

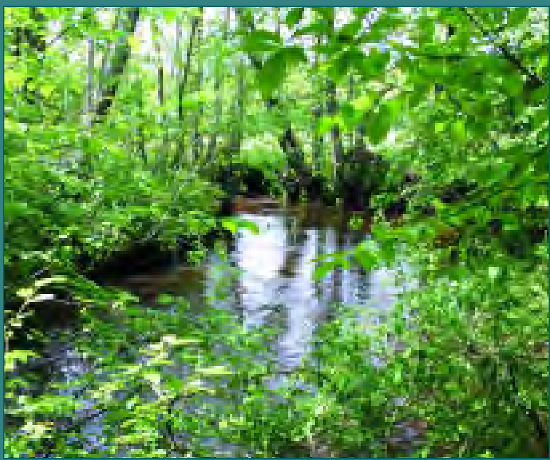
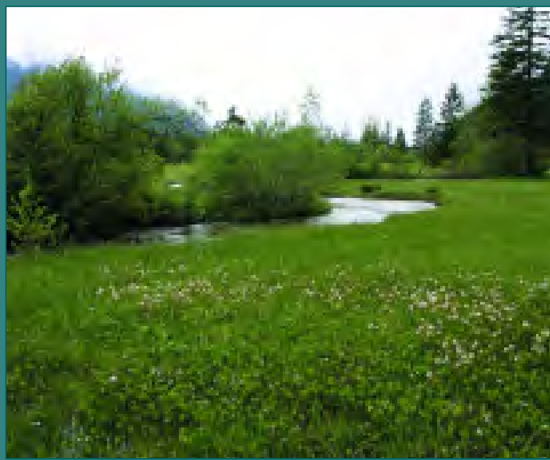

RIVER HABITAT SURVEY IN SOUTHERN BAVARIA AND THE TYROLIAN ALPS

RESULTS FROM 2006

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CONTENTS

Purpose.		1
Background to methods.		1
Survey, assessment and analyses.		3
Results.		4
Discussion.		8
Conclusions.		11
Appendix 1:	Brief notes on sites ALP-1 to ALP-15.	12
Appendix 2:	Characteristics of the Bavarian and Tyrolian streams and rivers surveyed in 2006.	18
Appendix 3:	HQA sub-scores and total scores for ALP-1 to ALP-15.	19
Appendix 4:	HMS scores and habitat modification classes for ALP-1 to ALP-15.	19
Appendix 5:	Selected habitat features and *ad hoc* observations of wildlife associated with ALP-1 to ALP-15.	20
Appendix 6:	Indicative values for water chemistry.	20
Appendix 7:	Improvements and recommendations for the RHS manual.	21
Appendix 8:	Many of the plants seen in the species-rich meadows alongside the Zeller Bach.	23
Appendix 9:	JNCC macrophyte survey results.	24

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WEB SITES

RHS: www.rhs@environment-agency.gov.uk

STAR: www.eu-star.at

Life in UK Rivers: www.riverlife.org.uk

Life Project Wild River Landscapes: www.tiroler-lech.at

Google Earth: http://earth.google.com/index.html

GLOSSARY OF ACRONYMNS

ALP	Unique acronym to identify sites from the 2006 survey on the RHS database
CEH	Centre for Ecology and Hydrology
CEN	Committee for Standardisation
GPS	Geo-referenced Positioning System
HMS	Habitat Modification Score
HMC	Habitat Modification Class
HQA	Habitat Quality Assessment
JNCC	Joint Nature Conservation Committee
LAWA	Landerarbeitsgeinshaft Wasser (German Working Group of the Federal States on water issues)
MTR	Mean Trophic Rank
PCA	Principal Component Analysis
RHS	River Habitat Survey
STAR	STAndardisation of River Classifications
WFD	Water Framework Directive

PURPOSE

The overall purpose of this work was to undertake River Habitat Surveys (RHS)[1] on a selection of rivers in Southern Bavaria and the Tyrolian Alps in Austria to test the technique and for inter-calibration purposes under the EU Water Framework Directive (WFD).

Specific objectives were to:

- Survey near-natural examples of different river types in southern Bavaria and Tyrolian Alps using the RHS, Joint Nature Conservation Committee (JNCC)[2], and Mean Trophic Rank (MTR)[3] macrophyte methods.

- Collect RHS and macrophyte data for European inter-calibration purposes and add to the database established for the STAndardisation of River Classifications (STAR) project[4].

- Generate data for subsequent use in testing and refining the draft CEN standard on morphological quality of rivers.

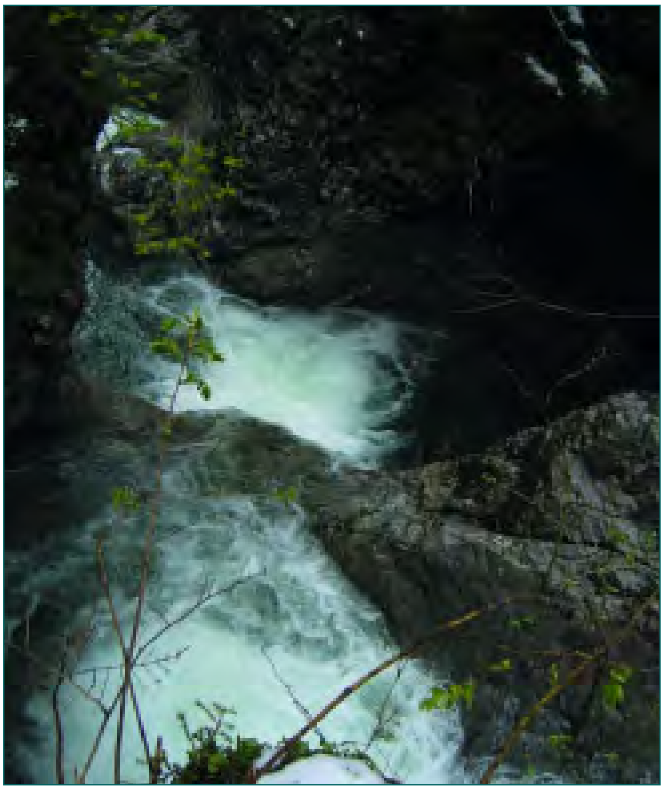
- Recommend improvements to the RHS guidance manual for use on UK and European rivers.

- Share our experiences of river survey and evaluation in the UK with staff from the Bavarian Environment Agency (River Engineering, Nature-Orientated Development of Waters) and Austrian Federal Agency for Water Management/Institute for Water Quality.

Bankside tree roots and woody debris contribute to HQA scores.

Habitat Quality Assessment (HQA) is a broad indication of overall habitat diversity provided by natural features in the channel and river corridor. Points are awarded for the presence of scoring features such as point, side and mid-channel bars, cliffs, marginal tree roots, woody debris, waterfalls, marginal reeds and floodplain wetlands. Additional points reflect the variety of substrate, flow-types, in-channel vegetation, and also the extent of trees and semi-natural land-use adjacent to the river.

Points are added together to provide the HQA. In contrast to HMS, the higher the score, the more highly rated the site. The diversity and character of river habitat features at any site is influenced by natural variation and the extent of human intervention, both in the channel and adjacent land. The RHS database allows HQA scores to be compared using sites with similar physical characteristics



Pools are also included in HQA scoring.

BACKGROUND TO METHODS

River Habitat Survey

River Habitat Survey is a method developed in the UK to characterise and assess, in broad terms, the physical character of freshwater streams and rivers. It is carried out along a standard 500m length of river channel, with observations made at 10 equally spaced spot-checks along the channel. Other information on valley form, land use in the river corridor etc, is also collected. Field survey follows the strict protocols given in the 2003 RHS Manual[1].

Data are entered onto the RHS database. This now contains field observations, map-derived information and photographs from more than 17,000 surveys undertaken since 1994. During 1994-96 a stratified random network of sites established a geographically representative baseline cross-section of streams and rivers across the UK[5].

The RHS database allows sites of a similar nature to be grouped together for comparative purposes. Slope, distance from source, height of source and site altitude are used to cluster RHS sample sites for so-called "context analysis" based on principal component analysis (PCA) plots[6].

Indices of habitat quality and channel modification can be derived from RHS data, and these can be used as a basis for setting physical quality objectives for rivers[7].

Heavily modified and artificial channels have high HMS scores.

(e.g. slope, distance from source) and geology. Features determining habitat quality for individual species such as otter, *Lutra lutra* and dipper, *Cinclus cinclus* can also be selected, thereby providing a more ecologically-specific context for comparing sites[8]. Carrying out RHS and macrophyte surveys at specially selected good quality sites provides the necessary calibration of HQA for a range of river types in the UK. These special surveys have been extended to mainland Europe, including Finland, Norway, Poland, the French Pyrenees, Slovenia and now the northern Alps.

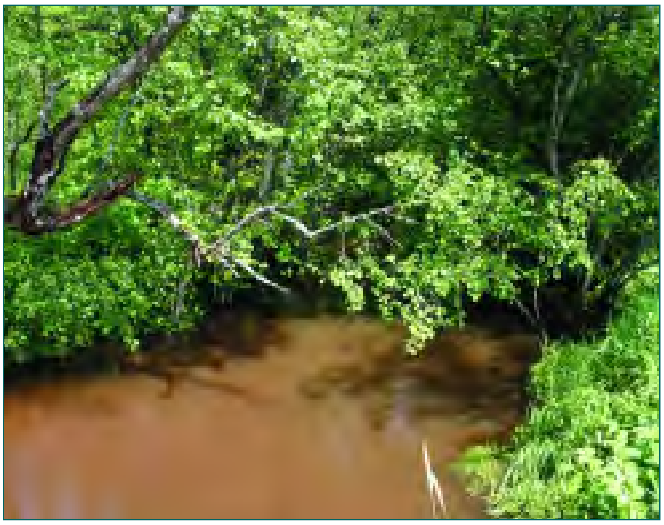
Habitat Modification Score (HMS) is an indication of modification to the river channel morphology. To calculate HMS for sites, points are awarded for the presence of artificial features such as culverts, weirs, current deflectors, and bank revetments. Points are also awarded for modifications to the channel such as re-sectioned banks or heavily trampled margins. The more severe the modification, the higher the score. The cumulative points total provides the Habitat Modification Score (HMS). A Habitat Modification Class (HMC) has been developed which allocates a site into one of five modification classes, based on the total score. In contrast to HQA, higher scores reflect more intervention and modification of the river channel.

The STAR (STAndardisation of River Classifications) project. The STAR project was a research project funded by the European Commission under the Fifth Framework Programme and continues to the implementation of the Key Action "Sustainable Management and Quality of Water" within the Energy, Environment and Sustainable Development Programme. A key aim was to provide relevant CEN working groups with draft methods.

JNCC surveys record plants in the water and at the base of the banks.

The STAR project, completed in 2005, aimed to provide standard biological assessment methods compatible with the requirements of the WFD. It also aimed to develop a standard for determining the class boundaries of 'ecological status' and another one for inter-calibrating existing methods. Results have been published in a special issue of *Hydrobiologia*[4].

RHS surveys were carried out at all 'core' STAR stream sites. In Austria, the Czech Republic, Denmark, Germany and Italy these 'core' sites were chosen to reflect a gradient in habitat and morphology degradation.



Accurate MTR surveys were prevented either by lack of aquatic plants or turbid water caused by heavy rain.

Macrophyte surveys

When undertaking special RHS on UK and European rivers, two macrophyte survey methods are normally used in tandem. The Joint Nature Conservation Committee (JNCC) method records aquatic and marginal plants in the same 500m as the RHS survey. Species from the main river channel, and the margins/base of the bank, are recorded separately on a three-point scale of abundance. A check-list of species is used to aid recording. Data are held on a JNCC database, and field data can be used to classify the plant community[2].

The second type of macrophyte survey normally carried out is the Mean Trophic Rank (MTR). This records only aquatic taxa, again using a check-list of species, but within a 100m length of river. Each species is assigned a trophic rank of 1-10, depending on its tolerance to eutrophication (1 = tolerant; 10 = intolerant). Cover abundance of species is estimated on a scale of one to nine, and the combination of cover values and trophic rank enables a MTR score to be derived. This provides an indication of the level of nutrient enrichment of the sites surveyed[3].

In Bavaria and the Tyrolian Alps we only undertook the JNCC survey because the aquatic vegetation was too sparse, or the water too turbid, to carry out meaningful MTR surveys.

SURVEY, ASSESSMENT AND ANALYSIS OF BAVARIAN AND TYROLIAN RIVERS AND STREAMS

Recommendations for rivers to visit and survey in Southern Bavaria were made by Walter Binder, whilst Helena Mühlmann recommended the Tyrolian sites in Austria. Final site selection on each surveyed river was made on the day. For approximate locations, see the map on the back page cover. Latitude and longitude coordinates for each site except ALP-15 were taken by Hugh Dawson using GPS; these were subsequently cross-checked using *Google Earth*. Appendix 1 includes the mid-site location for each site.

River Habitat Surveys were undertaken by Paul Raven and Hugh Dawson. Nigel Holmes carried out the macrophyte surveys.

The RHS survey form entries were cross-checked using digital photos taken in the field. Background information (altitude, geology, land use, water quality, climatic and hydrological regime), were derived from various publications[9-11] and topographical 1:25,000 or 1:50,000 scale maps in the *Alpenvereinskarte* and *Umgebungskarten (UK)* series (Appendix 2).

Basic water chemistry (pH, conductivity, hardness, nitrates, colour) was determined from samples taken in the field by Hugh Dawson. This gives a broad indication of this important influence on river biology (Appendix 6).

Incidental wildlife observations were made by Paul Raven. Because birds are good indicators of landscape character and, for contextual purposes, relevant species seen close to the sites, but not necessarily within them were also included (Appendix 5).

The field visit (28 May - 2 June 2006) coincided with an unseasonally prolonged cold and wet spell of weather - almost unprecedented for the time of year. This meant that surveys were generally carried out in the rain or heavy showers. High, turbid flows also restricted the availability of sites, forcing us onto smaller streams. The survey of ALP-4 and 5 on the Zeller Bach was particularly badly affected, so the results do not represent the true character of the flow types and in-channel morphology.

Peter Scarlett, at the Centre for Ecology and Hydrology (CEH), derived the PCA plot. Calculation of the RHS indices (HQA and HMS) was done by Paul Raven, using the 2005 version of these systems - in similar fashion to that done for the Slovenia report[12]. Identification of unknown bryophytes or those where there was uncertainty, was done by Ben Averis.

Notable plants such as fly orchid were recorded.

A complete set of RHS survey forms, a CD-Rom with digital photographs, maps showing locations, sketches and macrophyte lists for each site visited has been produced. The notes in Appendix 1 will appear in the comments box (Section P) of the RHS database entry. The abbreviated site names, starting with "ALP" are unique acronyms to identify them in the RHS database.

The eight rivers visited in southern Bavaria and Austria during 28 May - 2 June 2006 represented a range of alpine and sub-alpine watercourses. An additional site (ALP-15) in Austria was completed by PR whilst on holiday in late July 2006. In total, 15 RHS site surveys (500m lengths), and 12 JNCC macrophyte surveys, were completed. The RHS information comprises seven single surveys and two contiguous lengths (1km) on four rivers.

Fluvial fans show the high energy of alpine systems.

RESULTS

Context in relation to UK rivers

Superimposing the European STAR, 2005 Slovenian and the 2006 survey sites on the PCA plot for the UK clearly illustrates the more extreme altitude and stream energy characteristics of the alpine streams surveyed (Figure 1).

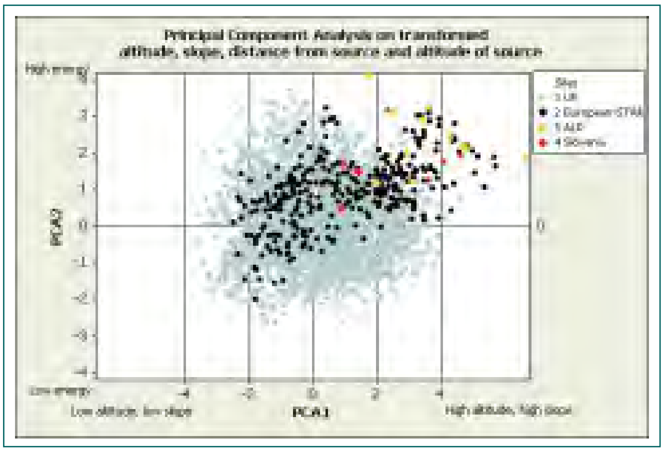


Figure 1: PCA plot showing UK, European STAR, Slovenian and ALP sites.

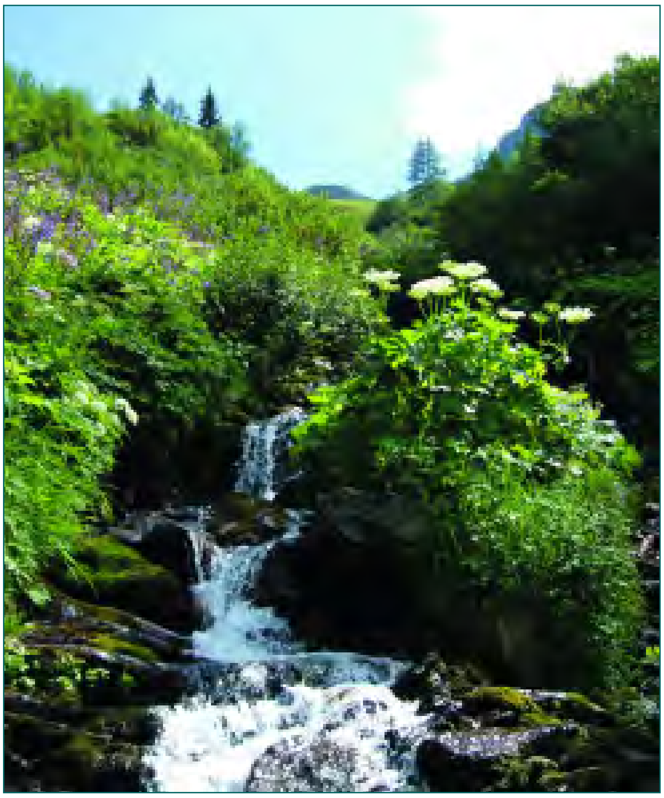
Morphological character

The streams and rivers in the Bavarian and Tyrolian landscape change significantly in character as a result of local channel gradient, valley form and human intervention. The River Leitzach, demonstrates this variation particularly well - from its source at over 1200m, to its confluence with the heavily modified Mangfall River, at an altitude of 530m. Over the 55km length of this river there are intermittent headwaters, spring-fed tributary streams, braided reaches, classical meandering where the valley floodplain widens out sufficiently, and straightened channel sections near towns built in the floodplain, such as Fischbachau. Every valley profile included on the RHS (gorge, deep vee, shallow vee, concave/bowl, asymmetric, floodplain) occurs, so the local character of a river reach depends very much on these factors.

TABLE 1: Basic landscape characteristics of the rivers surveyed in 2006. Sites arranged in descending order of channel gradient († averaged for more than one site; *braided reach).

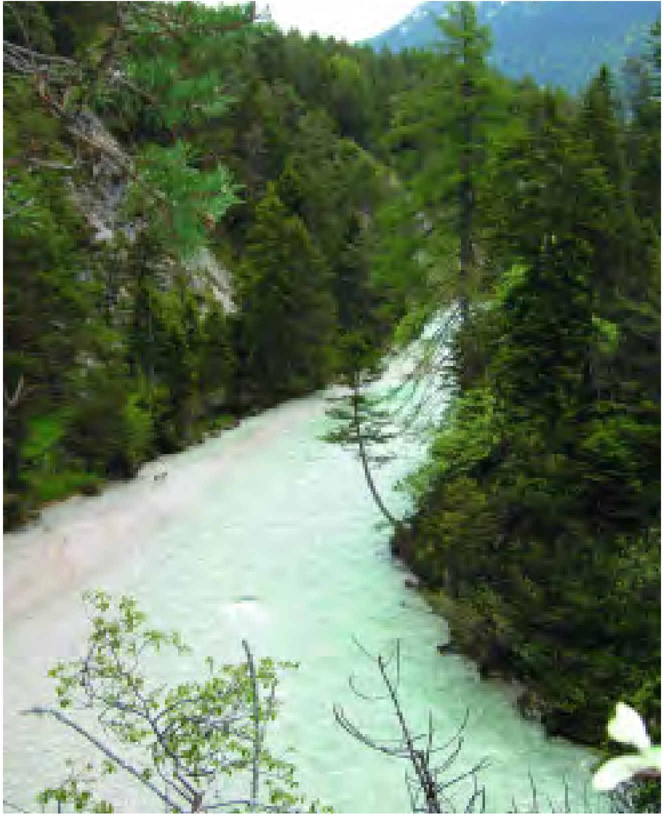
Site reference (ALP)	River	Channel slope (m/km)	Water width (m)	Bankfull width (m) (trashline width)	Predominant valley form	Altitude of source (m)	Distance from source (km)
15	Fellenbergbach	480	2.0	(4.0)	Deep vee (U)	2400	2.3
14	Schwarzwasserbach	110	6.0	(13.0)	Gorge	1660	8.8
13, 12	Isar headwaters	40[13], 20[12]	6.012	7.5[12]	U-shaped	1900	5.0; 6.0
11	Isar	10	32.0	(38.0)	Gorge (U)	1900	18.0
3,4	Leitzach	10	22.0	24.0†	Asymmetrical	1240	49.0; 49.5
7	Linder	10	12.0	110.0*	Asymmetrical(U)	1700	15.0
9,10	Illach	5	4.5	6.5	Concave/bowl	1290	7.0; 7.5
5, 6	Zeller Bach	4	5.5†	6.7†	Shallow vee	695	6.5; 7.0
8	Kleine Ammerquellen	4	5.0	7.5	Floodplain (U)	1290	1.4
1, 2	Alz	1	80.0	85.0	Asymmetrical	1500	85.0; 85.5

(U) within a glaciated valley



Steep, ungrazed slopes, ALP-15.

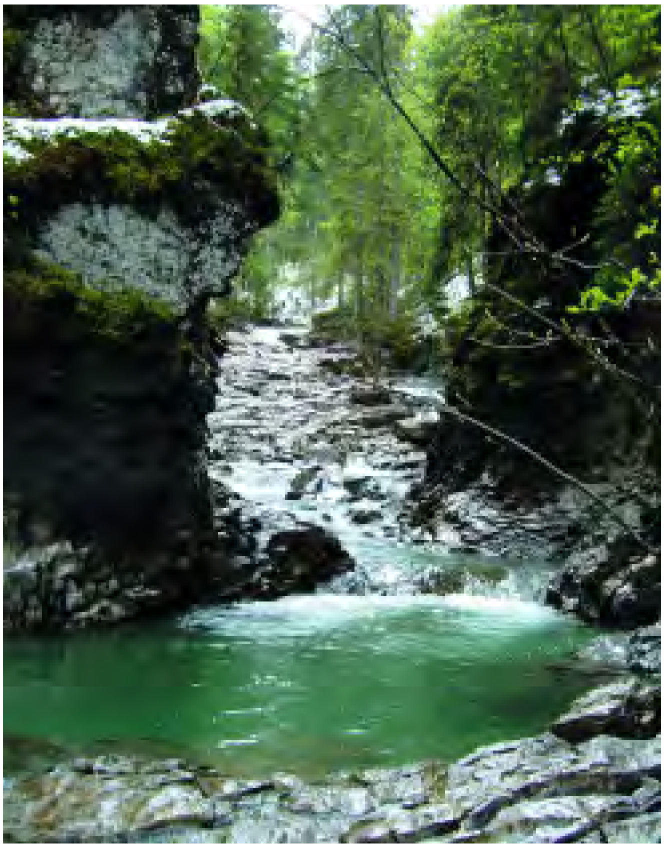
Braided channel and low terraces, ALP-12.



Steep, wooded valley of the Isar, ALP-11.

An overview of the landscape context, character and quality of the rivers visited is given in Tables 1 and 2, with more detailed information given in Appendices 2-5.

Six sites (ALP-7, 11, 12-15) were typical of fast-flowing streams and rivers in the near-natural landscapes of the Alps. ALP-15, high up in a glacial valley and near the tree-line, typified a mountain torrent where banks inaccessible to grazing livestock have scrub or tree cover. The influence of valley shape on habitat character is pronounced: ALP-12 and 13 show some braiding in the glaciated river valley floor, ALP-7 is extensively braided, whilst the steep,



Bedrock and cascades on the Schwarzwasserbach, ALP-14.

The Kleine Ammerquellen, ALP-8.

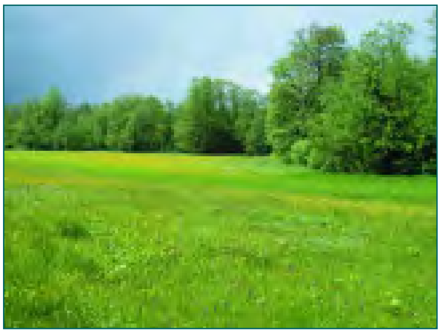
bedrock valley sides and gorge-like profiles in ALP-11 and ALP-14 produce a very different type of riverine landscape.

The Kleine Ammerquellen (ALP-8) was a surprise find; it has the characteristics of a chalk river (spring-fed, stable flow regime) as it flows through a rich wet meadow in the glaciated Linder valley at 850m altitude above sea-level. Downstream it is canalised, before discharging into a highly modified reach of the Ammer.

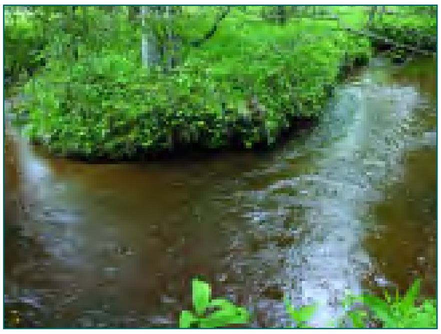
In the more rolling sub-alpine hills, we came across two distinct river landscapes. Firstly, the very active River Leitzach (ALP-3, 4) has created a distinct river terrace morphology, with extensive riparian scrub and woodland habitat, contrasting with the coniferous forest of the valley sides.

Spring-fed pool in the meadow at ALP-8.

Coarse woody debris on the Leitzach, ALP-3.



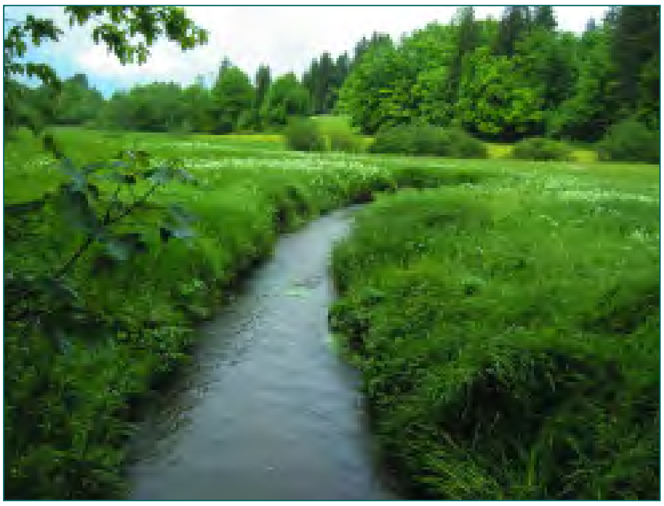
Herb-rich meadow alongside the Zeller Bach, ALP-5.



Tortuous meandering on the Illach, ALP-9.

Abundant orchids in the Illach meadows, ALP-9.

Secondly, the Zeller Bach (ALP-5, 6) and River Illach headwaters (ALP-9, 10) typify the smaller gently-sloping streams in a more agricultural landscape. Both are tree-lined, extravagantly meandering streams flowing through a landscape of herb-rich meadow and woodland. They are in designated 'Nature Parks' (which cover 29% of Bavaria) that afford some protection from intensification of agriculture or infrastructure development - major threats in the area. The nature of this threat was confirmed when we visited what we thought would be a near-natural stream, the Rinnenb, located 4km east of Bad Tolz. Unfortunately, it had been straightened and effectively destroyed as a good river habitat, although the adjacent marsh was still partly intact.



Recently straightened channel of the Rinnenb.

The River Alz (ALP-1, 2), just downstream from the Chiemsee Lake was very different from the other rivers surveyed - a much larger, reed-lined, gently-sloping reach flowing through a predominantly open, agricultural landscape.

Whilst in Munich, we also briefly visited the River Isar, where it is heavily modified, but work is underway to remove some of the more excessive bank reinforcements and restore a more natural channel character.

Comparison of RHS and LAWA morphological assessment was limited to ALP-1, 2 and 7 (Table 2), mainly because the LAWA surveys are largely restricted to mainstem rivers. The scale of the LAWA map for the whole of Germany (1:1,000,000) also made it difficult to match RHS sites and LAWA reaches with confidence. Nevertheless, for purely illustrative purposes, the LAWA class was estimated for all sites visited, using the broad guidance in Table 3.

The Alz was the largest river surveyed.

TABLE 2: An overview of habitat and water quality of the rivers surveyed in 2006. Sites arranged in descending order of channel gradient.

Site reference (ALP)	River	RHS habitat modification score and class	LAWA biological water quality class* (estimated)	LAWA morphological class (estimated)
15	Fellenbergbach	0 (1)	N/k (1)	N/k (1)
14	Schwarzwasserbach	180 (2)	N/k (1)	N/k (1)
12,13	Isar headwaters	0 (1); 0 (1)	N/k (1)	N/k (1)
11	Isar	120 (2)	N/k (1)	N/k (1)
3,4	Lietzach	0 (1); 0 (1)	2	(1-2)
7	Linder	16 (1)	1-2	1
9,10	Illach	100 (2), 0 (1)	1-2	N/k (1-2)
5,6	Zeller Bach	0 (1); 0 (1)	2	N/k (1)
8	Kleine Ammerquellen	140 (2)	(1-2?)	N/k (1)
1,2	Alz	30 (2); 10 (1)	2	2

* LAWA water quality class (1: uncontaminated; 1-2: slightly contaminated; 2: moderately contaminated).

TABLE 3: The LAWA morphological classification system for rivers in Germany[11].

Description of morphological structure	Modifications within river reach	Class	Percentage of rivers
Unchanged.	Matches the potential natural state.	1	2
Slightly changed.	Slightly influenced by one-off, localised structures.	2	8
Moderately changed.	Moderately influenced by multiple, localised interventions.	3	11
Distinctly changed.	Distinctly influenced by different interventions on river bed.	4	19
Obviously change.	Negatively influenced by a combination of interventions, such as straightening, embankments, horizontal construction projects, congestion management, flood protection and activities in water meadows.	5	27
Strongly changed.	As (5) but very negatively influenced.	6	23
Completely changed.	As (5) but completely negatively influenced.	7	10

Macrophytes

All sites, other than the Klein Ammerquellen (ALP-8), were noteworthy for the almost total lack of plants in the channel. This was particularly so for the high energy rivers flowing in U-shaped valleys where cobbles constantly move on the bed.

The largest river surveyed, the Alz, was too deep and flowing too high to be surveyed accurately. However, all the areas waded were cobble-dominated and devoid of vegetation, but the margins supported a rich fringe of reeds and sedges.

The high flows and coloured water in the Zeller Bach and Illach made macrophyte survey almost impossible due to poor water clarity. Both rivers were heavily shaded, limiting the potential for macrophyte growth. A small amount of water-crowfoot (*Ranunculus*) was present in the Zeller Bach, but the beds of both streams were very sparsely colonised. The near-vertical banks were colonised by bryophytes typical of shaded woodland. Both rivers had herb-rich wetland/fen/bog habitat adjacent to them with orchids, gentians, and other colourful herbs growing alongside 10 types of sedge (Appendix 8).

The Klein Ammerquellen (ALP-8) had sedges, grasses and mosses (e.g. *Fontinalis antipyretica* and *Rhynchostegium riparioides*) growing in the channel, presumably because of the greater stability of flow and river-bed. Its 'chalk-stream' character was confirmed by the species occurring in a modified reach downstream from the site where mare's-tail, *Hippuris vulgaris* and fan-leaved water-crowfoot, *Ranunculus circinatus* were seen.

The Isar sites had virtually nothing growing in the channel. ALP-11, was difficult to survey but it was clear that no macrophytes grew there apart from the sparse presence of some bryophytes and alpine plants at the edges. The same was true for ALP-12 and 13, but sparse growth of bryophytes was noted on some trees, and occasionally enormous boulders, on the river bank.

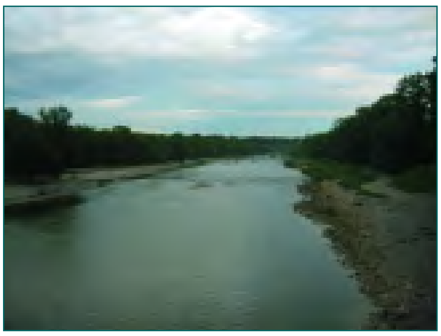
LAWA classification map of southern Bavaria.
Class 1 (purple) - Class 7 (red).

The flora of the Schwarzwasserbach (ALP-14) and Fellenbergbach (ALP-15) were similar in that they both were slightly richer in bryophytes, possibly due to the presence of more consolidated boulders and bedrock. However even here, torrential flood and ice scour preclude anything other than sparse growth.

Water quality

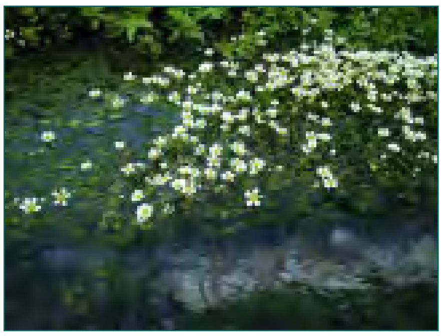
Results from field tests confirmed that the Dolomitic limestone gives rise to medium calcareous water. The water was probably affected by seasonal snow-melt and recent heavy rain, which diluted the total hardness (Appendix 6).

Most rivers in Bavaria are classified as slightly to moderately contaminated by organic pollution represented by LAWA biological quality grades 1-2[11]. The sites we visited reflected that, general pattern (Table 2). ALP-11 is used as a “reference condition” site for biological water quality on the basis of its macroinvertebrates in Austria. It was assumed that ALP-12 and 13, located 12 kilometres upstream from ALP-11, had equally good water quality.



The Isar in Munich where the banks have been re-naturalised.

Agriculture dominates the land alongside the Alz, ALP-2.



Macrophytes such as *Ranunculus* were rarely encountered.

DISCUSSION

The quality of Bavarian rivers[11]

There are about 70,000 kms of rivers in Bavaria and 150 large natural lakes (270 km^2 total area). Affecting these are 23 major dams and flood retention reservoirs and 4,200 water power stations. Over the past 100 years numerous streams and rivers have been engineered to harness water power and protect against floods. The effects of canalisation are particularly striking along formerly braided reaches of rivers such as the Inn. Since the mid-1970s some of the lost riparian habitats have been restored through the landscape management of these straightened rivers, allowing wetland and backwater habitats to develop alongside.

River water quality has improved since 1973 as point source pollution has been tackled, but diffuse pollution from agriculture is still a major factor. Risk assessment in preparation for the Water Framework Directive indicates that for the 900 water bodies, representing 23,400 km of river in Bavaria, almost 40% are at risk or possibly at risk of failing to achieve good ecological status because of nutrient enrichment problems (Table 4).

TABLE 4: Percentage of rivers at risk of failing to achieve good ecological status by 2015: a comparison between Bavaria and England and Wales. Figures in brackets represent diffuse pollution pressure.

Reason for failure Category	Morphological impact		Water quality (nutrients)	
	England & Wales	**Bavaria**	**England & Wales**	**Bavaria**
At risk	28	33	37 (58)	31
Possibly at risk	30	33	2 (29)	8
Not at risk or probably not at risk	42	34	61 (13)	61
River length (km)	51,000	23,400	51,000	23,400

Similarly, two-thirds of these rivers are at "possible" or "confirmed" risk of failing because of morphological pressures. Comparison with figures for England and Wales are shown in Table 4. In Bavaria 23% of rivers are provisionally classified as being heavily modified or artificial, but that figure increases to 54% if candidate reaches are confirmed. In England and Wales the provisional figure is about 40%.

Pressures on the Bavarian landscape

Fragmentation of habitats in Bavaria, as in other parts of Germany and Europe, as a result of transport infrastructure and other development is increasing. The area of "open countryside" (defined by the absence of any road carrying more than 1000 vehicles per day and any railway line in an area of at least 100 km^2) in Bavaria declined from 20% to 15% between 1998 and 2003[13].

This is important because streams and rivers near roads, railways and even small farm tracks usually have reinforced banks and are often straightened.

Glacier retreat is a well-documented effect of climate change in the Alps and this will have an impact on the hydrology of rivers in the short and longer-term.

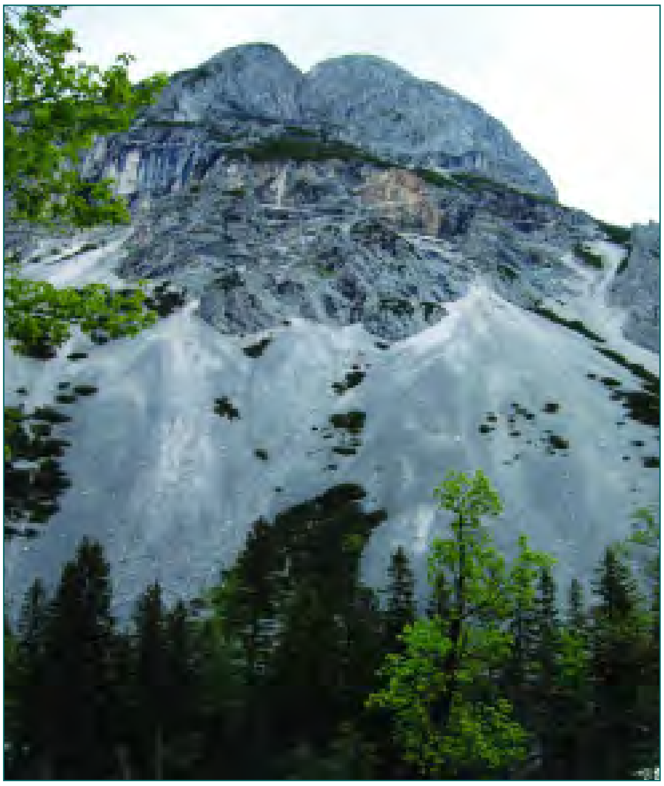
The character of Tyrolian streams and rivers

Observations confirm that there are many hundreds of kilometres of excellent streams in the Austrian Tyrol cascading down the steep alpine valley sides though rock, scree, meadows or dense spruce forest. The tree-line is at about 2100 m. Where livestock (cattle, sheep, goats) can graze, the streamsides are largely devoid of woody vegetation; but where streams are inaccessible to livestock such as those in steep valleys ravines or in gorges, scrub and trees to develop. Gentler gradients near farmsteads and settlements usually result in substantial modification through removal of boulders from the channel bed and formation of embankments. ALP-15 was specifically chosen to illustrate the scrub and tree development in contrast to grazed and modified reaches upstream and downstream.

Historical map of the River Inn, showing braided channel before canalisation.

Straightened, armoured channel of a formerly braided river, near ALP-8.

Shrub and tree growth is prevented along many alpine streams where livestock can graze - upstream from ALP-15.



Some scree slopes are spectacular, ALP-12.

Rivers such as the Ziller, flowing in glaciated valleys with broad valley floors (often >1km wide), can be substantially modified. Naturally braided, the single channels are now heavily reinforced and embanked, with pasture, settlement road and rail links protected from all but the most severe flooding. Several also have major dams that serve as water supply and hydropower reservoirs with warning signs for walkers highlighting the dangers of 'flood waves'.

We briefly visited the riparian woodlands on the extensively braided River Lech near Reutte. The 500m wide river channel is reinforced, embanked and has major groynes to control erosions, but the extensive riparian woodlands and scrub offer a good habitat for flora and fauna. Major rehabilitation is being carried out as part of an EU-LIFE project, www.tiroler-lech.at.

Comparison of hydromorphological methods

As previously established by cross-comparison of survey methods, scale is an important factor in the differences of quality assessment between RHS and the LAWA morphological assessment method[14].

LAWA provides an overview of the degree of modification to the river channel over several kilometres, whilst RHS can provide the necessary smaller-scale (500m length) scrutiny of both habitat features present and more exactly the extent of channel modifications.   The complementary link is that LAWA provides a strategic, linear overview of all mainstem rivers in Germany, whilst RHS provides a statistically valid, site-based assessment of habitat quality and channel modification. Applying the draft CEN guidance standard on habitat quality assessment will be the next stage in comparison of these methods.

One obvious difference is that the Isar at ALP-11, Kleine Ammerquellen at ALP-8 and the Schwarzwasserbach at ALP-14 would all be classified as LAWA class 1. The presence of just one footbridge at each site means that for RHS assessment they are classified as HMS class 2. This means that scale-based rules that put localised modifications into proportionate context will need to be developed, tested and used with care.

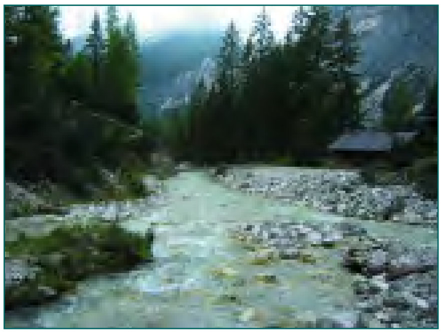
Very unstable channel substrates prevent macrophyte growth, ALP-7.

The spectacular river landscape of the Lech, near Reutte.

Sign warning of hydropower releases.

Groynes extend perpendicularly across the Lech, near Reutte.

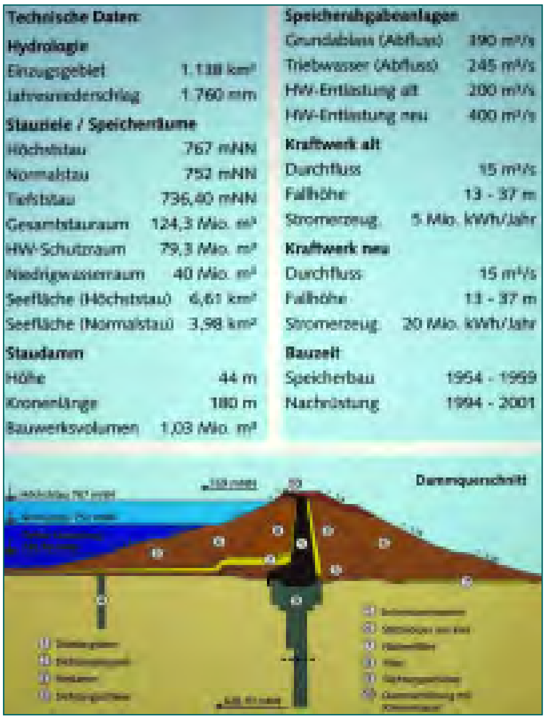
Himalayan balsam - a widespread non-native plant along many rivers in Bavaria and the UK.



Remote headwater alpine streams are often modified - upstream from ALP-13.

Invasive non-native plants

As in the UK, several kinds of non-native plants, and Japanese knotweed, *Fallopia japonica* in particular, are a problem along rivers in parts of Germany and Austria. We recorded Himalayan balsam, *Impatiens glandulifera* at six sites (ALP-1 to 6). In addition, observations when driving between sites suggest that Japanese knotweed is also well established along several watercourses. During 1994-96 Himalayan balsam occurred at 14.4% of RHS baseline survey sites in England and Wales, and Japanese knotweed at 8.6% of these sites[5]. Both species have spread considerably since then.



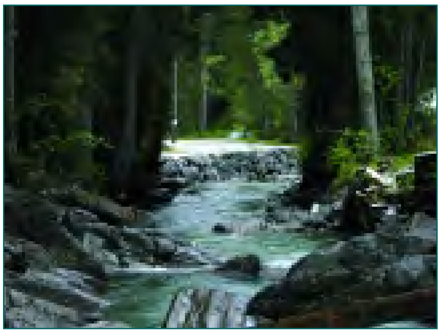
The dam across the Isar creating the Sylvensteinsee.

CONCLUSIONS

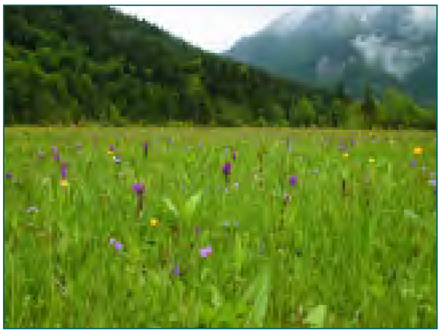
We achieved all our main objectives and several conclusions can be drawn.

The sheer energy, mobility and scale of alpine rivers makes them difficult to survey. This confirmed conclusions made during our surveys of the Julian Alps in Slovenia in 2005[12]. As a result, RHS is really only practicable on the smaller streams and headwater reaches of larger rivers, although heavily modified medium-sized rivers could be easily surveyed.

Flood storage to protect Munich - the Sylvensteinsee lake.



Bank reinforcement is commonplace alongside roads or farm tracks.

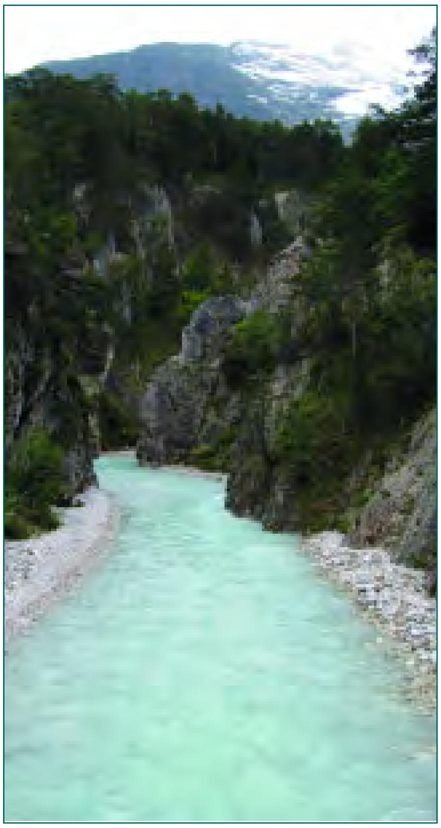


Thankfully, herb-rich meadows are still a common feature in nature park areas, ALP-8.

Local channel gradient and valley form determine the natural character of streams and rivers, whilst human modification to the channel and adjacent land-use are major factors. Consequently the habitat features observed in any particular 500m stretch will reflect how these factors interact.

Except on steep, inaccessible slopes there are very few reaches of unmodified rivers in southern Bavaria and Austria. This is because of extensive river channel works to straighten and reinforce them or impoundment structures for flood control, hydropower generation or water transfer. Even small tracks leading to farmsteads have bank reinforcement work to protect them - a reflection of how active alpine rivers in valley floors have been modified. This reaffirms the morphological classification maps produced by the LAWA work and the difficulty of finding near-natural stretches of river except on very steep slopes or in ravines and gorges. The estimate of 2% of pristine river length in Germany (Table 3) closely matches that in the UK where strict criteria for reference conditions have been applied to 17,000 RHS sites.

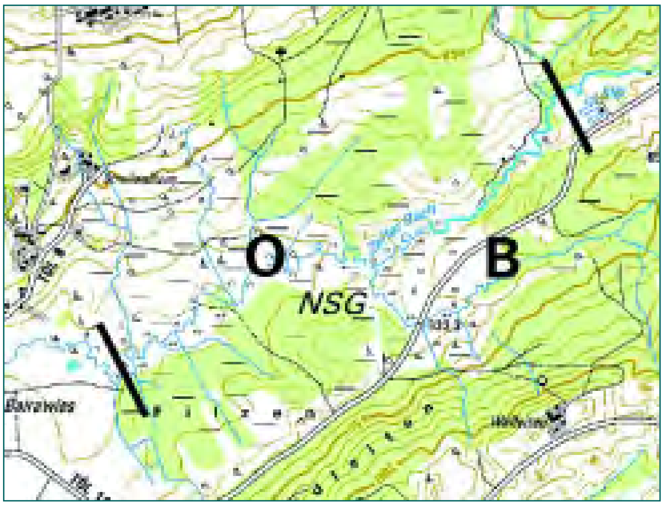
Lady's slipper orchid - a speciality of braided alpine rivers, found at ALP-11.



Pristine conditions are confined to gorges and ravines.

Those rivers that flow in deep gorges will be near-natural, and apart from the installation of hydropower dams, they are likely to remain so. The herb-rich meadows and extravagant meanders illustrated by the sites visited on the Zeller Bach and River Illach will be ecologically valuable in a local and regional context. They are vulnerable to channel straightening and drainage, a threat graphically illustrated when we visited two sites that had been recommended as semi-natural in character on previous information, but had subsequently been modified.

In the UK drainage and land-use change have resulted in 98% of unimproved (i.e. species-rich) grassland being lost since 1945. The Bavarian Nature Park designation ought to provide the necessary protection for these streams and adjacent meadows so that their undoubted ecological value is maintained into the future. It will be a test of the Water Framework Directive whether the low intensity land-use needed to protect these ecologically-important habitats is central to the programme of measures needed to ensure that good ecological status is maintained or achieved by 2015.



Map showing the tortuous meanders of the Zeller Bach, ALP-5,6.

Reed-dominated mature island and natural berms on the Alz.

The Chiemsee is a popular resort.

Woody debris on the Leitzach.

APPENDIX 1: Brief notes on sites ALP-1 to ALP-15.

River Alz: 28 May 2006; ALP-1 and 2; HQA = 51 and 31; HMS = 30 and 10. Back-to-back surveys (1km). 47° 58.083'N, 12° 29.220'E; 47° 58.035'N, 12° 28.743'E.

A wide, deep, reed-lined channel in an agricultural landscape about 4 km downstream from Seebruck, which is at the outflow of the Chiemsee lake. Smooth flow, moving at about 1m per second and swollen by recent rain and snow-melt was predominant.

A large, reed-covered mature island dominates ALP-2, which is also virtually treeless, with consequently a low HQA score of 31. Marshy margins, with reeds and sedges forming a shallow natural berm/terrace, are extensive. Cattle pasture and some tilled land dominate the left bank in ALP-2; this changes to beech woodland downstream in ALP-1 as the channel abuts a valley side.

River Leitzach: 29 May 2006; ALP-3 and 4; HQA = 72 and 70; HMS = 0 and 0. Back-to-back surveys (1km). 47° 52.234'N, 11° 50.699'E; 47° 52.298'N, 11° 50.477'E.

A highly mobile river, with a distinct terraced profile and well-developed riparian scrub, in a wooded valley 3km south of Feldkirchen. The cobble-dominated substrate, extensive bars and mid-channel islands and actively-eroding cliffs are characteristic of rivers in the area. Coarse woody debris is a major feature, with high eroding river bluffs where the channel abuts the valley side.

The river width, including the terraces, is about 80-100m, with the channel itself constantly cutting into and moving laterally in alluvial deposits. This has created a complex, terraced profile colonised by trees and a dense understorey of butterbur, *Petasites hybridus*.

The river corridor land here is owned by the Bavarian Water Agency. This allows the sustainable management option of leaving the channel to move about laterally and compares with extensive reinforcement of river banks, which often happens elsewhere.

Zeller Bach: 30 May 2006; ALP-5 and 6; HQA = 67 and 63; HMS = 0 and 0. Back-to-back surveys (1km). 47° 50.055'N, 11° 33.092'E; 47° 50.331'N, 11° 32.095'E.

A very small, tributary of the River Isar, this extravagantly meandering, deeply-incised, tree-lined (mainly alder, *Alnus glabra*) stream flows through an orchid and herb-rich meadow and wetland fen/bog some 3-4km downstream from the village of Dietramszell.

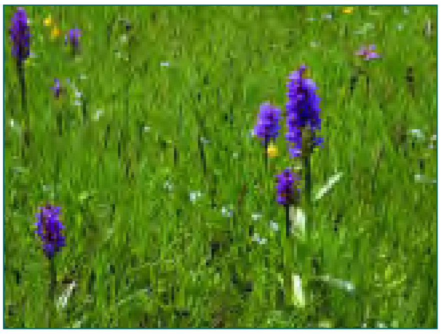
Numerous exposed bankside tree roots, (mainly ash, *Fraxinus excelsior*), fallen trees, and debris dams were all major habitat features and obvious factors influencing the channel habitat. A terraced profile was evident on the inside of several meander bends, with water avens (*Geum urbanum x rivale*) often dominating the flora at these locations.

The adjacent herb-rich meadows and sedge-dominated wetland habitats demonstrated an interesting ecological gradient from acidic bog to calcareous fen conditions towards the river channel.

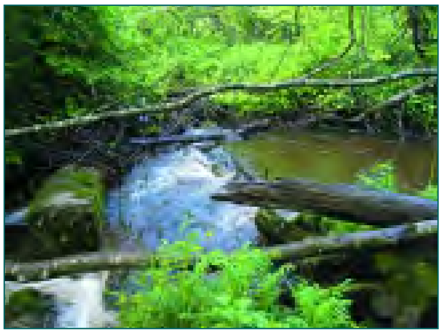
The complex channel character of the Leitzach.

River bluff and point bar on the Leitzach.

The tree-lined, meandering Zeller Bach.



Herb-rich meadow flora alongside the Zeller Bach.



Dilapidated weir structure upstream from ALP-5.

Conditions were not ideal, with coloured water and high flow because of overnight rain. This would have affected the flow-types observed on the day (mainly run-pool sequence) and possibly the absence of riffles was a direct consequence.

Some collapsed, dilapidated low weirs (comprising concrete blocks) were evident, probably to take water onto the meadows in the past. We started downstream from them to ensure they didn't have any effect on habitat character.

River Linder: 31 May 2006; ALP-7; HQA = 62; HMS = 16. Single 500m site. 47° 34.257'N, 10° 59.402'E.

A braided river flowing in a 1km wide glaciated valley between the villages of Linderhof and Graswang, about 6km south-west of Oberammergau. The river channel is more than 100m wide, but water width is about 20m, with up to four wet and three dry braided channels. Managed coniferous forest dominates adjacent land use, with some wetland habitat on the north bank associated with a small tributary stream.

It is typical of many remnant braided rivers in the Alps, because the channel has been modified - in this case, with a set-back embankment along the south bank, protecting a road about 500m away. Some gravel extraction from the mid-channel bars was also evident, but all the typical features of a naturally-braiding reach were present. Coarse woody debris was liberally scattered on the mid-channel bars.

Kleine Ammerquellen; 31 May 2006; ALP-8; HQA = 66; HMS = 140. Single 500m site. 47° 34.510'N, 11° 03.580'E.

A crystal-clear groundwater-fed stream meandering across the 1km wide, glaciated valley floor of the Linder, 2km east of Graswang and 4km due south of Oberammergau. Flow was relatively high, but survey conditions were not affected, although terrestrial grasses were under water at the time. This suggests that the upper reaches may dry out completely at times, but downstream the aquatic flora was similar to a classic English chalk-stream.

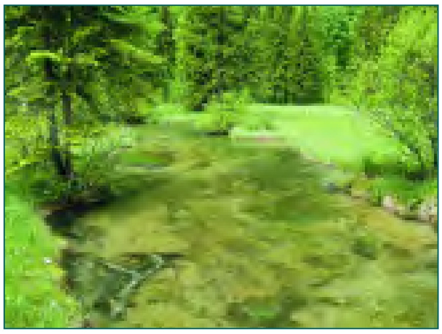
Wetland backwater, left bank, ALP-7.

Set-back embankment, right bank, ALP-7.

Classic braided channel features, ALP-7.

Gravel removal, upstream from ALP-7.

Herb-rich meadow flora, ALP-8.



Stable flow and crystal clear water, ALP-8.

The extravagantly herb-rich meadow (with gentians, orchids, globeflower, *Trollius europaeus* and Scottish primrose, *Primula scotica* prominent) contains pockets of damper wetland habitat, making this a very attractive landscape for visitors. Paths and a minor footbridge are evidence of this use. Occasional willow saplings (*Salix*) and self-sown conifers dot the low river banks, although there is a change in character of land-use as the river briefly abuts the steep, heavily-wooded valley side to the north.

Stoneworts (*Chara* spp.) grow in small, spring-fed pools and feeder streams which cross the meadow. A canalised section downstream from ALP-8 then flows directly into the Ammer River, itself heavily armoured at this point.

River Illach: 1 June; ALP-9 and 10; HQA = 64 and 67; HMS = 100 and 0. Back-to-back sites (1km). 47° 40.644'N, 10° 56.080'E; 47° 40.665'N, 10° 55.857'E.

ALP-9 and ALP-10 are located in the headwater reaches of the Illach River near Wildsteig, 12km north-west of Oberammergau. The slope and size of the river is very much like the Zeller Bach (ALP-5 and 6) and consequently it has a similar extravagantly meandering, heavily-shaded, tree-lined character. It flows through an extremely herb-rich meadow, bog and wetland.

Spring-fed pool in meadow, ALP-8.

The preponderance of fallen trees and occasional debris dams had an obvious impact on shaping the channel habitat. Like the Zeller Bach, distinct terraces colonised by saplings were to be found on the inside of some of the meander bends.

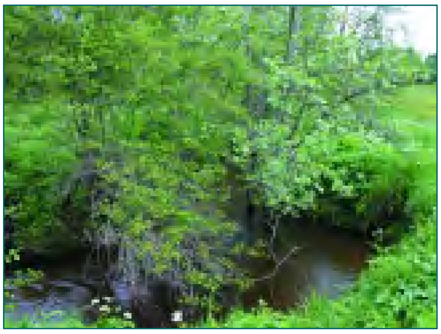
Although the water was brown in colour because of the heavy overnight rain, survey conditions were good enough to allow flow and channel features to be recorded with more confidence than when surveying the Zeller Bach.

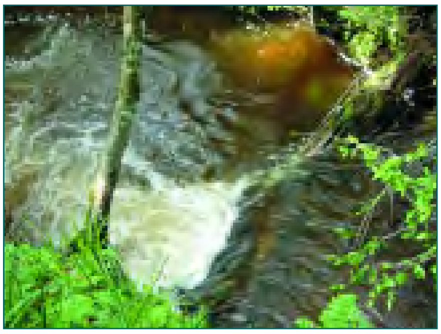
River Isar: 2 June 2006; ALP-11; HQA = 70; HMS = 120. Single 500m site. 47° 22.785'N, 11° 17.600'E.

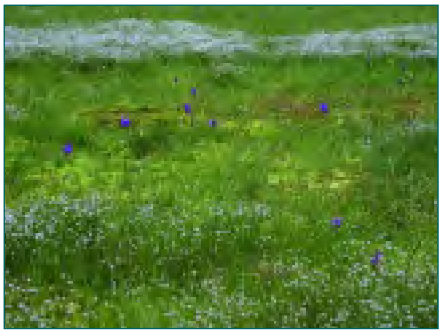
A spectacular location in a glaciated alpine valley 2.5km east of Sharnitz, where the gorge-like profile constrains the river but unvegetated bars dominate the channel. Surprisingly, given the force that water must travel through this reach, a distinct terrace profile has formed on the inside of a meander bend, and is now colonised by herbs, grasses and saplings as well as more mature conifers. We found lady's slipper orchid, *Cypripedium calceolus* growing just above this terrace.

The densely-forested bedrock slopes form an attractive landscape and the river is popular with canoeists. The only modifications are a small footbridge which joins the north bank to a large point bar, and some houses high up the valley overlooking the downstream end of the site.

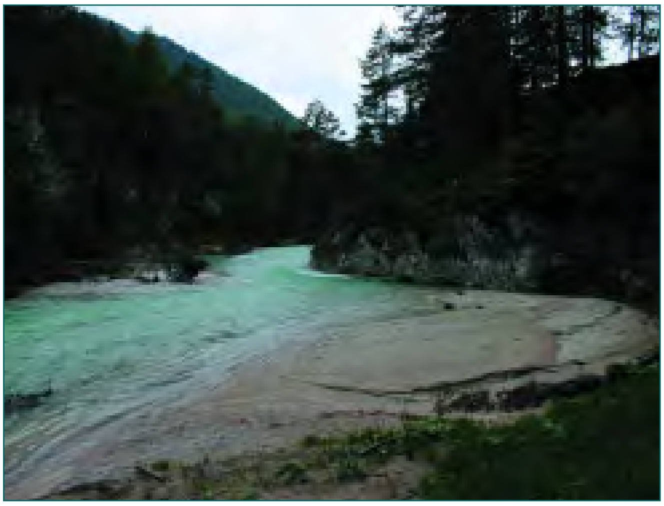
Tree-lined channel and woody debris, ALP-9.


Tortuous meandering of the Illach.


One of several debris dams, ALP-9.


Eleocharis growing in a spring-fed mire alongside the Illach.


The Isar is popular with canoeists.


Large sandy deposit reflects sheltered conditions at this point, ALP-11.

Classical picture postcard scenery, ALP-11.

Recent channel downcutting plus cobble debris on the right bank, ALP-12.

Trees on river terraces, ALP-13.

Snapped trees - evidence of avalanche damage, ALP-13.

The site is a reference condition sampling spot for the Austrian Water Framework Directive monitoring programme for aquatic macroinvertebrates.

Isar headwaters: 2 June 2006; ALP-12 and 13; HQA = 75; HMS = 0 and 0. Two single 500m sites. 47° 22.387'N, 11° 25.467'E; 47° 22.158'N, 11° 25.988'E.

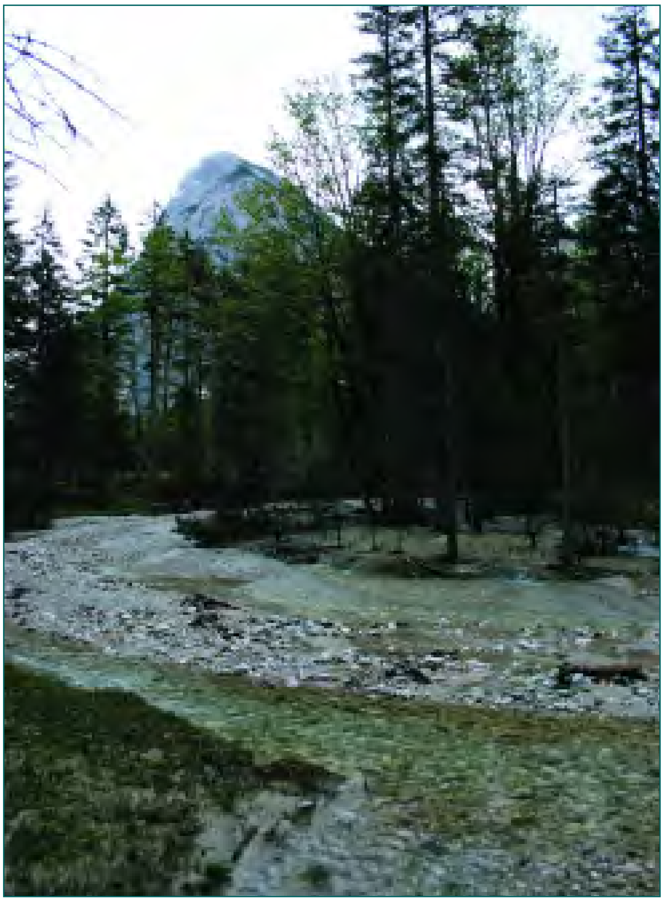
These sites are 12km upstream from ALP-11. Apart from a 2km ravine section immediately upstream from ALP-11, much of the braided headwater channel of the Isar river flowing in the glaciated U-shaped valley floor have been modified. Gravel bars have been reprofiled and banks reinforced, presumably to protect the forestry access road. We only found two 500m sections (ALP-12 and ALP-13) suitable and accessible for survey - further confirmation of how extensively modified alpine streams and rivers in flat valley floors have become.

A braided channel and complex of low terraces colonised by conifer trees in the wooded, glaciated valley floor were the main features of ALP-12. This was offset by spectacular screes on the glaciated valley slopes. There was a major alluvial fan deposit at the downstream end of the site, at the confluence of two tributaries. Huge quantities of cobble-sized debris had been deposited by the tributary torrent - a feature clearly visible using *Google Earth*.

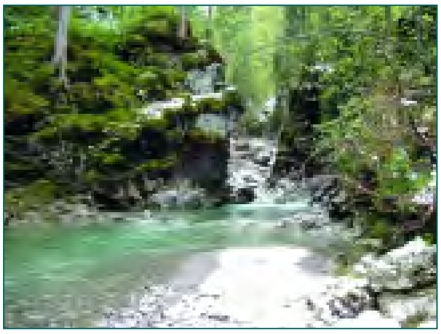
A little way upstream, ALP-13 presented a more complex picture. Just downstream from a precipitous narrow gorge section, the boulder-stream was flanked on one side by the massive glaciated valley side with forested scree and on the north side by an alpine meadow with gentians (*Gentiana* spp.).

The terraced profile of the channel is more than 50m wide, with consolidated material colonised by self-seeded conifers and Juniper scrub. The water-filled part of the channel is 7.5m wide, and is more active in nature than ALP-12, presumably because it has twice the gradient (40m/km).

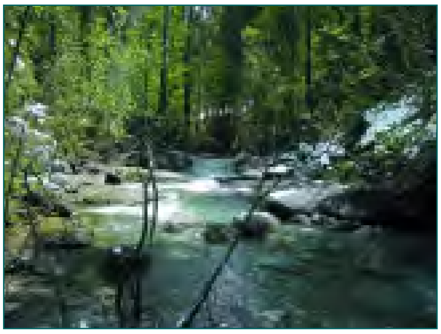
Scree - a source of gravel; plus evidence of gravel removal from the channel.



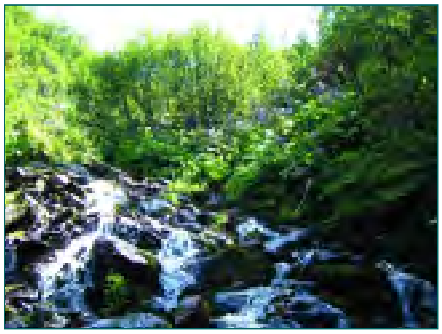
Braiding and low terraces, ALP-12.



Classic bedrock channel, ALP-14.



Bedrock, boulders and cascades, ALP-14.



The very steep gradient prevents bankside grazing by livestock, ALP-15.

A small run-of-river hydropower installation upstream from the site probably powered the summer house associated with the alpine meadow, whilst historical mining, marked on the 1:25,000 scale map may have accounted for some of the darker cobble and other deposits seen in the site.

Schwarzwasserbach: 3 June 2006; ALP-14; HQA = 61; HMS = 180. Single 500m site. 47° 21.180'N, 10° 09.418'E.

The Schwarzwasserbach flows west of the small Austrian ski resorts of Rizlern and Hirschegg. Several centimetres of overnight snow was still lying when we surveyed the site. The river is in a very steep, narrow, heavily wooded valley. Other than a footbridge and footpath on the wooded slope of the left bank, the landscape is near-natural in character for about 600m. In stark contrast, upstream and downstream of the site, the gradient is more gentle, and major bank re-sectioning and reinforcement work has taken place.

The steep channel gradient and bedrock in the gorge-like section surveyed included a large waterfall (>20m high) and scour pools deeply etched into the bedrock.

Fellenbergbach: 29 July 2006; ALP-15; HQA = 52; HMS = 0. Single 500m site. 47° 08.176'N, 11° 53.340'E.

A high altitude, very steep (22°) alpine stream, at the head of a glaciated valley 4km south-east of Mayrhofen. The stream has eroded a 20m deep-vee 'valley' in the massive moraine deposits. The channel is dominated by cascades and has a very unstable bouldery substrate. Tall herbs, alder buckthorn, *(Frangula alnus)* scrub and heathland grow on the adjacent steep slopes. The stream is inaccessible to the cattle that graze gentler slopes both upstream and downstream of the site. This scrubby landscape contrasts to intensively-grazed streamside habitats elsewhere, and also the steep, forested bedrock reaches further downstream.

Spectacular waterfall, ALP-14.

Mountain torrent in glacial moraine at 2000m, ALP-15.

APPENDIX 2: Characteristics of the Bavarian and Tyrolian streams and rivers surveyed in 2006.

KEY: *distorted by high-flow conditions † includes intermittent headwater reaches

Feature	ALP-1,2	ALP-3,4	ALP-5,6	ALP-7	ALP-8	ALP-9,10	ALP-11	ALP-12,13	ALP-14	ALP-15
Geology and surrounding landscape	Moraine, peatlands; hills	Moraine; hills	Alluvium, peatland; hills	Flysch, alluvium, peatlands; mountains	Peatlands; mountains	Moraine; hills	Dolomitic limestone; mountains	Dolomitic limestone; mountains	Dolomitic limestone; mountains	Dolomitic limestone; mountains
Predominant land-use	Pasture	Woodland	Meadow	Forest	Meadow	Meadow	Forest	Forest	Forest	Scrub
Valley shape	Asymmetrical	Asymmetrical	Shallow vee	Asymmetrical (U)	Flat (U)	Concave-bowl	Gorge	U-shaped	Deep vee	Deep vee (U)
Valley relief	30m	100m	80m	600m	600m	90m	600m	800m	200m	400m
Altitude (mid-site)	515m	560m	630m	900m	845m	860m	980m	1220m	1150m	1880m
Slope (m/km)	1m/km; 1m/km	10m/km; 10m/km	4m/km; 4m/km	10m/km	4m/km	5m/km; 5m/km	10m/km	20m/km; 40m/km	110m/km	480m/km
Distance from source† (mid-point)	85; 85.5km	49.0; 49.5km	6.5km; 7.0km	15.0km	1.4km	6.5; 7.0 km	18.0km	6.0; 5.0km	8.8km	2.3km
Height of source	1500m	1240m	695m	1700m	1290m	1290m	1900m	1900m	1660m	2400m
Water width	80.0; 80.0m	22.0; 22.0m	5.0; 6.0m	20.0m	5.0m	4.0; 4.5m	32.0m	6.0; 7.5m	6.0m	2.0m
Bankfull (or trashline) width	85.0; 320.0m	24.0; 24.0m	6.5; 7.0m	120.0m	7.5m	6.0; 6.5m	38.0m	15.0; 22.0m	13.0m	4.0m
Extent of braiding	None	None	None	Extensive	None	None	Some	Some	None	None
Predominant channel substrate	Gravel	Cobbles, pebbles	Gravel	Cobbles	Gravel	Gravel-pebbles	Cobbles	Pebbles, cobbles	Bedrock	Boulders
Predominant flow type	Smooth	Unbroken waves	Rippled*	Unbroken waves	Unbroken waves	Rippled-unbroken waves	Broken waves	Unbroken waves	Chute	Chute
HQA score	51, 31	72, 70	67, 63	62	66	64, 67	70	75, 75	61	52
HMS (and class)	30(2), 10(1)	0(1), 0(1)	0(1), 0(1)	16(1)	140(2)	100(2), 0(1)	120(2)	0(1), 0(1)	180(2)	0(1)
Impacts within site	Agriculture	Negligible	Negligible	Embankments	Negligible	Old weirs upstream	Negligible	Negligible	Negligible	None
Nature Area?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	?	Yes

APPENDIX 3: HQA sub-scores and total scores for ALP-1 to ALP-15.

Site number (ALP)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Flow-types	5	4	7	8	8	6	7	9	10	10	9	7	10	10	10
Channel substrates	4	4	5	6	5	5	6	4	5	6	8	7	9	9	8
Channel features	3	3	8	4	4	4	8	2	7	5	8	9	6	8	7
Bank features	2	3	14	18	4	2	13	11	5	7	11	14	16	1	0
Bank vegetation structure	10	1	12	11	12	12	6	11	12	11	12	12	12	6	6
In-stream vegetation	3	5	4	3	5	2	0	10	3	1	0	0	0	2	2
Land-use	7	5	4	4	7	7	3	5	6	6	13	14	8	9	8*
Trees and associated features	12	2	14	11	18	18	12	7	12	12	7	11	11	11	5
Special features	5	4	4	5	4	7	6	7	4	9	3	2	4	6	7
Total HQA score	**51**	**31**	**72**	**70**	**67**	**63**	**62**	**66**	**64**	**67**	**70**	**75**	**75**	**61**	**52**

*scrub counted as natural land-use

APPENDIX 4: HMS scores and habitat modification class for ALP-1 to ALP-15.

Site number (ALP)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HMS score	30	10	0	0	0	0	16	140	100	0	120	0	0	180	0
Habitat modification class	2	1	1	1	1	1	1	2	2	1	2	1	1	2	1

Islands, however small, feature in HQA scores, ALP-8.

APPENDIX 5: Selected habitat features and *ad-hoc* observations of wildlife along the Bavarian and Tyrolian alpine rivers surveyed in 2006

P: present; E: extensive. Species presence denoted by ✓. Superscript is the ALP site number.

Habitat features	ALP-1,2 Alz	ALP-3,4 Leitzach	ALP-5,6 Zeller Bach	ALP-7 Linder	ALP-8 Kleine Ammerquellen	ALP-9,10 Illach	ALP-11, 12, 13 Isar headwaters	ALP-14 Schwarzwasserbach	ALP-15 Fellenbergbach
Waterfall/cascades								E	E
Braided channel				E			P		
Unvegetated bars		E		E			E	P	
Vegetated bars/islands	E	P	P						
Debris dams			P						
Riparian woodland		E					P[12]		
River terraces		E		E			E[12, 13]		
Natural berms	E[2]	P	P		E	P			
Herb-rich meadows			E		E	E	P[13]		
Swamp	E[2]								
Wildlife observations									
Lady's slipper orchid							✓[11]		
Dipper		✓					✓	✓	
Grey wagtail							✓[11]		✓
Pied wagtail	✓								
Reed warbler	✓								
Red-crested pochard	✓								
Great-crested grebe	✓								
Crag martin					✓		✓[11]		
Kingfisher	✓								
Goosander				✓					
Red-backed shrike			✓		✓				
Alpine swift									✓

APPENDIX 6: Indicative values for water chemistry.

Single spot field determinations were made using test papers and a conductivity meter. Key: Nitrate tr = trace or <5mg/l; Total hardness scale as calcium carbonate: 'soft' = 70-125mg/l or low hardness; 'medium' = 125 - 250 mg/l or medium hardness; 'hard' = 270 - 360 mg/l or high hardness.

Site reference	Acidity ± 0.1 pH units, (value after 3-7 days, if changed)	Conductivity at 20°C ($\mu S\ cm^{-1}$)	Total hardness (Ca & Mg) (± 40 mg/l CaCO3)	Nitrate	Water colour
ALP-1, 2	7.3	328	Medium	none	sl. greenish
ALP-3, 4	-	-	-	-	-
ALP-5, 6	7.0 (7.1)	363	Medium - hard	trace	sl. brown - turbid
ALP-7	6.8 (7.3)	267	Medium	trace	
ALP-8	6.5 (7.2)	390	medium - hard	trace	none
ALP-9, 10	7.0	266	medium	sl. trace	none
ALP-11	6.5 (7.3)	222	soft - medium	none	sl. opaque sl. bluish
ALP-12	6.7 (7.3)	213	soft	none	sl. bluish
ALP-13	6.7 (7.3)	207	soft - medium	sl. trace	none
ALP-14	- (7.0)	208	soft - medium	none	none

APPENDIX 7: Improvements and recommendations for the RHS manual

The following observations and recommendations follow on from those made as a result of our Slovenian visit[12].

Valley form: near-horizon and wider context

Determining predominant valley form has always been a problem, except in clear cut cases such as deep vee or floodplains with no obvious valley sides. On mainland Europe the problem is often compounded by the effect of scale. The Alps are dominated by glaciated (U-shape) valleys, but incised streams flowing down the sides will often be deep vee or even gorge-like for some distance. *It is recommended* that the predominant valley shape is more explicitly related to the context of the river channel (i.e. near-horizon) because it is this that determines the character and behaviour of the river, whilst a note is made of the wider landscape where appropriate. ALP-15 provides an excellent example of a (near-horizon) deep vee, within a moraine filled glacial U-shaped valley.

Valley form: spot-check observations

There is a big difference in recording bankface and banktop vegetation structure in gorge and deep-vee valleys. *It is recommended* that the guidance manual clearly explains that at each spot-check the bankface/banktop observations are made in relation to the valley shape at that point.

Valley form: gorge/deep vee

True gorge profiles (bedrock, with >80⁰ slope) will be extremely difficult and treacherous to survey, so sites with predominant gorge valley form should be checked for the health and safety assessment.

Banktop/trashline along very steep streams

Steeply-inclined stream banks in deep vee valleys will rarely have a distinct notch or obvious strandline because the slope will not allow development of either. In these cases, other clues will need to be used to determine where to delineate bankface and banktop such as the line of growth of mosses and liverworts - below this, intense scour or winter ice will prevent bryophytes becoming established.

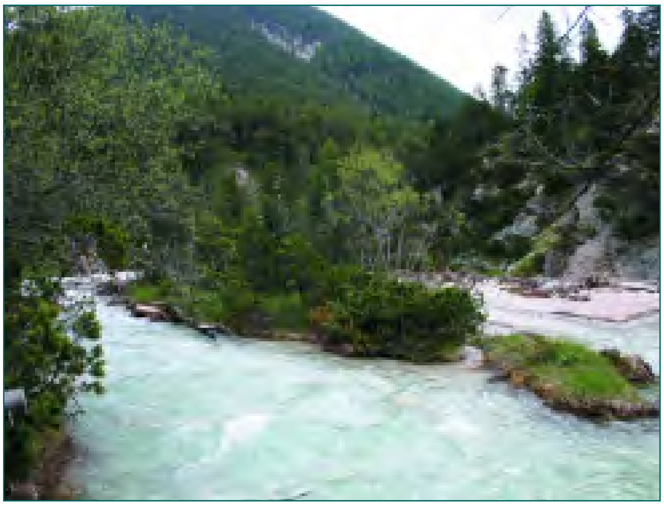
True gorge sections are impossible to survey accurately and safely.

Natural berms/terraces: vegetation

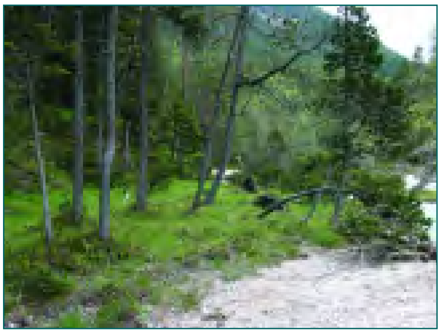
We found low (<0.5m high) terraces, colonised with coniferous trees at ALP-11, 12 and 13. The occurrence at ALP-11 in a predominantly gorge-like reach means that natural berms and terraces are not just confined to over-widened or very actively meandering streams in flat or asymmetrical valleys.

It is recommended that a note is made of whether saplings or trees are growing on the terrace to differentiate from more recent formation when grass and herbs are likely to be the dominant vegetation.

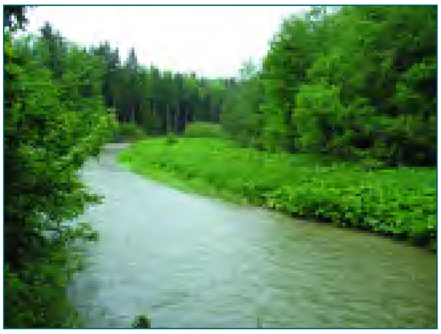
A stream cut into glacial valley moraine, ALP-15.



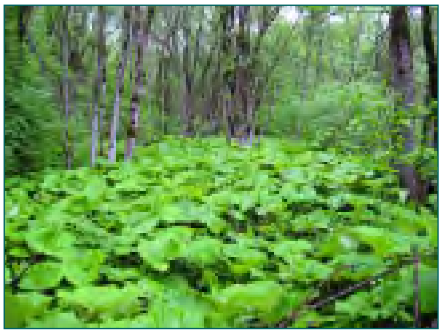
Clues other than strandlines are needed to determine the channel / bank boundary in deep vee valleys, ALP-11.



Low terrace with trees, ALP-11.



Actively-moving channels produce natural berms, developing into terraces, ALP-4.

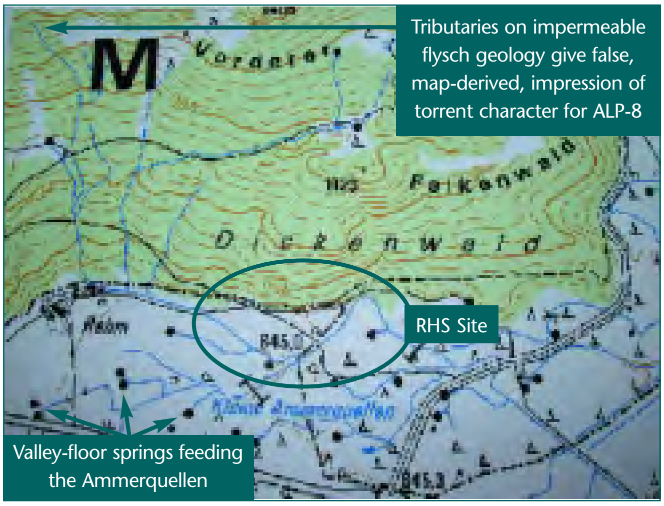


Mature river terrace, with even-aged stands of trees and shrubs, ALP-3.

Use of *Google Earth*

Google Earth is a freely available, web-based world-wide aerial photograph/satellite image resource. It provides a readily accessible tool to provide landscape-scale context for RHS and other field surveys. Resolution of images varies according to location, but images can help to distinguish individual features such as point, mid-channel and side bars. These can be clearly seen for sites ALP-1, 2, 3 and 4. Not surprisingly, trees mask completely the channel at ALP-5 and 6. Resolution in more mountainous landscapes is generally much lower; consequently features in ALP-7 and 8, 9, 10, 11-13, 14 and 15 are indistinguishable.

Nevertheless, *it is recommended* that *Google Earth* is used to provide context on land-use and, wherever possible, channel and riparian land-use features. It is also a useful cross-check for latitude and longitude co-ordinates for GPS readings taken in the field. It can also be used to help select potential sites prior to special survey work.



The Kleine Ammerquellen (ALP-8), clearly showing several spring sources (black dots) and mountainside tributaries of contrasting very steep gradient.

River character and PCA plot

The PCA plot as currently derived depends on map-derived information, with height of source prominent as a determinand. For groundwater-fed streams and rivers this may produce misleading results. For instance, the Kleine Ammerquellen (ALP-8) has a tributary some 445m higher and only 1.4 km away. This results in a high energy position on the PCA plot. But this source is on impermeable Flysch geology and is not a true reflection of the dolomitic-limestone elsewhere which determines the groundwater nature of the flow. The importance of local gradient and hydrological regime in addition to the PCA plot is therefore paramount in comparing similar sites.

Google Earth image of the Letizach River at ALP-3,4.

Appendix 8: Many of the plants seen in the species-rich meadows alongside the Zeller Bach.

Latin Name	English Name	Indicative Cover
Alnus glabra	Alder	A
Angelica sylvestris	Wild Angelica	O
Anthoxanthum oderatum	Vernal Sweet-grass	O
Anthyllis vulneraria	Kidney Vetch	F
Briza minor	Lesser Quaking-grass	O
Caltha palustris	Marsh Marigold	O
Carex acuta	Slender Tufted-sedge	A
Carex curta	White Sedge	F
Carex echinata	Star Sedge	O
Carex elata	Elongated Sedge	F
Carex nigra	Common Sedge	F
Carex panicea	Carnation Sedge	F
Carex rostrata	Bottle Sedge	F
Carex vesicaria	Bladder Sedge	O
Carex viridula	Yellow-sedge	F
Circium palustre	Marsh thistle	A
Cirsium dissectum	Meadow Thistle	O
Convallaria majalis	Lily of the Valley	O
Dactylorhiza praetermissa agg.	Marsh Orchids	F
Equisetum arvense	Creeping Horsetail	O
Equisetum fluviatile	Water Horsetail	R
Equisetum palustre	Marsh Horsetail	R
Erica tetralix	Cross-leaved Heather	O
Eriophorum angustifolium	Common Cotton-grass	R
Eriophorum vaginatum	Hare's-tail Cotton-grass	F
Filipendula ulmaria	Meadowsweet	F
Filipendula vulgaris	Dropwort	F
Frangula alnus	Alder Buckthorn	F
Galium palustre	Marsh bedstraw	F
Galium spp.	Other bedstraws	F
Gentiana sp(p.)	Gentians	O
Geranium pratense	Meadow Cranes-bill	R
Geum rivale	Water Avens	O
Geum x intermedium	Hybrid Water Avens	O
Juncus effuses	Soft Rush	O
Juncus inflexus	Hard Rush	O
Listera sp.	Twayblade	R
Lotus pedunculatus	Marsh Bird's-foot Trefoil	F
Lychnis flos-cuculi	Ragged Robin	F
Lysimachia nummularia	Creeping Jenny	O
Lysimachia thyrsiflora	Tufted Loosestrife	R
Lysimachia vulgaris	Yellow Loosestrife	F
Lythrum salicaria	Purple Loosestrife	R
Maianthemum bifolium	May Lily	R
Mentha spp.	Water mint and others	O
Menyanthes trifoliatus	Bogbean	F
Molinea caerulea	Purple Moor-grass	O
Myosotis scorpioides	Water Forget-me-not	F
Paris quadrifolia	Herb-Paris	R
Persicaria bistorta	Bistort	R
Phragmites australis	Common Reed	R
Pinguicula sp.	Butterwort	R
Polygala spp.	Milkwort	O
Polygonatum spp.	Solomon Seals	R
Polygonum bistorta	Meadow bistort	F
Potentilla erecta	Marsh Cinquefoil	O
Potentilla palustris	Water Avens	R
Primula veris	Cowslip	O
Primula scotica	Scottish Primrose	O
Pyrola sp.	Wintergreen	R
Ranunculus aconitifolium	Aconite-leaved Buttercup	O
Ranunculus acris	Meadow Buttercup	F
Rhinanthus sp.	Yellow Rattle	R
Rumex acetosella	Sheep's Sorrel	O
Sanquisorba officinalis	Greater Burnet	O
Scirpus sylvaticus	Club-rush	O
Stachys officinalis	Betony	R
Sphagnum sp.	Bog Moss	F
Thalictrum flavum	Meadow-rue	F
Tofieldia pusilla	Scottish Asphodel	O
Trichophorum cespitosa	Deer Grass	F
Trolleus europaeus	Globe-flower	O
Vaccinium sp.	Bilberry	O
Valeriana dioica	Marsh Valerian	F
Valeriana officinalis	Common Valerian	F
Vicia spp.	Vetches	F
Viola palustris	Marsh Violet	O

Cover: D = Dominant; A = Abundant; F = Frequent; O = Occasional; R = Rare

APPENDIX 9: JNCC macrophyte survey results.

Figures (scale 1-5) are relative, and absolute, estimates of cover within the river channel (first two figures) and the second two are estimates for the margin. For more details, see[2].

JNCC Check-list taxa\Sites (ALP)	1	3	4	5	7	8	9	10	11	12	13	14
ALGAE												
Batrachospermum sp.						2200						
Filamentous green algae (other)						2200			1100			1100
LIVERWORTS												
Chiloscyphus polyanthos						1111	1111	1111				
Conocephalum conicum							33	33		11	11	11
Jungermannia sp(p).									11	11	11	
Pellia endiviifolia				11					11	11	11	1111
MOSSES												
Amblystegium fluviatile	1111								1111			2121
Brachythecium plumosum											1111	2121
Brachythecium rivulare						1111	1111	1111	11			2132
Brachythecium rutabulum							21	11				
Bryum pseudotriquetrum						1111			11	11	21	1111
Calliergon cuspidatum						1111	11	11				1111
Cinclidotus fontinaloides												
Cratoneuron filicinum							1121	1111	1111		1121	1111
Dichodontium pellucidum / flavescens									11	11	21	2132
Fissidens crassipes / curnovii / rufulus												3132
Fontinalis antipyretica			1100			2211	2111	2111				
Philonotis fontana						1111						
Rhynchostegium riparioides						3311	2111	2111				3131
Schistidium rivulare												1111
Sphagnum sp.						1122						
Thamnobryum alopecurum												1111
PTERIDOPHYTES												
Equisetum fluviatile	1111					1111	1111	1111				
Equisetum palustre	1111			11		1111	1111	1111				
Other Ferns						11	11	11				
HERBS												
Angelica sylvestris		11	11	11	11	11	11	11				
Callitriche stagnalis				11								
Caltha palustris	1122					1111	1111	1111				
Cardamine amara				11	11	2222	1111	1111				
Epilobium hirsutum	1111	11	11			1100						
Eupatorium cannabinum		11	11		11	1111	11	11				
Filipendula ulmaria	1133	11	11	11	21	1122	1111	1122				
Galium palustre	1122					1111	1111	1111				
(*Heracleum mantegazzianum*)		11	21									
(*Impatiens capensis*)		11	11									
(*Impatiens glandulifera*)	11	22	22	11								
Lotus pedunculatus						1111			11	11	11	1111
Lycopus europaeus	1111											
Lysimachia vulgaris	1111											
Lythrum salicaria	1111	1111	11									
Mentha aquatica	1133	2122	1122	11		11	1111	11				
Menyanthes trifoliata						1111						
Myosotis scorpioides	1122					1111	1111	1111				
Myosoton aquaticum		11	11									
Persicaria amphibia	1122											
Persicaria hydropiper												
Petasites hybridus		3133	3133		3132		1122	1111	1121			
Potentilla erecta					1121	1111			11	11	11	1111
Ranunculus penicillatus ssp. pseudofluitans				3100								
Rorippa nasturtium-aquaticum	1122											
Solanum dulcamara	2122											
Stachys palustris	1122											
Symphytum officinale	1122											
Tussilago farfara		1111	1111						1121	2121	2132	
Valeriana officinalis					11	11	11	21				
Veronica anagallis-aquatica / catenata (indeterminate)							11					
Veronica beccabunga					1111	1111		1111				
Veronica scutellata								21				
Viola palustris					1111				11	11	11	1111
Other non-aquatic dicotyledons	1111	1122	1122	32	1133	1122	1122	1122	32	1132	31	11

APPENDIX 9: continued

JNCC Check-list taxa\Sites (ALP)	1	3	4	5	7	8	9	10	11	12	13	14
TREES AND SHRUBS												
Alnus glutinosa	1111										32	
Salix sp.	2122	3133	3133	11	2233			2122	3132	11	1111	11
Conifererous Trees		22	11		1111	1122	1122	1111	1121	3132	1121	11
Other Deciduous Trees and Shrubs	1122	1122	1122	3132	1122	3233	3233	3233	1121	1121	2133	11
MONOCOTYLEDONS												
(*Acorus calamus*)	22											
Carex acuta	2122	1122				11	11	11				
Carex acutiformis	2122											
Carex curta						11	11	11				
Carex disticha	1122											
Carex elata	3233					11	11	11				
Carex flacca		11			1122	11	11	11	1132	21	11	11
Carex hirta	1122											
Carex panicea					1122	11	11	11				
Carex paniculata					1122	11	11	11				
Carex remota						11	11	11				
Carex riparia	2133											
Carex rostrata					2233	1111	1111	1111				
Carex viridula												11
Deschampsia cespitosa	11											
Iris pseudacorus	2122											
Juncus articulatus					2211							
Juncus inflexus						11	11	11				
Lemna minor	1100											
Phalaris arundinacea	2133	3132	3132	2132								
Phragmites australis	3233				1122							
Scirpus sylvaticus	11	11			1111	1111	1111	1111				
Other monocotyledons	1111	1122	1122	1132	3322	1111	1111	1111	32	1121	1132	11
Non- JNCC Check-list taxa												
Plagiochila sp.									11	1121	1132	
Bryum alpinum											2121	
Climaceum dendroides						11						
Dicranella sp.										11	11	
Drepanocladus sp.											2121	
Mnium hornum								11				11
Mnium undulatum							11	11				
Plagiomnium rostratum							22	11				11
Rhizomnium punctatum			11				11	11				11
Acer pseudoplanus										11	11	
Agrostis stolonifera		1111	1111		1121	3322	1111	1111				
Alchimilla sp.						11				11	11	
Alnus glabra		1122	1111	2133	1121	2233	3233	3233				
Barberia stricta		11	11									
Betula sp.										21	11	
Equisetum arvense		1122	2122						11	1111		
Erica sp(p.)									21	11	21	
Frangula alnus	1111											
Galium malugo					21							
Geum rivale hybrid				11		11	11	11				
Hesperis matronalis						11						
Lonicera sp.							11	11				
Lysimachia nemorum	11											
Maianthemum bifolium									11	11	11	11
Mentha hybrid		2122	2122									
Mercurialis perennis							11	11				
Oenanthe silaifolia	1100											
Paris quadrifolia										11	11	
Persicaria bistorta						11	11	11				
Pinguicula sp(p.)						11					11	
Polygonatum sp.												11
Primula scotica						11			11		11	
Primula sp.						11						
Prunus padus				1122								
Ranunculus aconitifolius						11	11	11				
Rhinanthus sp(p.)						11	11	11				
Sanguisorba officinalis						11						
Scrophularia nodosa		11	11		11	11	11	11				
Sisymbrium sp.									11	11		
Sonchus sp(p.)						11	11	11				
Sorbus aucuparia							11	11	11	11	11	11
Thalictrum sp(p.)	1122					11	11	11				
Vaccinium sp.									1121	1121	21	
Valeriana dioica						11	11	11				

APPROXIMATE LOCATIONS OF SITES SURVEYED

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