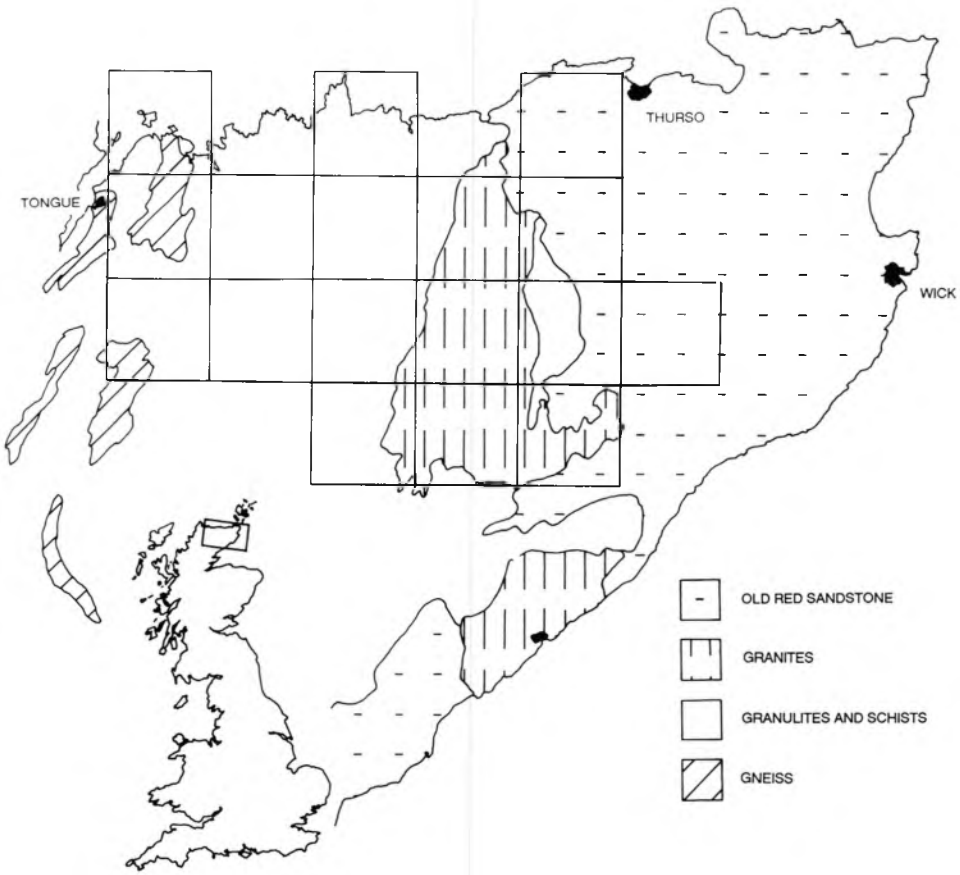

Figure 1. Map of Caithness and Sutherland study area showing main geological divisions of the area and the approximate extent of the area covered by ground census in July 1988 (as indicated by 10 km National Grid squares).

July 1988. A total of 186 sites were visited at least once, most twice and a few on more occasions; it was considered that one or two visits to large numbers of sites was most effective in assessing the ecology and breeding success of waterfowl. Many of the lochs in Caithness were visited during 1987 as part of a Nature Conservancy Council survey. Physical features of many of the lochs were recorded and water samples taken for pH and conductivity determination (S. Bell *in litt.*). In situations where physical data were not available from 1988, information from the 1987 survey has been used.

Throughout the text, the Gaelic term dubh-lochan (plural dubh-lochain) is used to describe bog-pool systems which are such a feature of the peatlands. They are topographical feature of bog surfaces isolated from bedrock and hence invariably highly acidic and base-poor (oligotrophic).

Water pH was measured using a Whatman 2500 001 portable pH/temperature probe and conductivity using Whatman conductivity sensors. Physical characteristics of lochs and stretches of river or stream were recorded in the field (e.g. number of islands, water colour, water clarity, dominant shore substrate, emergent vegetation, habitat type, waterbody type) or derived from maps (e.g. area of waterbody, altitude, geology) and were scored according to Table 1. Emergent vegetation was classified according to the dominant National Vegetation Classification stand type, the extent and cover of the types present were not assessed. Additional information was derived through local observers.

Table 1. Scores used in physical characteristics of lochs and water courses, Caithness and Sutherland July 1988. All other parameters were recorded as logical continuous variables.

Parameter score	Water colour	Water clarity	Habitat type	Waterbody type	Substrate
1	colourless	clear	dubh-loch	dystrophic	boulders
2	pale brown	slightly cloudy	loch	oligotrophic peaty	stoney
3	light brown	turbid	stream	other oligotrophic	sandy
4	brown	peaty	flood-plain	mesotrophic	silty
5	dark brown	very peaty	–	sp. poor eutrophic	organic mud
6	–	–	–	eutrophic	peaty

The underlying geology of the Flow Country falls into three basic types: sedimentary rocks (old red sandstones), igneous intrusive rocks (e.g. granites) and metamorphic rocks (such as the schists). All lakes were assigned to geological type using British Geological Survey maps.

From these data, a reduced data matrix was constructed of species presence/absence, number of adult birds, numbers of juveniles and the ecological variables for each of the 99 waterbodies for which we had complete data. This data set was subjected to more detailed analysis to examine ecological correlates in this biogeographical unit (as distinct from the lowlands of northeast Caithness also surveyed but outwith the peatland area).

The data matrix was analysed using Detrended Correspondance Analysis (DCA; Hill 1979, Hill & Gauch 1980, Gauch 1982) with the aid of software developed by Ter Braak (1988). Detrending by second order polynomial was used to remove some of the instability inherent in detrending by segments (Hill 1979, Minchin 1987). Analysis was restricted to the numbers of birds present at each site because the small numbers of sites where successful breeding occurred restricted interpretation of breeding data.

Results

Species abundance and distribution

Table 2 shows the total number of birds located in the whole of the study area. Red-throated Divers were common residents of dubh-lochain as well as some of the larger lochs, but the population was modest and fewer were present in 1988 than found by previous ornithological surveys (an estimated 39 pairs in the 1988 study area; D.A. Stroud *in litt.*), although early failed nesters may have left the area by July. The area continues to be of considerable importance for Black-throated Diver, with 31 occupied sites representing 20% of the British population (Campbell & Talbot 1987). All records of Mute Swans *Cygnus olor* came from the large shallow water lochs of the northeast Caithness lowlands away from the peatland areas.

Census of previously known moulting sites for Greylag Geese within the peatlands failed to locate the hundreds of birds which have been present in previous years. However, the moorland lochs and lochans of the higher ground proved to be important brood rearing areas, with grid square ND04 holding over 200 geese, including 30% of all goslings found in the survey. The total post-breeding population (excluding any missed moulters) is likely to exceed 700 birds.

Female Wigeon with broods of near-fledged ducklings were most often encountered in the slack waters of streams and rivers where these met the larger lochs of the peatlands. The numbers missed in dense vegetation makes the total of 18 successful pairs a minimum estimate for the study area. Gadwall *Anas strepera* bred successfully at three sites, while Teal *Anas crecca* were the most abundant species of waterfowl after Greylag Geese. Although broods of between one and eight ducklings were seen at a variety of habitats, moorland pools and dubh-lochain harboured highest densities. Mallard *Anas platyrhynchos* were common and widespread, but being an early nesting species even in northern Scotland, July census totals probably underestimate the true post-breeding numbers.

Tufted Ducks *Aythya fuligula* were present on the shallow eutrophic lochs of the northeastern lowlands, and very few were

Table 2. Total number of waterbird records from the Caithness and Sutherland study area, July 1988.

Species	Juveniles *n*	Broods *n*	Other individual sightings (incl. parents attending young and non-breeding adults) *n*	Total
Red-throated Diver	5	5	29	34
Black-throated Diver	6	5	50	56
Dabchick	0	0	3	3
Mute Swan	30	8	67	97
Whooper Swan	0	0	1	1
Pink-footed Goose	0	0	1	1
Greylag Goose	431	63	212	643
Shelduck	4	1	2	6
Wigeon	61+	18	107	168+
Gadwall	14	3	5	19
Teal	143	42	95	238
Mallard	74+	18+	172	246+
Pintail	0	0	1	1
Pochard	0	0	15	15
Tufted Duck	65	14	59	124
Common Scoter	37	13	50	87
Goldeneye	0	0	1	1
Red-breasted Merganser	45	11	17	62

present in the peatland areas, all on lochs of high base status. Fifty Common Scoter females were present on 47 different lochs during the survey, all within the peatlands, and 13 broods were located. All broods were on lochs, but two different females were showing signs of brooding behaviour along two river systems. Female Red-breasted Mergansers *Mergus serrator* with broods were noted on larger, clear water lochs in both peatland and lowland situations.

The habitat

The peatland wetlands surveyed ranged from 10 to 280 m above sea level, from less than 1 to 653 ha in extent, with up to five islands present on some lochs. Acidity varied between pH 4.2 and 7.5 and conductivity from 56 to 216 μmhos. The differing geology had relatively little effect on the frequency distributions of pH (Fig. 2), although the lowest and highest pH readings were associated with sedimentary rock formations. The bimodal distribution in all three geological classes presumably reflects the true peatland lochs isolated from the buffering capacity of the bedrock (and hence highly acidic) and those lochs which retain a high buffering capacity due to water contact with the rocky substrate (despite recharge from the surrounding blanket mire).

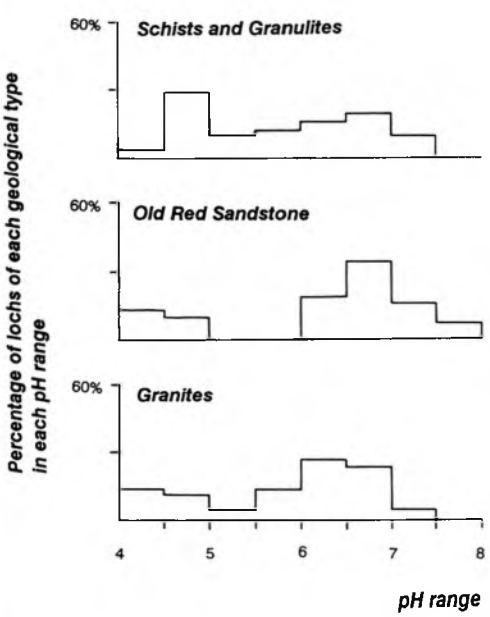

Figure 2. Frequency distributions of pH measurements of waterbodies in Caithness and Sutherland according to substrate type.

Correspondance analysis

This technique broadly defines the major factors which may affect the distribution of the waterfowl species studied on the lochs (Fig. 3). The factors of greatest importance in determining the species abundance on the different lochs were as follows (in descending order of importance): conductivity, habitat type, water quality, substrate type, number of islands, waterbody type and pH (Table 3). The first three axes of the analysis accounted for 72% of the variance, 47.9% on the first axis (a general habitat classification incorporating conductivity and habitat type), 14.2% on the second axis (number of islands) and 10.0% on the third axis (waterbody type and pH). On the basis of this species ordination, it is clear that the species of highest conservation interest (Black-throated Diver and Common Scoter) as well as the locally rare and restricted Tufted Duck are separate from the more common and widespread species. Most species showed some preference for lochs of high conductivity, clear water and sandy substrates, the exceptions being Red-throated Diver (a classic dubh-lochan species in Scotland, Gomersall *et al.* 1984) and Greylag Geese which were most abundant on more base-poor, peaty waters. Many of the dabbling ducks were separated by their use of streams rather than lochs both on the second and third axes, the most extreme being the Wigeon, where broods were almost exclusively found along watercourses.

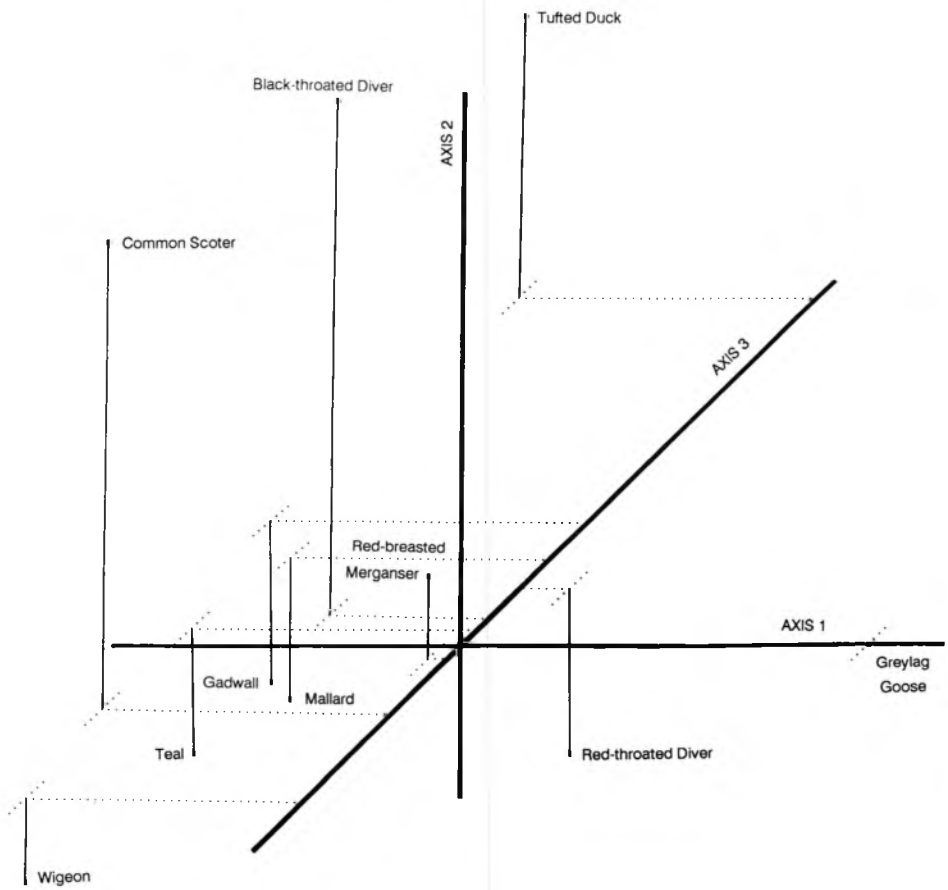

Figure 3. Projection of waterfowl species on a three-dimensional distribution from Detrended Correspondance Analysis. Percentage of total variance (t) are given for each axis and the eigenvectors for the axes loadings shown in Table 2. The first axis represents a general calssification of the habitat, including conductivity and habitat type; axis 2 is the number of islands and axis 3 the waterbody type and pH.

Variation in acidity

Water acidity was highly correlated with conductivity, waterbody type, habitat type and water colour (Table 2); water pH is a simple measurement which is easy to monitor, and some data are available from 1987. More detailed analysis of species distribution with regard to pH was possible. Lochs and water courses were arranged by 0.5 pH increment classes and the percentage occurrence of each species calculated for each acidity class (Fig. 4). This clearly shows habitat preferences of the different species, ranging from the Black-throated Diver, Wigeon and Common Scoter which clearly select for waterbodies of lowest acidity, totally avoiding the very acid waters, through species such as the Red-throated Diver which appear to select mid-range pH waters to Teal which use peaty habitats most regularly and appear to shun more base-rich situations. Mallard show little preference between sites, and less common species such as the Red-breasted Merganser, Tufted Duck and Gadwall occur in too small numbers to be able to demonstrate preferences.

There was a very high correlation between pH and conductivity measured at a sample of the lochs in 1987 (S. Bell pers. comm.) and by the present study in 1988 (pH $r = 0.92$, $P<0.001$; conductivity $r = 0.73$, $P<0.001$). This suggests that water quality is likely to be constant over at least short periods of time and may explain the site-loyalty of the rarer species such as Black-throated Diver and Common Scoter which apparently return to the same lochs each year to breed.

Discussion

The survey covered the great majority of standing waters in the peatlands of Caithness and Sutherland during July 1988. Whilst waterfowl which had attempted to breed, failed and left the area may be expected to have departed this late in the summer, the survey was effective in estimating successful breeders. Hence, whilst we have little data to modify the population estimates of Stroud *et al.* (1987) for breeding waterfowl, the proportion of successful breeding pairs is alarmingly low for some species. In particular, the Red-throated Diver gives cause for concern if only 13% of the 39 estimated pairs rear young. Black-throated Diver (17%), Greylag Goose (21%) and Wigeon (23%) all show low

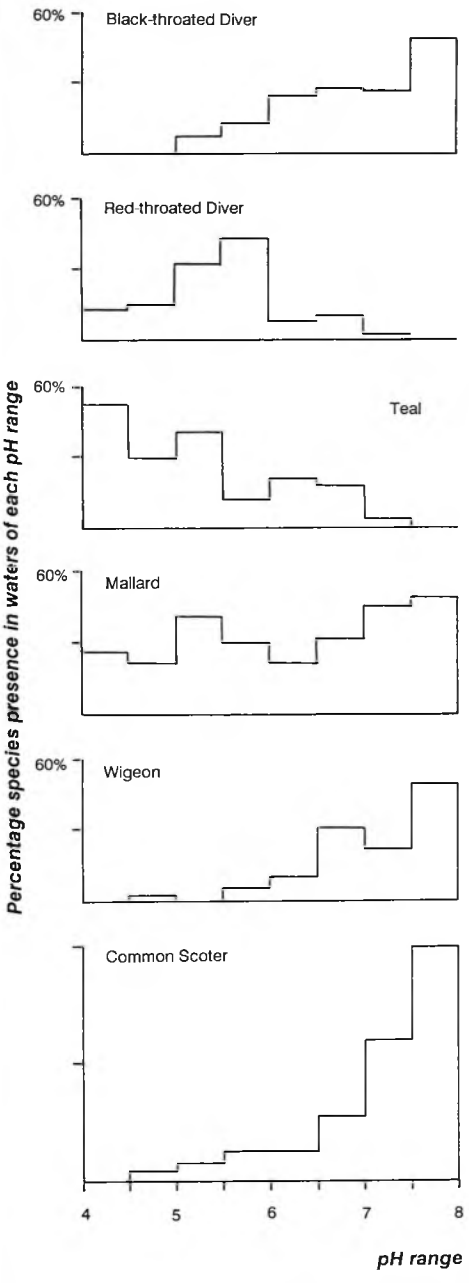

Figure 4. Frequency (percentage occurrence) distribution of waterfowl species present amongst waterbodies in each 0.5 pH unit classes, Caithness and Sutherland July 1988.

Table 3. Habitat variables used for the correspondance analysis, showing (upper) eigenvectors for each of the first three axes and (lower) the correlation matrix for all environmental parameters used in the analysis (values exceeding 0.173 are statistically significant $P<0.05$).

	AXIS 1	AXIS 2	AXIS 3
Altitude	−0.1370	0.1389	0.0192
Island number	−0.1435	0.2244	0.1549
Conductivity	−0.4130	−0.0382	0.1130
pH	−0.0808	0.0808	−0.0733
Water colour	0.3883	−0.0330	0.0231
Water suspension	0.1118	0.0325	−0.0482
Habitat type	−0.4194	−0.2736	−0.3136
Waterbody type	0.0719	−0.0129	−0.1269
Substrate	−0.2170	−0.0832	−0.0379

	Alt	Isl	Con	pH	Wcl	Wsu	Hty	Wbt
Islands	0.0444							
Conductivity	0.3417	0.2038						
pH	0.3476	0.0697	0.6633					
Water colour	−0.1890	−0.0956	0.0117	0.3550				
Water suspension	−0.1162	−0.0335	0.1071	0.1580	0.4653			
Habitat type	−0.0978	−0.0977	0.3816	0.4013	0.0542	−0.0440		
Waterbody type	−0.2742	0.0151	0.2516	0.5636	0.3917	0.3521	0.3687	
Substrate	0.2300	−0.0202	0.2776	−0.1073	−0.2051	0.2519	0.1565	−0.1892

breeding success assuming previous population estimates to be accurate. Common Scoter (35% of females present with young associated) is higher, but brood size was small (mean 3.0, range 1–6, less than in Irish populations whilst less than half grown; Partridge 1987).

The principal waterfowl species nesting in the peatlands of Caithness and Sutherland fall into three categories: nationally rare species, locally rare species and the more common and widespread species. The species of highest conservation interest, Black-throated Diver and Common Scoter, select those lochs with high pH and conductivity and having islands. One female Common Scoter on an acidic loch (pH 4.2) was seen to leave her brood of newly hatched young to feed on a nearby pool of pH 5.3. Two weeks later, the whole family had moved to another lochan (pH 6.5). Since such habitat is restricted within the study and generally rare within the Highlands of Scotland, the limited distribution of scoters is understandable. Wigeon are relatively uncommon as a breeding bird in Britain, and this may again be a reflection of their use of relatively base-rich water courses which were clearly selected for in the peatland areas. More common species such as Teal (which prefer more acid waters) and the ubiquitous Mallard are consequently unaffected by the availability or otherwise of base-enriched waters.

Relatively few waterbodies in the Caithness and Sutherland peatlands are of high water quality, and most of these are situated on sedimentary bedrock. From an apparent constancy of water chemistry, there is little doubt that this contact with the basal bedrock facilitates buffering of an otherwise highly acidic peatland catchment run-off. The resultant water quality is very different from often adjacent acidic waterbodies and in many situations this also results in differing flora and fauna (including very rare British invertebrates, see Lindsay *et al.* 1988). The base-status of these lochs also contrast with waterbodies in lowland Sutherland and Caithness which lack the acidic run-off and are consequently far more eutrophic. It is well demonstrated that in northern situations, eutrophic waters support more diverse and productive phytoplankton and zoobenthos than oligotrophic ones (e.g. Holopainen & Paasivirta 1977, Kwiatkowski & Roff 1976, Roff & Kwiatkowski 1977) and hence possess the most diverse waterfowl communities with highest densities (e.g. Danell & Sjoberg 1978, Nilsson & Nilsson 1978, DesGranges & Darveau 1985). In north Scotland, we observed the same phenomenon, with the rarer species associating with lochs of high pH and conductivity within oligotrophic peatland ecosystems.

These lochs and river systems are hence unique in the British Isles for their conservation interest. Many of the lochs of greatest importance have been surrounded by forestry in the last five years. It has been shown that changes in ground-water acidity have profound impacts on freshwater systems (e.g. Eriksson *et al.* 1980, Bobee *et al.* 1982, Stoner *et al.* 1984) and that afforestation of peatland catchments lead to increased sedimentation and acidity (Stoner & Gee 1985, Leeks & Roberts 1987, Francis & Taylor 1989).

With the national significance and increasing rarity of species such as the Black-throated Diver (Campbell & Talbot 1987) and Common Scoter (Partridge 1987) in Britain and Ireland, the impact of this land-use change on the freshwater lochs and streams of Caithness and Sutherland must be monitored in order to determine the effects on the complex ecology of the area.

The survey could not have been carried out without the active support and assistance of the landowners and managers of the areas, whom we sincerely thank for permitting access and for talking birds with us! Our grateful thanks go to all who took part in the survey, namely M. Ayress, G. Clarkson, T. Drew, A. Fox, B. Hughes, S. Laybourne, C. Liggett, M. Proctor, S. Richardson, D. Rigby, D. Salmon, P. Shimmings, J. Smith, A. Temple, P. Tovey, P. Turner and A. Watts. Thanks also to L. Cranna, T. Keatinge and K. Scott of the Nature Conservancy Council for help, support and advice with the project and to S. Bell for supplying information on water quality from the NCC survey of 1987. D. Stroud supplied previous survey data and he, M. Owen and J. Kear improved earlier drafts.

References

Andren, H., Angelstam, P., Lindstrom, E. & Widen, P. 1985. Differences in predation pressure in relation to habitat fragmentation: an experiment. *Oikos* 45:273–277.

Barko, J.W. & Smart, R.M. 1983. Effects of organic matter additions to sediment on the growth of aquatic plants. *J. Ecol.* 71:161–176.

Batterbee, T.W., Appleby, P.G., Odell, K. & Flower, R.J. 1985. ^{210}Pb dating of Scottish lake sediments, afforestation and accelerated soil erosion. *Earth Surface Processes and Landforms* 10:137–142.

Bobee, B., Grimard, Y., Lachance, M. & Tessier, A. 1982. *Nature et etendue de l'acidification des lacs du Quebec.* Rapport scienifique 140, Ministiere de l'Environnement de Quebec.

Burt, T.P., Donahoe, M.A. & Vann, A.R. 1983. The effect of forestry drainage operations on upland sediment yields: the results of a storm-based study. *Earth Surface Processes and Landforms* 8:339–346.

Campbell, L.H. & Talbot, T.R. 1987. The breeding status of Black-throated Diver (*Gavia arctica*) in Scotland. *Brit. Birds* 80:1–8.

Danell, K. & Sjoberg, K. 1978. Habitat selection by breeding ducks in boreal lakes in northern Sweden. *Viltrevy* 10:161–190.

DesGranges, J.-L. & Darveau, M. 1985. Effect of lake acidity and morphometry on the distribution of aquatic birds in southern Quebec. *Hol. Ecol.* 8:181–190.

Eriksson, M.O.G., Henrikson, L., Nilsson, B.I., Nyman, G., Oscarson, H.G. & Stenson, A.E. 1980. Predator-prey relations important for the biotic changes in acidified lakes. *Ambio.* 9:248–249.

Francis, I.S. & Taylor, J.A. 1989. The effect of forestry drainage operations on upland sediment yields: a study of two peat-covered catchments. *Earth Surface Processes and Landforms* 14:73–83.

Gauch, H.G. 1982. *Multivariate Analysis in Community Ecology. Cambridge Studies in Ecology: I).* Cambridge, The University Press. 298 pp.

Gomersall, C.H., Morton, J.S. & Wynde, R.M. 1984. Status of breeding Red-throated Divers in Shetland, 1983. *Bird Study* 31:223–229.

Harriman, R. 1978. Nutrient leaching from fertilised forest watersheds in Scotland. *J. Appl. Ecol.* 15:933–942.

Hill, M.O. 1979. *DECORANA – A Fortran program for Detrended Correspondance Analysis and Reciprocal Averaging.* Ithaca, New York Cornell University.

Hill, M.O. & Gauch, H.G. 1980. Detrended Correspondance Analysis, an inproved ordination technique. *Vegetatio* 42:47–58.

Holopainen, I.J. & Paasivirta, L. 1977. Abundance and biomass of the meiozoobenthos in the oligotrophic and mesotrophic lake Paajarvi, southern Finland. *Ann. Zool. Fennici* 14:124–134.

Hornung, M. & Newson, M.D. 1986. Upland afforestation: influences on stream hydrology and chemistry. *Soil Use and Management* 2:61–65.

Kwiatkowski, R.E. & Roff, J.C. 1976. Effects of acidity on the phytoplankton and primary production of selected northern Ontario lakes. *Can. J. Bot.* 54:2546–2561.

Leeks, G.J.L. & Roberts, G. 1987. The effects of forestry on upland streams – with special reference to water quality and sediment transport. In J. Goode (Ed.) *Environmental effects of plantation forestry in Wales.* Institute for Terrestrial Ecology, Grange-over-Sands.

Lindsay, R.A., Charman, D.J., Everingham, F., O'Reilly, R.M., Palmer, M.A., Rowell, T.A. & Stroud, D.A. 1988. *The Flow Country: the peatlands of Caithness and Sutherland.* NCC, Peterborough. 174 pp.

Milner, N.J., Scullion, J., Carling, P.A. & Crisp, D.T. 1981. The effects of discharge upon sediment dynamics and consequent effects on invertebrates and salmonids in upland rivers. *Appl. Biol.* 6:153–220.

Minchin, P. 1987. An evaluation of the relative robustness of techniques for ecological ordination. *Vegetatio* 69:89–107.

Nature Conservancy Council. 1986. *Nature Conservation and Afforestation in Britain* NCC, Peterborough.

Nilsson, S.G. & Nilsson, I.N. 1978. Breeding bird community densities and species richness in lakes. *Oikos* 31:214–221.

Partridge, K. 1987. *The Common Scoter* Melanitta nigra *in Ireland – A review of the breeding population with special reference to Lough Erne.* Report to Dept. Environment, Northern Ireland. RSPB, Sandy.

Reed, T.M., Langslow, D.R. & Symonds, F.L. 1983. The breeding waders of the Caithness flows. *Scot. Birds* 12:180–186.

Robinson, M. & Blyth, K. 1982. The effect of forestry drainage operations on upland sediment yields: a case-study. *Earth Surface Processes and Landforms* 7:85–90.

Roff, J.C. & Kwiatkowski, R.E. 1977. Zooplankton and zoobenthos communities of selected northern Ontario lakes of different acidities. *Can. J. Zool.* 55:899–911.

Stoner, J.H., Gee, A.S. & Wade, K.R. 1984. The effects of acidity on the ecology of streams in the upper Tywi catchment in west Wales. *Env. Poll.* 35A:125–157.

Stoner, J.H. & Gee, A.S. 1985. Effects of forestry on water quality and fish in Welsh rivers and lakes. *J. Inst. Wat. Eng and Sci.* 39:27–45.

Stroud, D.A., Reed, T.M., Pienkowski, M.W. & Lindsay, R.A. 1987. *Birds, Bogs and Forestry: the peatlands of Caithness and Sutherland.* NCC, Peterborough. 121 pp.

Ter Braak, C.J.F. 1988. *CANOCO – A Fortran program for Canonical Community Ordination by correspondance analysis, principal components analysis and redundancy analysis. Version 2.1.* Technical Report LWA-88-02. Wageningen, Netherlands.

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