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Looking beyond the shores of the United Kingdom: addenda for the application of River Habitat Survey in Southern European rivers

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ABSTRACT

River Habitat Survey (RHS) is a system which records and quantifies the physical and vegetational structure of river channels and their immediate floodplains. In the United Kingdom, where it has been applied since the 1990s, it has brought an understanding of state of rivers nationally and has proved to be a useful part of scientific investigation. It is now obvious that such a method should be applied more widely, especially in the European context, where river data is lacking for many countries and there is a need for a standard, internationally comparable method. In this paper an extension to the basic survey method is presented, with the aim of improving the detail and quality of data collected for highly dynamic, braided rivers, more common in the rest of Europe, particularly the south, than in the UK itself. The changes to the survey form included the recording of secondary flow and substrate types for each transect, in addition to the usual recording of primary types. Where more than one wetted channel was present data were collected for both the main and secondary channels. These were common in the areas studied, for instance in autumn 2000 secondary channels were found at 9 out of 11 sites in northern Italy and 4 out of 11 sites in the south. Additionally, the results showed that with the recording of both primary and secondary flow types for each transect the average number of flow types found per site was increased by between 1 - 2.2. For substrate types the average increase per site was close to 1. Certain flow types, in particular 'chute' and 'no perceptible', and substrate types, for example 'sand', tended to be under-represented by the basic survey method. The relevance and implications of these results are discussed with respect to the southern European situation and the point is made that the detail required from RHS depends on the original motivation for choosing to apply it. Where it is part of a detailed biological or ecological study the extra information provided by the extended form presented here is potentially useful.

Key words: river hydromorphology, habitat, flow type, RHS, AQEM, STAR, WFD

1. INTRODUCTION

River Habitat Survey (RHS) is a methodology developed by the Environment Agency of England and Wales during the last decade of the 20th century (Raven *et al*. 1998b; 1998c; Environment Agency 1997), in collaboration with various academics, which has been and continues to be applied extensively in Britain and Northern Ireland. Data have been collected from more than 12,000 sites and a huge, easily accessible database created. To give a brief overview it is a technique for the assessments of river habitats, which aims to provide nation-wide conservation-relevant information about the physical state of rivers. It differs from previously applied methods in aim, method and emphasis (Fox *et al*. 1998). Its closest antecedent was River Corridor Survey (NRA 1992), which was not designed to quantify and categorise rivers as a part of a national database, but instead to map habitat features to aid river management decisions at the local level (Raven *et al*. 1998a; Fox *et al*. 1998). The physical habitat assessment which RHS provides complements other data, such as water quality/chemistry data or biological survey (Raven *et al*. 1998b), or used as part of a wider scheme for considering the conservation value of rivers, such as SERCON (Wilkinson *et al*. 1998; Boon *et al.* 1997).

RHS employs a method that records a large set of qualitative and quantitative data, instead of relying on a mapping approach. The data allows the direct comparison of sites, enabling, for example, an investigation of river types (Jeffers 1998b) and the identification of high quality and impoverished sites (Raven *et al*. 1998b). On the whole it does not provide the type of detailed site information required to manage individual habitat features at a site, although it has proved useful in two catchment management studies when used in partnership with other information (e.g. GIS) (Webb *et al*. 1998; Raven *et al*. 2000), has been used to provide background information as part of a river rehabilitation project (Kemp & Harper 1997) and is currently being applied to catchment management planning (Raven *et al*. 2000). One significant difference of RHS to previous surveys is that, although it is not a geomorphological survey (Newson *et al*. 1998), it was developed with input from geomorphologists, meaning that the physical river is examined and quantified using a better directed eye than previously. A second important development is that, in addition to the collection of qualitative information for each site, bank and in-channel features are 'sampled' for 10 transects, spaced at 50 m intervals. This converts essentially qualitative data into weakly quantitative variables (Jeffers 1998a) and is an important development because it allows quantitative testing, analysis and unbiased comparison between rivers. When this is scaled up to a database of thousands of sites, its potential for question answering is huge.

There is scope for integration with wider ecological studies, for instance, to provide habitat information upon which biological information can be collected. Buckton & Ormerod (1997) published the first study to link RHS data directly with biota. RHS data were significantly correlated with the distributions of 5 bird species, common of Welsh upland streams. RHS-derived habitat variables showed potential as predictors of species presence/absence. A wider study of the biodiversity in acid-sensitive rivers in Wales (Brewin *et al.* 1998) considered two of these bird species (the dipper, *Cinclus cinclus* and the common sandpiper *Actitis hypoleucos*), benthic macroinvertebrate species data and RHS data. Of the invertebrate species, half were significantly but weakly correlated with RHS data and macroinvertebrate abundance categories assigned to sites using habitat variables were 50% successful. RHS has also been taken to the Himalayas where Manel *et al.* (1999) examined habitat preference and impact of anthropogenic landscape changes on 15 river birds species.

Naura and Robinson (1998) linked RHS data to the occurrence in Britain of the endangered species, the white-clawed crayfish (*Austropotamobius pallipes*). This study provides a concise demonstration of the utility of RHS while underlining the fundamental importance of high-quality biological data. Although successful in developing a predictive model, some of the discovered 'habitat requirements' of crayfish were known to be artifacts resulting from non-random site selection.

RHS has also been put forward as a provider of data suitable for the development of an objective system to class rivers by type. A river typology system is useful as a basis upon which to design biological or ecological projects and as an aid to data interpretation. Many column centimetres, both scientific and legislative, are currently given over to talk of defining reference conditions for different types of rivers and the subsequent comparison of degraded sites with these reference conditions, in a type-specific manner. This definition of river types, however, can be looked at as an interesting challenge or a large problem beset with huge difficulties. The working typologies currently employed, in South Europe at least, are acknowledged to be inadequate (Buffagni *et al.* 2001).

Newson *et al.* (1998) attempted to develop a geomorphological typology from RHS data plus additional variables to describe the dynamic element of the rivers. Although finding an 'intuitively sensible' classification they failed to develop a working predictive dynamic typology, citing as possible reasons a lack of breadth of river type and the lack of information suitable to summarise the current state of activity of the channel.

Initial attempts to impose any kind of general (rather than geomorphological) categorical typological system on the RHS dataset were met with, at best, only partial success (Naura, pers. comm.). The solution found was to use a method able to describe the continuum of river types found in Britain rather than to use a categorical method to force sites into immutable categories. Jeffers (1998b), using an ordination (PCA) of the map-derived variables altitude, slope, distance to source and height of source, found that these 4 variables alone provided the most useful description of the variation encompassed by 4569 RHS sites in England and Wales. Habitat differences between rivers of different 'types' could then be predicted from the position of the sites on the ordination diagram.

RHS has a growing relevance in the context of increasing international integration within Europe. The Water Framework Directive (EU 2000) requires the countries of the EU to carry out stream assessment activities sufficiently detailed to meet a number of requirements. New demands are also being made at the national level. In Italy, for example, recent legislation (D.L. 152/99 and succedants) concerning - among other things - the hydromorphological assessment of rivers, will require, when suitable methods are available for Italy, the collection of data to enable a better understanding of biological and chemical data. At present a survey method which satisfies all of these demands does not exist for Italy and for South Europe in general. The index of "Fluvial functioning" (I.F.F., Siligardi *et al.* 2000) is currently being applied to provide the best possible data in a short time, although the method falls short on many counts of what is required by the WFD. Four European countries have, at the present time, relatively well-developed national programs of hydromorphological river assessment, suitable for application under the WFD. These are the Austrian nation-wide method, the French 'PSEQ', the German 'Leitbild' and RHS from the United Kingdom (CEN/TC230/WG2/TG5: N18). These 4 methods are currently undergoing a Europe-wide inter-calibration exercise, which will, among other things, set up common reference definitions for river channel and bank assessments, define boundaries between quality classes and produce a CEN standard to fulfil the WFD demands.

RHS was the method chosen for application and adaptation to the Italian and South European situation primarily because of its wide range of possible outcomes and for the objective approach in describing the riverine environment. In addition, the ease of getting resource materials and of accessing to training made this method comparatively more attractive than those from other European Countries. Other attractions of RHS included the transect data in the survey methodology, the recording of 'flow-types' based on their definitions by Padmore (1997a; 1997b; 1998), Padmore *et al.* (1998) and the speed and ease of application.

It is our opinion, however, that RHS in its current incarnation may lack resolution, meaning that can fail to

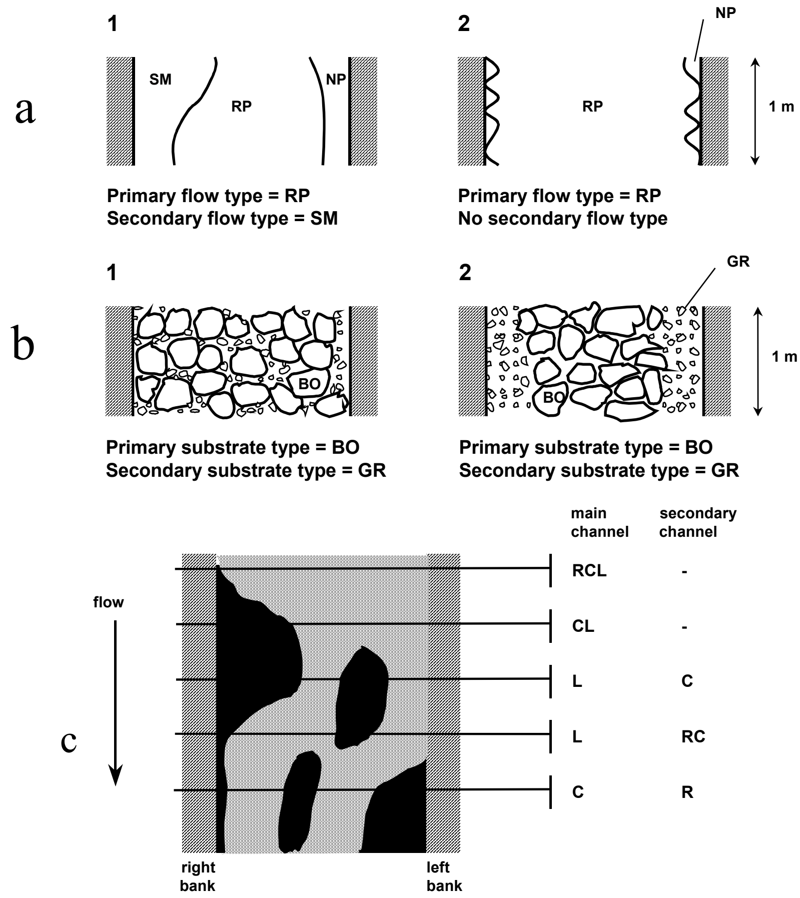

Fig. 1. Illustrated examples for the additional river features proposed are set out above **a**) Primary and secondary flow types for two transects (1 and 2). **b**) Primary and secondary substrate types for two transects (1 and 2). **c**) Examples of wetted channels position in the river (see Table 2 for definitions).

pick up subtle yet meaningful changes between sites. This may be a negligible effect when working with hundreds or thousands of sites, but given that ecological studies where taxa are sampled and identified are often limited to a few tens of sites or less, this lack of resolution is a potential problem. Raven *et al*. (2000) observe that the use of RHS data to predict species distributions is limited by the level of detail recorded by the survey as well as by assumptions made on species habitat requirements.

Of particular relevance to Southern Europe (our area of concern) is the fact that RHS assesses only the habitat provided by one (main) channel. In the U.K. this is perhaps a limited problem, Raven *et al*. (1998a; 2000) report that braided channels (currently recorded as 'present' or 'extensive' braided/side channels, section O) are uncommon in lowland rivers (less than 5% of sites), although they are present in more than 5% of upland sites. According to Raven *et al*. (2000) RHS in its current form is unsuitable for large (>100 m wide) or multi-thread rivers and recommend that the underlying survey design should be retained, but adapted to local conditions. The danger of this, however, is that if there are many RHS offshoots being applied in many different places, data comparability is lost and the international comparison of RHS data is potentially very interesting.

In our study areas (the hilly "Appennini" areas in Italy), multiple channels are common (North = 9 out of 11 sites, South = 4 out of 11, autumn 2000) and they appear to make an important contribution to habitat. The recording of the number of channels as well as the position and features of secondary channels perhaps go some way to making the survey better descriptive of dynamic sites, a lack identified by Newson *et al*. (1998).

Here we present the modified RHS form used in Italy and the results obtained. No datapoint was removed or changed from the RHS method used in Britain. This therefore preserves the ability to compare results directly. The 'changes' consisted of the collection of additional datapoints. These new datapoints included, for every transect: the position of the wetted channel within the entire channel; the estimated water width; estimated channel width; a secondary substrate type; a secondary flow type; a secondary bank material (Fig. 1 and Tab. 1). In the bank modifications section the option to record 'naturalistic' bank reinforcement (i.e. 'soft' engineering, such as the dense planting of willows) was added, as RI(N).

Tab. 1. Definition of river features discussed in the text.

River feature	Definition
River bank	Permanent side to river (definition from 1997 RHS manual).
River bed	The entire area between the base of the right bank and the left bank. Includes wetted area and dry bed (such as mid/side/point bars).
Base of bank	The break in slope between the river bed and the river bank.
Total channel width	Measured from the base of one bank to the base of the other, i.e. the width of the river bed. If greater than □30 m it should be measured with a rangefiner (or by pacing), if less, it should be estimated, using a ranging pole as a guide.
Number of wetted channels	The total number of distinct, wetted channels in the cross-section at the time of survey. Note: transect data are only collected for two of them (Main and Secondary, see below), regardless of the total number.
Main channel	The channel estimated to have the highest discharge (not necessarily the widest).
Secondary channel	Channel showing the largest differences from the main channel in terms of width/depth ratio, current velocity, substrate, etc. (Possibly, do not assess channels inundated newly or frequently subjected to drought events, e.g. daily or weekly).
Water width primary/ secondary channels	Wetted channel width of main or secondary channel. To be measured/estimated for each transect (see total channel width).
Channel position	The total channel width is considered as three sections left (L), centre (C) and right (R). The positions of the main and secondary channels are then recorded (relative to their position within the entire channel, not their position relative to the other wetted channels).
Primary flow type	The flow type occupying the greatest percentage of the cross section.
Secondary flow type	The second-most dominant flow-type of the cross section. This should be recorded even when relatively inferior to the primary flow type (small areas can be relevant for macroinvertebrates, fish or other biota). As a rough guide flow types occupying < 10% of the transect should be ignored.
Primary substrate type	The substrate type occupying the greatest percentage of the cross section.
Secondary substrate type	The second-most dominant substrate-type of the cross section. As with flow type, as a rough guide substrate types occupying < 10% of the transect should be ignored. Substrate types may be recorded as secondary either if they form discrete patches of differently sized material or if they are mixed with the primary substrate type.
Primary/secondary bank material types	To be determined using the principles described for substrate type, above, but applied to the banks.

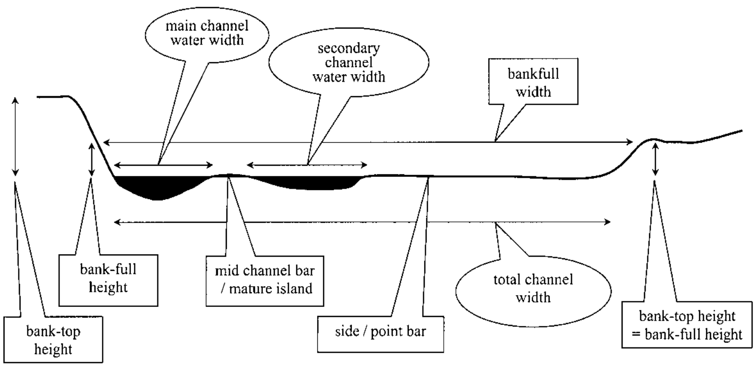

Fig. 2. A cross-sectional diagram is shown above. Labels with oval borders are the new measures to be made for every transect (page 2 of the RHS form) while those with square borders are measurements already collected, once per site (section L Channel Dimensions) for traditional RHS (1997).

If more than one channel was present, data were also collected, for every transect, for one secondary channel. These were channel position; water width; dominant and secondary channel substrates; dominant and secondary flow types; channel modification; channel features and channel vegetation types (see Figs 2, 3, Tab. 1 and methods). In table 1, the definition of the main river features discussed in the text is provided.

In addition, all features recorded on the left side of section K of the original RHS form were counted (n° of waterfalls, ponded reaches, etc.). An altered section K is required. As the original RHS form counts only riffles, pools and point bars (on page one), if was felt that for Southern Europe, where riffles and pools are often not the dominant features, it was useful to extend this section, to encompass the high variety of flow types and frequently alternating hydraulic features that are in many cases present. We also recorded some additional details (when necessary) for section M, for instance, indicating whether the weirs found were 'check dams' (or 'briglie', designed to control flow in an erodable channel), which were particularly common on the rivers studied.

South Europe RHS **10 spot-checks**

Spot-Check1 is at: upstream [ ] downstream [ ] of site

primary / secondary

Physical attributes (to be assessed across channel within 1 m wide transect)

Total channel width (including bars; excluding bank face)	1	2	3	4	5	6	7	8	9	10	
Left bank	Ring EC or SC if composed of sandy substrate										
Material (NV, BE, BO, CO, GS, EA, PE, CL, CC, SP, WP, GA, BR, RR, BW)											
Bank modification (NK, NO, RS, RI(N), PC(B), BM, EM)											EM whole stretch
Bank feature (NV, NO, EC, SC, PB, VP, SB, VS)											
Number of wetted channels											
Total Water width (m)											
Main Channel (highest discharge)	GP-Ring either G or P if predominant										
Channel position (Left, Centre, Right):											Enter channel substrate/flow type not occurring in spot checks but present in >1% whole site
Water width (m)											
Channel substrate (NV, BE, BO, CO, GP, SA, SI, CL, PE, AR)											
Flow type (FF, CH, BW, UW, CF, RP, UP, SM, NP, NO)											
Channel modification (NK, NO, CV, RS, RI, DA, FO)											
Channel feature (NV, NO, RO, MB, VB, MI, TR)											
Secondary Channel	GP-Ring either G or P if predominant										
Channel position (Left, Centre, Right):											
Water width (m)											
Channel substrate (NV, BE, BO, CO, GP, SA, SI, CL, PE, AR)											
Flow type (FF, CH, BW, UW, CF, RP, UP, SM, NP, NO)											
Channel modification (NK, NO, CV, RS, RI, DA, FO)											
Channel feature (NV, NO, RO, MB, VB, MI, TR)											
Right bank	Ring EC or SC if composed of sandy substrate										
Material (NV, BE, BO, CO, GS, EA, PE, CL, CC, SP, WP, GA, BR, RR, BW)											
Bank modification (NK, NO, RS, RI(N), PC(B), BM, EM)											EM whole stretch
Bank feature (NV, NO, EC, SC, PB, VP, SB, VS)											
Banktop land use and vegetation structure	(to be assessed over a 10 m wide transect)										
Land use: choose one from BL, CP, OR, MH, SC, TH, RP, IG, TL, WL, OW, SU, RS											
Land use within 5m of left banktop											
Left banktop (B, U, S, C)											
Left bank face (B, U, S, C)											
Right bank face (B, U, S, C)											
Right banktop (B, U, S, C)											
Land use within 5m of right banktop											
Channel vegetation types	to be assessed over a 10 m wide transect: use E (>33% area) or tick if present										
none											
liverworts/mosses/lichens											
emergent broad-leaved herbs											
emergent reeds/sedges/rushes											
floating-leaved (rooted)											
free-floating											
amphibious											
submerged broad-leaved											
submerged linear-leaved											
submerged fine-leaved											
filamentous algae											

Use end "catch-all" column for types not occurring in spot-checks as well as overall assessment over 500 m: use E (≥33% area) or tick if present.

main channel / secondary channel

Fig. 3. Proposed form for recording the spot-checks features, corresponding to page 2/4 of the U.K. RHS form. Concerning the wetted channels position in the river (see Fig. 1), if there is only one wetted channel, filling the entire width between the banks the answer is LCR (Left, Center and Right) for the main channel. If there is one wetted channel, covering the left and centre of the total channel, but dry on the right, the answer is LC. If there are two channels, the main on the left and the secondary in the center then it is main L and secondary C.

Why collect these extra data? The reasoning behind the estimation of total channel width and water width was that these variables, although collected very roughly (i.e. estimated or measured with a rangefinder, when larger than 20m), will be very useful in the definition of river typologies in South European Countries. This is because there are a significant number of rivers (perhaps a definable river type) which, naturally, for most of the year have one or more relatively narrow wetted channels within a wider, dry channel (see Fig. 2). It is hoped that the ratio of wetted channel to entire channel will be helpful to define the reference conditions for this river type, to study the seasonality of the phenomenon and then to enable artificially modified deviants from the natural condition to be identified. The collection of wetted channel position data as well as the number of wetted channels is also related to this desire to describe both the natural and degraded conditions of this river type. The recording of both wetted width and overall channel width is perhaps of great relevance world-wide. Manel *et al*. (1999) working in the Himalayas (likely to be of a different 'typology' than South European rivers) report that, "Wetted-channel widths on average were only 43% of bank widths. This reflected the braided nature of Himalayan river channels in which discharge at the time of sampling occupied only a proportion of the channel typically filled during monsoon floods".

Why record secondary substrate and flow types? This is related to the suspected lack of resolution in the current RHS survey transects, stated above. The current method is to characterise a 1 m wide transect with one substrate type and one flow type. A site is therefore described by 10 such recordings of main flow and substrate types. This is taking a fairly broad-brush approach to habitat assessment. For instance, it is fairly plausible that all 10 transects can have identical dominant substrate and flow types, while varying considerably if looked at in greater detail. Indeed, Jeffers (1998a) described the RHS data as only 'weakly' quantitative, the proposed collection of 20 instead of 10 features will increase the quantitativeness of the data. Furthermore, variation in habitat at the smaller scale is, we assert, likely to be ecologically relevant, particularly when considering macroinvertebrates. For instance, of two transects recorded as having rippled flow and cobbles one may be found to have smooth flow and silt as secondary habitat characteristics, while the other broken waves and boulders. Although this is obviously a hand picked, fairly extreme example, there is evidence to suggest that there are real concerns. Padmore (1997a) found that transect data of the type collected in RHS tends to under-represent marginal deadwaters (no-perceptible flow) and chutes and that slower flow types may be ignored by the data-collector if faster types are present. Indeed, it is recommended that preference be given to faster instead of slower flow types in the RHS methodology: "Where there are two flow types, both occupying about 50% of the wetted channel, the faster flow type should be recorded" (Environment Agency 1997). We propose that the small effort required to record one extra substrate and flow type will allow a more accurate picture of a river site to be gleaned from the transect data. The current study must assess the validity of this assertion.

Why record data for a secondary channel? Because if a secondary channel is present it is undeniably providing habitat and a habitat assessment system should attempt to assess this contribution. It is possible that secondary channels will provide habitat types which are not present in the main channel or that when a side channel is present, the main channel itself may contain an altered set of habitats (for instance, related to lower discharge). Again, these ideas need to be examined.

This is not to say that the proposed extension to the RHS method presented here will make it perfect. Other areas of weakness exist, which require further thought and discussion and we are happy to initiate the debate. In particular, it is necessary to better define the "time scale", either in terms of actual time passed (i.e. weeks, months, years) or in terms of hydrological events (i.e. usual length of inter-spate period, fixed return time spates, most recent bankfull spate, etc.). This is relevant for, above all, identification of bars and definition of banktop: in relatively natural rivers, in many cases, it is possible to recognise bars of different ages present simultaneously along the same river stretch and across the same transect. The question is then: when is a bar old enough to be considered not as a bar but the bank? Time scale seems to be one of the most essential points of studies on river habitats.

One of the main questions that this paper needs to address is "Does the collection of two instead of one flow type and substrate type per transect better represent the conditions of each transect and therefore the whole site?". The current results contain information that can be used to address this question. At the site level, we first ask "Do we find more flow/substrate types per site if both primary and secondary are recorded for each transect?" If the answer to this is yes, then the conclusion is that the new survey did consider the site in greater detail compared to the old. Secondly, we can ask the question "Do some substrate/flow types have a tendency to be secondary while others tend to be primary?" A yes to this question would imply that the presence and therefore contribution to habitat of flow types that are typically secondary is underestimated by traditional RHS.

The aims of this paper are to:

(i) present the modified data collection form;
(ii) present and examine the first data collected using this method;
(iii) explore the future development of RHS, including the utility of the extra variables collected, with

special emphasis on its possible use in South European rivers.

2. STUDY AREAS

Eleven sites were studied in each of two areas, the Northern Appennini (provinces of Parma/Piacenza) and Southern Appennini (province of Salerno) of Italy. River sites were chosen, following the remit of the AQEM project (Buffagni *et al*. 2001; Hering *et al*. 2002), to represent conditions ranging from reference (suffering from no anthropogenic impacts) to heavily impacted, in terms of morphological alteration in the Northern Appennini and in terms of water quality impairment in the Southern Appennini (Buffagni *et al*. 2002). The sites of the Northern Appennini were relatively similar in character. All had 'medium-sized' catchment areas according to the categories of AQEM (193 - 780 km^2, except for one smaller site (82 km^2). In general they were course sediment streams in mountain valleys (slopes ranged from 0.35 - 1.54%). Their floodplains were, in most cases, narrow compared to channel and water width (channel widths 25 - 123 m; estimated floodplain widths [left + right bank floodplain + channel width] ranged from 30 - 500 m). Multiple channels and braiding were common (9/11 sites, September 2000). They were also highly dynamic, between the second and third sampling periods (winter 2000/1) large floods completely re-arranged many sites. At one site a significant portion of wooded bank was lost to the river and at another the main wetted channel was shifted laterally by close to 100 m. Anthropogenic interference to the morphology of the sites ranged from nothing to sites having a number of concrete/stone weirs to sites having 100% bank reinforcement.

Sites in the Southern Appennini were of more variable character than in the north. All had small catchment areas according to the AQEM categories (10 - 93 km^2), except for one site which was 'medium' (278 km^2). The majority of sites were small streams (channel widths 5 – 15 m) in mountain valleys and had, on the whole, small floodplains (10 - 250 m), relatively high slopes (0.63 – 4.44%) and coarse substrate. The anthropogenic modification ranged from natural to straightened to those with large proportions of their bed and banks concrete-reinforced. Two sites (one being the largest) had low slope (0.25 – 0.43 %), larger numbers of macrophytes and were situated in a very large, flat, floodplain area (1000 - 2000 m wide). Both of these were straightened and partly reinforced. In September 2000, 4/11 sites contained multiple channels. Water quality ranged from very good to heavily impacted by sewage.

3. METHODS

The River Habitat Survey data presented here were collected as part of the E.U. AQEM project (www.aqem.de). For every AQEM field site in Italy, a large fieldwork program was carried out, including the habitat-specific sampling of invertebrates (Buffagni *et al*. 2001), during three fieldwork periods (May/June 2000, September/October 2000, February/March 2001). Here, the RHS data are presented, from each of the three sampling periods. For a detailed description of the investigated AQEM sites, see Buffagni *et al*. (2002).

The River Habitat Survey was carried out during the first field period using the standard form (Environment Agency 1997) with slight modification, then during the second field period with versions of the extended form presented here (Fig. 3). A consequence of this is that the complete set of additional variables was not collected for every site and every season. During the third sampling period, in both the Northern and the Southern Appennini, for every RHS transect, all flow types present were recorded. This was to provide data about the total number and identity of flow types per transect and per site, to compare with the information obtained from the recording of only primary flow types, and primary plus secondary flow types.

RHS was carried out only at 2 of the 11 sites in the Northern Appennini in June, at one of these sites (a reference site) two RHS surveys were carried out, one applied upstream of the other. In September RHS was carried out at all of the 11 sites. At one of these sites (an impacted site) two surveys, one upstream and one downstream, were applied. Therefore, on this occasion 'number of sites' was 12 (see table 2). In February, 'number of sites' was again 12 rather than 11, because the survey was applied twice, upstream and downstream, at the reference site surveyed twice in June. For the Southern Appennini, RHS was applied once each at each of the 11 sites, in each of the three sampling periods.

3.1. New page 2 of the RHS form

Figure 3 shows the new RHS page two for South European rivers.

The changes to the original form were, for each transect:

(i) the position of the wetted channel within the entire channel: right, centre or left; more than one may be chosen, i.e. L, LC, CR, LCR etc.;
(ii) estimated water width;
(iii) estimated channel width (not bankfull, but bank-bottom!);
(iv) a secondary substrate type (if present);
(v) a secondary flow type (if present);
(vi) a secondary bank material (if present);
(vii) For each transect, where there was more than one wetted channel, additional 'channel' and 'macrophyte' data were collected for the secondary channel. The 'channel' data were: channel position; water width; channel substrate; flow type; channel modification; channel feature.

Note: in the case of the bank modification, bank feature, channel modification and channel feature ques-

Tab. 2. Number and percentage of flow and substrate types gained by recording more than one feature per transect. Concerning flow types, the average gain per site indicates the gain when recording 2 flow types (first column) and the full list of flow types observed along each transect (second column, only recorded in February/March 2001) (FT: flow types; ST: substrate types).

		Flow types				Substrate types	
		Average gain per site		% of transects with		Average gain per site	% of transects with 2 ST
	Number of sites	2 FT	all FT	2 FT	≥3 FT		
Southern Appennini							
May/June 2000	11	1.0		61		0.2	39
October 2000	11	1.1		70		1.1	85
March 2001	11	2.2	3.5	95	92	1.0	92
Northern Appennini							
June 2000	3	1.3		61		1.0	90
September 2000	12	1.3		80		0.9	78
February 2001	12	1.4	2.9	95	83	1.1	97

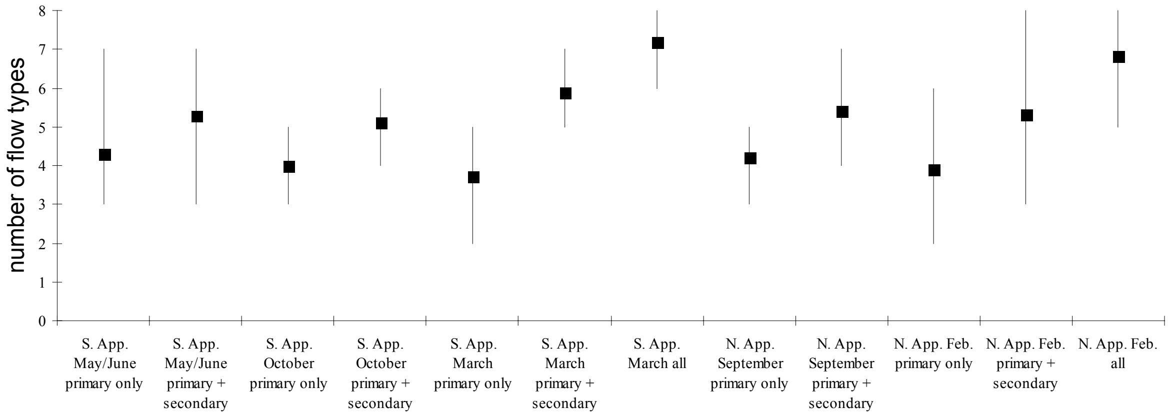

Fig. 4. Number of flow types found with three intensities of sampling effort in Southern and Northern Appennini, for all seasons. Squares: average; line: total range.

tions, more than one answer can be given in traditional RHS, here the only change is that each cell has been divided into two.

At the level of the sweep-up, the section 'Extent of channel features' (section K, page 3) was altered, to count a range of channel features (waterfalls, cascades, rapids, riffles, runs, boils, glides, pools, ponded reaches, unvegetated point bars, vegetated point-bars) instead of recording simply 'none', 'present' or 'extensive' as before. The option 'extensive' (≥33%) was retained, thereby preserving comparability with traditional RHS.

The extended method was found to take approximately 2 hours for simple sites and up to 4 hours for complicated sites (e.g. where total channel width was >100 m with many side channels or where the sites had channels and banks difficult to negotiate).

4. RESULTS

First the results for flow types will be presented, then the results for substrate types.

Table 2 gives an overview of the flow type data. In May/June 2000, for both the N. and S. Appennini, approximately 60% of the transects were judged to have secondary flow types. This value was higher in September/October 2000 at 70-80% and higher again in February/March 2001 at 95%. In February/March (the only sampling period for which the data were collected) 92 % of Southern Appennini sites and 83% of Southern Appennini sites had 3 or more flow types. Figure 4 shows the number of flow types found with three intensities of sampling effort. What can be noted is that with the recording of primary and secondary flow types, compared to only primary, there is a rise in the average number of flow types per site of between 1 and 1.4, except for the S. Appennini in March 2001, which was particularly high with 2.2. As well as a rise in the average, in almost every case, the maxima and minima rose by a similar amount. Therefore, sites both with a low number and high number of flow types gained with increased sampling effort. Only the S. Appennini in the first sampling period (May/June 2000) did not show a rise. It may not be a coincidence that these transects also had one of the lowest percentages of secondary flow types recorded (61%). The recording of secondary flow types did not, however, entirely solve the problem of missed flow types at the site level. With the recording of

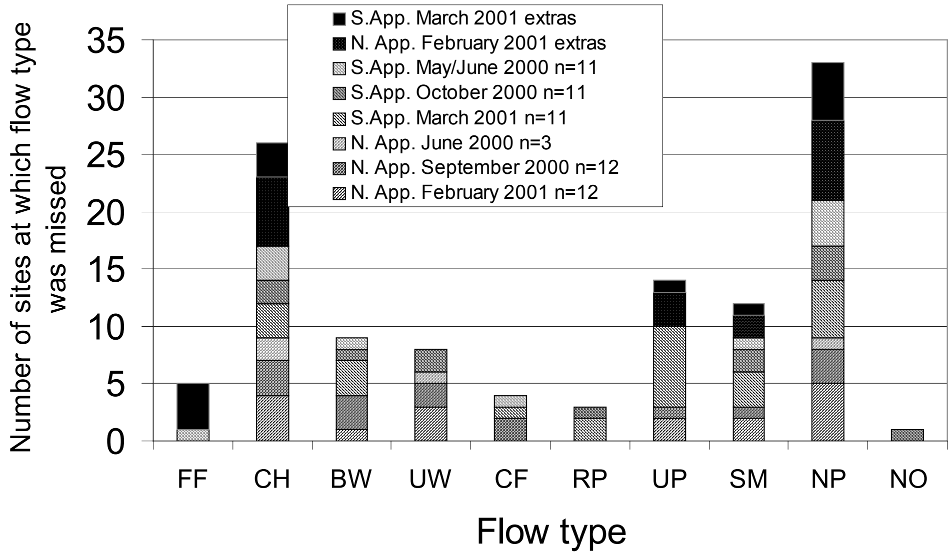

Fig. 5. Total number of sites at which flow types would have been missed by the standard RHS application (one flow type recorded per transect). The flow types, per site, which were present but not dominant (recorded as secondary, or 'extras' - when there were 3 or more) are reported.

all flow types per transect for the last sampling period, an average of 1.3-1.5 additional flow types were found per site, compared to the recording of only primary and secondary. It is also noticeable that with the recording of all flow types the average number of flow types found per site, 7.3 for the Southern Appennini and 6.8 for the Northern Appennini, were both close to the 7, which is the total number of flow types excluding those recorded only rarely ('free-fall', 'chaotic' and 'no' flow).

Figure 5 shows the identity of the flow types, per site, which were present, but not as a dominant flow type, at a site (recorded as secondary, or 'extras' - when there were 3 or more). It shows that at least once for every flow type the situation occurred where the flow type at a site was only recorded as secondary. The flow types to which this happened most frequently were 'no perceptible' and 'chute'. The recording of all flow types in February/March 2001 (see 'extras') showed that these same flow types were also those most likely to be missed at the site level, even after the recording of secondary flow types.

Figure 6 reveals the number of times each flow type was recorded either as primary or secondary per transect. 'Chute' flow, in both areas (N. and S. Appennini) and in all seasons, tended to be a secondary flow type, although it was recorded as a primary flow type for a number of transects. 'No perceptible' flow, like 'chute' identified by figure 5 as a potentially 'missed' habitat at the site level, was found in the Southern Appennini, in all seasons, more often as a secondary, than a primary habitat. This flow type was more frequent in October (recorded 33 times, summing primary and secondary) than in May/June (11) or March (12) and during October, although more commonly found as a secondary flow type, it was recorded relatively frequently as a primary flow type. In the N. Appennini, 'no perceptible' flow was more common in September (31) than in February (12). In September, the division between primary and secondary was close to the null hypothesis while in February, in contrast, it was never recorded as a primary flow type (it is interesting to note that the number of times that 'no perceptible flow' was recorded as a secondary flow type was identical in both months).

The only flow type which tended in all situations to be recorded as primary was 'rippled' flow (although this result was not at all strong in the case of the S. Appennini in October or in March). In every site and season it was the most commonly recorded flow type and the frequencies were similar in all cases.

Otherwise, the results were mixed. 'Unbroken waves' in both areas were more frequent (50-60) in the third sampling period (February and March) than the other two periods (29-39), but in the Northern Appennini in February they tended to occur as secondary flow types while in the Southern Appennini in March they clearly occurred more often as primary. In the second sampling period they did not differ from the null hypothesis in either area and in the first, for the S. Appennini they showed a marginal bias towards being primary. 'Broken standing waves' showed an obvious tendency towards being secondary in the Southern Appennini in May/June, a slight tendency in October and were otherwise (S. Appennini March, N. Appennini September) similar to the null hypothesis or marginally

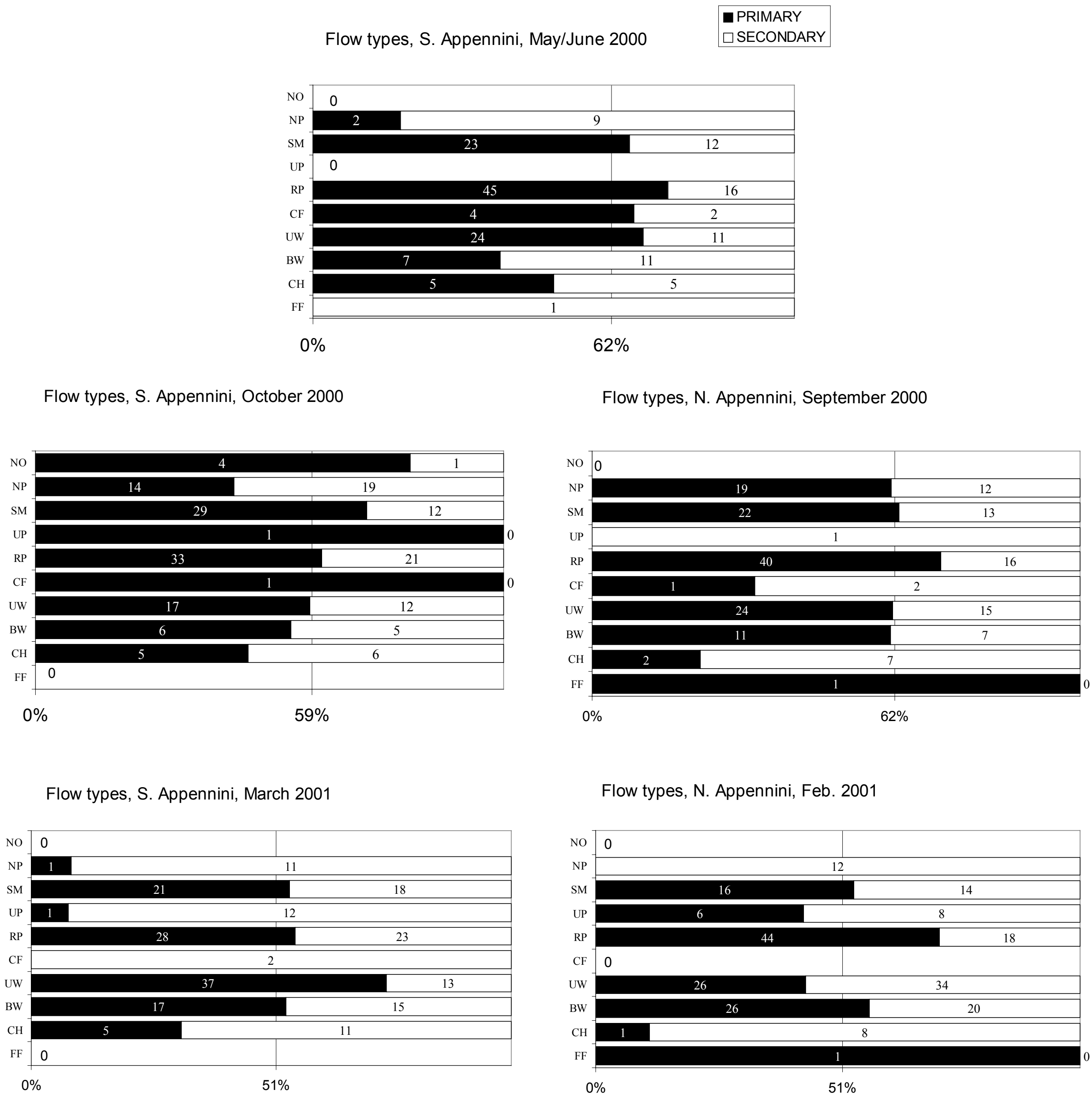

Fig. 6. Number of times flow types were recorded as primary (darker bars) or secondary (lighter bars). Numbers indicate the number of times the flow type was found in each category. Each bar is scaled such that number of primary + number of secondary = 100%. The black, vertical line shows the percentage of the total that should be primary flow type if the null hypothesis is equalled. N_0 = there is no difference between the proportion of times a particular flow type is found as primary as opposed to secondary. This value, in every case, was higher than 50% because secondary flow types were not recorded for every transect, meaning that the total number of primary flow types recorded was higher than the total number of secondary flow types (see Tab. 2). Data from the N. Appennini in June are not presented, as only three sites were surveyed (see Tab. 2).

biased towards being dominant (N. Appennini, February). The frequencies of ‘broken standing waves’ were variable, for example, these were more than double in the third sampling period, compared to the second, for both the Northern and Southern Appennini. The frequencies with which ‘smooth’ flow was found were fairly similar in all cases (31-42) and close to the null hypothesis in all cases except for the Southern Appennini in October, where it showed a dominant tendency.

The data from the third sampling period, which recorded for every transect every flow type observed, was able to provide an assessment of the flow types which would still be missed even after recording two flow types per transect (Fig. 7). Free-fall was found 6 times

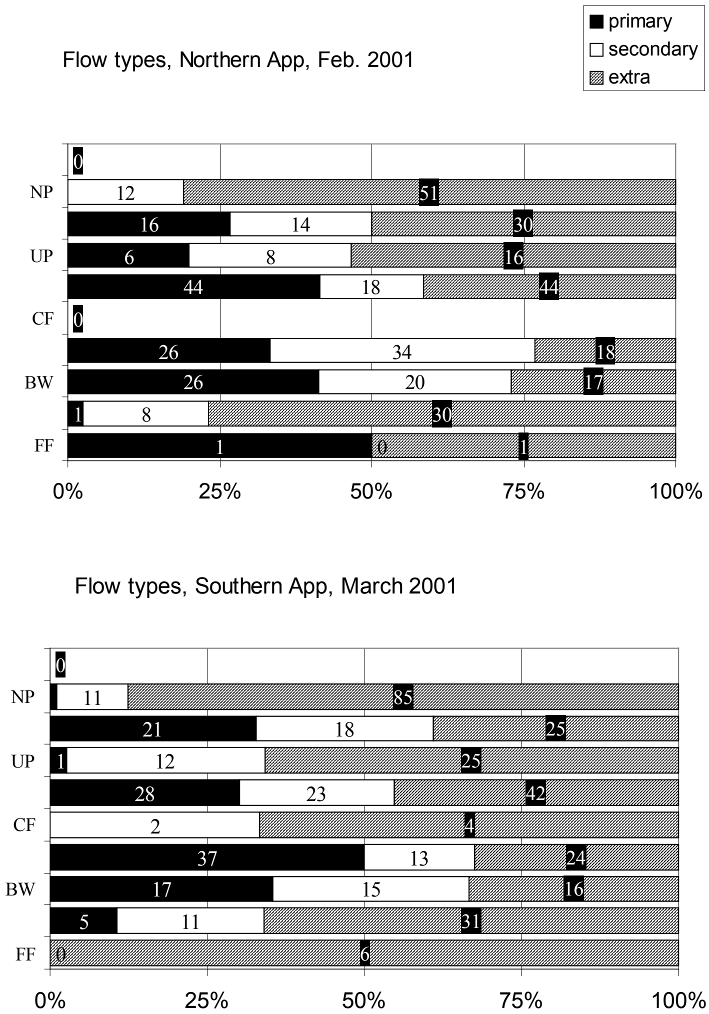

Fig. 7. Number of times flow types were recorded as primary (dark bars), secondary (white bars) or 'extra' (grey bars), for the third sampling period and for both Appennini areas.

as an 'extra' flow type in the Southern Appennini and one time in the Northern Appennini. These were predominantly 'natural' examples of free-fall (i.e. not created by human construction), often small, associated with 1 or a small group of boulders. Overall, it was an exceedingly rare flow type, otherwise recorded only three times during the recording of primary and secondary flow types, taking together every site and season. Two of these recordings were of the same transect in two different seasons, which happened to fall across a dam and the other was associated with a small concrete weir. This result is mirrored by figure 4. At 4 sites in the Southern Appennini in March free-fall would not have been recorded as part of the transect data had it not been for the recording of all flow types.

Otherwise it emerged that the same flow types as those that tended to occur as secondary rather than primary also tended to be 'extra', namely 'no perceptible' and 'chute' flow. Upwelling flow also fitted this pattern, especially for the Southern Appennini, where it was seen only once as a primary flow type, 12 times as a secondary flow type and 25 times as a extra flow type. In contrast, the flow types 'unbroken' and 'broken waves' showed a clear tendency to occur either as primary or secondary flow types, rather than as 'extras'.

Reasons behind the much higher frequencies of upwelling flow in the third sampling period compared to the first two, as well as the subject of chaotic flow will be discussed later.

Moving on to consider the substrate types, table 2 gives the percentage of transects for which secondary substrates were recorded. These were, on the whole, high, between 78-97%, except for the S. Appennini in May/June, for which only 39% had secondary substrate types. The reasons behind this will be addressed in the discussion. Figure 8 shows the number of substrate types found per site considering only primary substrate types and then primary and secondary together. For the

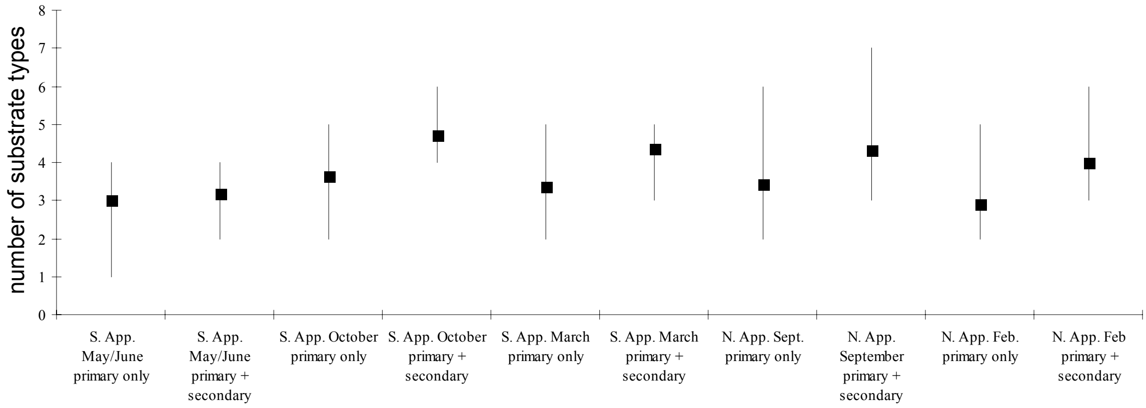

Fig. 8. Number of substrate types found with two intensities of sampling effort in Southern and Northern Appennini, for all seasons.

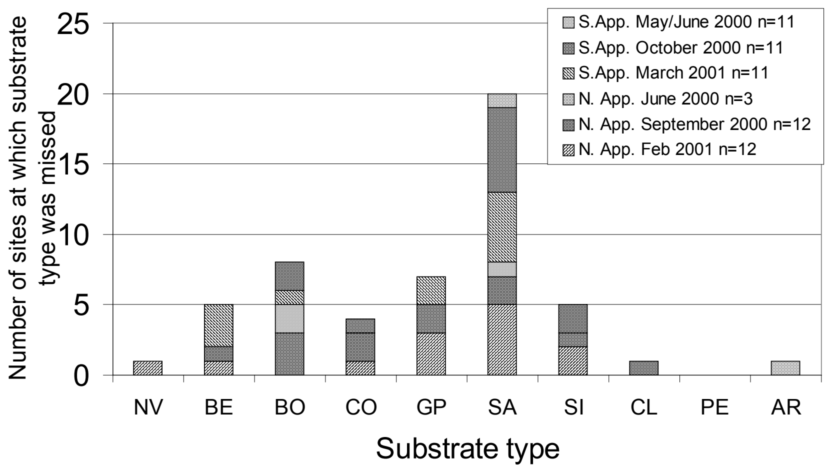

Fig. 9. Total number of sites at which substrate types would have been missed by the standard RHS application (one substrate type recorded per transect). The substrate types, per site, which were present but not dominant are reported.

Southern Appennini in May/June, when only 39% of the transects were found to have secondary substrate types, the change in number of different substrate types found per site was, unsurprisingly, small (0.2) (see table 2). The minimum, a site having only one primary substrate type, increased to 2 with the inclusion of secondary substrate types, although it has to be admitted that this new substrate type was 'artificial' (concrete). Otherwise the average increases were close to 1 per site (0.9-1.1). (see table 2).

Figure 9 shows the substrates that would have been missed by the transect data, per site, had secondary substrate types not been recorded. Similar to the results concerning flow types, every substrate type, on at least one occasion, occurred at a site only as secondary (except for peat, which was not found in the study areas). The substrate type which commonly occurred only as secondary was 'sand' (S. Appennini in October, 6 out of 11 sites, in March, 5 out of 11 sites; N. Appennini in February, 5 out of 12 sites). 'Boulders' were also found only secondarily on a number of occasions.

When the graphs showing the number of times each substrate type was found as primary and secondary are considered (Fig. 10) the only substrate type to show the same tendency in every case is sand, which is consistently more likely to be found as a secondary habitat. 'Gravel/pebble' substrate showed no tendency towards being primary or secondary, being close to the null hypothesis in all cases except for the last sampling period where, in both the Northern and the Southern Appennini, it tended to be secondary. Recalling what was noted above for figure 9, that at the site level, in the N. Appennini in September, boulders were found to occur only as secondary substrate types at three sites, it is interesting to note that figure 10 shows for the N. Appennini in September, that at the transect level boulders are more commonly observed as primary rather than secondary substrates. For the last sampling period for both areas, where boulders occurred they clearly tended to be primary. In this case, the results between the transect level and the site level showed a closer match, as just one site was found to have boulders present only as a secondary substrate.

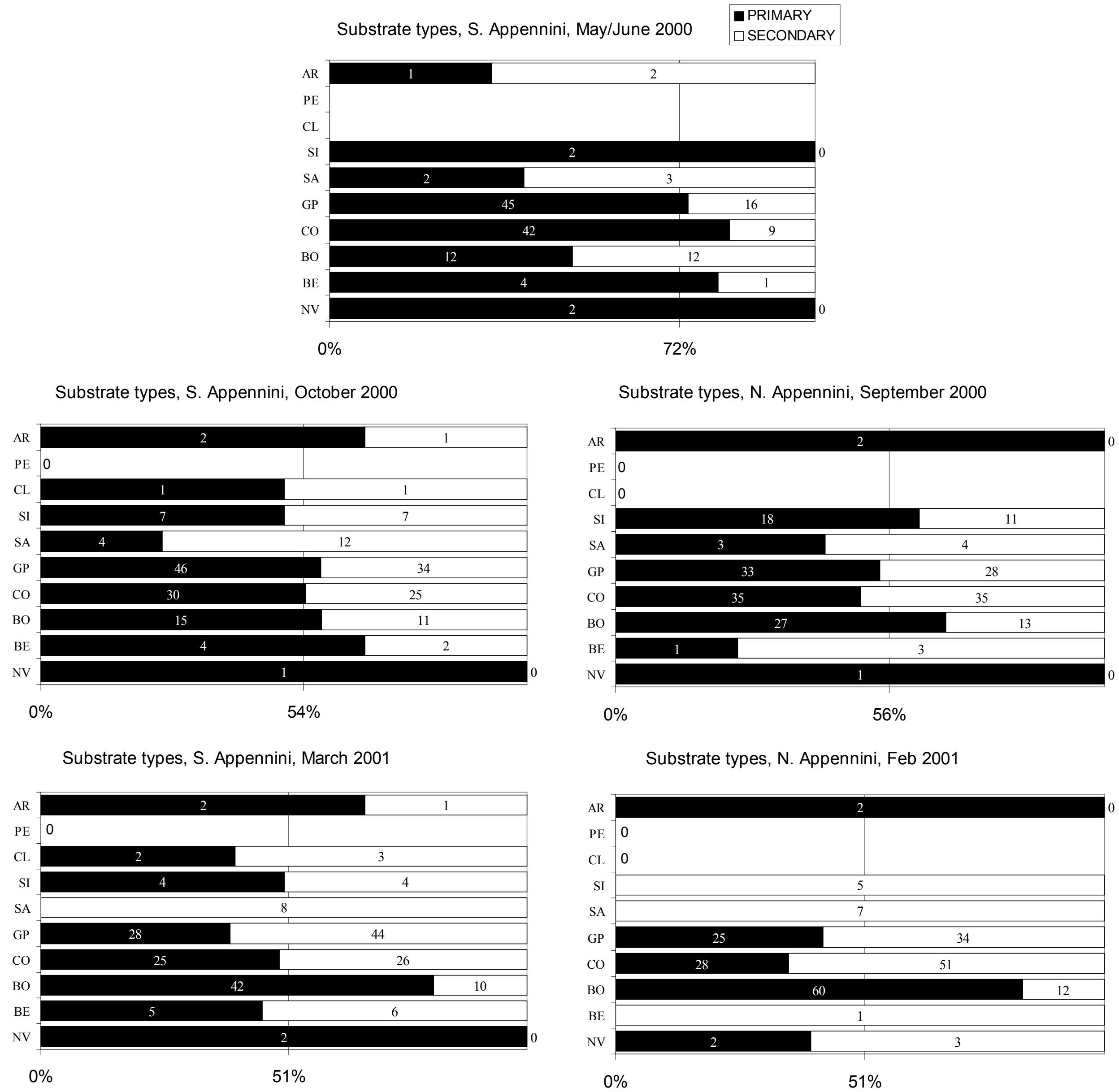

Fig. 10. Number of times substrate types were recorded as primary (darker bars) or secondary (lighter bars). Numbers indicate the number of times the substrate type was found in each category. Each bar is scaled such that number of primary + number of secondary = 100%. The black, vertical line shows the percentage of the total that should be primary substrate type if the null hypothesis is equalled. N_0 = there is no difference between the proportion of times a particular flow type is found as primary as opposed to secondary (see legend of Fig. 6 for full explanation). Data from the N. Appennini in June are not presented, as only three sites were surveyed (see Tab. 2).

5. DISCUSSION AND CONCLUSION

This paper set out to present an extended, more internationally applicable version of the RHS forms as well as to give a first taste of the data collected using these forms. The main question to be addressed was whether the extended form is useful. One of the drawbacks of traditional RHS is that it generates datapoints for every site, making data input a big job and data analysis unwieldy (although the purpose built user-interface program to a large extent copes with this problem, but only for the central database and depending on the type of question asked). In the current study, a number of additional datapoints were collected and we must ask whether they bring enough new and interesting information to justify the time and effort expended for their collection.

The collecting of secondary flow types has confirmed their existence. The vast majority of transects had identifiable secondary flow types. It is easy to argue that, if more than one flow type is present, to record two is to describe the transect more accurately. Is this greater level of accuracy useful? The aim of RHS is not to describe in detail a short section of river (for example, one riffle/pool unit, which is the scale at which many macroinvertebrate surveys, including AQEM, are carried out) but instead to give a broad picture of the physical habitat present over a 500 m stretch.

Is the more detailed information at the level of the transect useful at the level of the site? The results from this study show that, on average, one more flow type was found per site, with the recording of secondary flow types. This has implications for the indices derived from RHS, for instance, the higher the number of flow types found at a site, the higher the habitat quality is considered to be according to the Habitat Quality Score (Raven *et al*. 1998b). One 'extra' flow type per site may not seem a huge gain, but considering that the total possible number of flow types is 8 (excluding 'none', which is a dry channel, and 'chaotic', which is strictly speaking not a flow type but a mix of flow types) and that in no one site were all 8 flow types found simultaneously in May/June or September/October the identification of one more flow type per site is a significant event. A site with three flow types may be found to have four, thereby increasing its flow types by 1/3.

The results also supported the collecting of two flow types per transect because certain flow types were found to have a tendency to occur as secondary, meaning that with traditional RHS their presence would be under-estimated. One habitat, 'chute' was found consistently, across area and season, to tend to be secondary (although it was identified as a primary habitat on a number of occasions). This fits with the finding of Padmore (1997a, also reported in Newson *et al*. 1998) who found that chute flow often occurred as secondary to other flow types in a transect. This is not surprising as this flow type is often associated with a single substrate feature, such as one boulder, and a particular set of local depth and slope conditions. For it to be dominant over the channel many such boulders, or a bedrock formation, creating the correct hydraulic conditions must be present. While it may often be a flow type of small size, its ecological impact is undisputed, providing habitat e.g. to the Diptera Blephariceridae, the filtering Simuliidae etc. Padmore 1997a also mention that the RHS transect data is likely to under-represent marginal deadwaters and that the less energetic flow types (e.g. 'smooth') may be missed when surrounded by the more energetic (e.g. rippled). The result of this study, for the S. Appennini agree that 'no perceptible flow' tends to be missed, both at the transect and the site level. For the Northern Appennini, although there was no evidence that at the transect level it was more often secondary than primary, it would have been missed at three sites in October, if secondary flow types had not been recorded. This apparent contradiction simply means that for all the sites taken together there was no overall trend but that at a few sites it was only found as secondary. This could result from chance or perhaps further data analysis may reveal that the sites at which it was missed share a character not common to all the N. Appennini sites.

The other flow-type mentioned by Padmore (1997a) as being potentially under-represented was 'smooth flow'. The frequencies with which it was found here as primary and secondary, however, show no evidence that this flow type tended to be secondary and therefore under-represented, although at the level of the site, on 4 occasions (summing every sampling area and season) it was missed.

If certain flow types tend to be under-represented by single flow type recording, others must be over-represented. The most likely candidate to emerge from these results is rippled flow. This was missed only at one site and showed a tendency to be primary in the S. Appennini in May/June and in the N. Appennini in September, but not in the S Appennini in October. Rippled flow is the most common flow type in every case (season and area) and although it tends to be a primary flow type, it is also the most common secondary flow type, because of its ubiquitous nature.

Overall the results support the collection of at least secondary flow types, as they suggest that ecologically significant information is gained. Furthermore, we do not believe the 'cost' of this extra work to be very high, as surveyors may actually find it easier and faster to record two flow types per transect because, given that there is often more than one flow type present in a channel, fewer tricky decisions need to be made about which to ignore.

It could be argued that the recording of secondary features and finding on average one more substrate/flow type per site achieves no more than the sweep-up section of RHS is designed to do. We would counter this for 3 reasons. The first reason is that, in any case, sweep-up data is not collected for flow-type, while for substrate types, they should be present >1% of the 500 m long site before they are recorded in the sweep-up. This is quite difficult to estimate. We would guess, but have not been able to ascertain, that on average, the number of extra substrate types gained per site from the sweep-up data is significantly less than 1 (particularly as the inclusion of a single box for the sweep-up column encourages the recording of no more than one extra per site). Secondly, the data collected with the recording of secondary features is quantitative; the frequencies of primary and secondary flow types are available. Quantitative data is more open to statistical analysis and a total of 20 (instead of 10) flow or substrate datapoints per site means that the data have greater resolution, enabling more subtle differences to be detected between sites. Secondly, we expect secondary feature data to be more reliable than sweep up data, the transect data are collected during a detailed examination of a small area (a 1 m wide transect) while the sweep-up data are collected during a general appraisal of the entire site.

The same type arguments put forward to support the collection of secondary flow types can also be made for substrate types. Similar numbers of 'extra' habitat types were gained per site and each substrate type (except for peat) was 'missed' on at least one occasion. Sand was the habitat missed most often at the site level, as well as the one with the greatest tendency to occur as a secondary habitat at the transect level. It is unsurprising that in these course sediment rivers sand was seldom a dominant substrate type in the cross-section, as it is the most mobile substrate size and is therefore likely to occur in smaller areas of surface deposit rather than to be the major component of the river bed structure. The other habitat frequently 'missed' at the site level was boulders, which apparently contradicted the transect-level finding that, at least for the Northern Appennini, September as well as less strongly for the S. Appennini in October, it was most likely to occur as a primary habitat. This implies that there were two distinct types of site, those where it tended to occur as primary and those where it tended to occur as secondary. One surprising feature of the data is that in May/June only 39% of the transects had secondary substrate types in the S. Appennini, compared to 85% (October) and 92% (March).

Whether this reflects a true increase in substrate types per transect between the first and subsequent sampling periods is unknown. It is also possible that, as the first sampling period in the south was the first for which this method was tested, the surveyors became more likely to 'see' and record secondary substrate types with time (although this did not appear to be the case within the first sampling period in the south, for which there was no significantly increasing trend with time in the number of secondary substrate types recorded).

These first results from the extended RHS method suggest that it does collect useful information, over and above that collected by normal RHS. Furthermore, these preliminary results are only the first indication of what can be achieved. For a clearer understanding of the underlying relationships, further work is needed, as the current, simple method which groups results by area and season hides a good deal of inter-site variability, in terms of river type (e.g. size, slope) and degree of anthropogenic physical modification. It is hoped that the current project can be used to link different scales of river study. The AQEM project in Italy is perhaps the first time that RHS has been performed alongside smaller scale work, such as macroinvertebrate sampling and recording of smaller scale habitat information, such as type, depth and local flow type.

A number of hypotheses and expectations have been formulated that will be investigated in the future using this data.

These are:

(i) The number of secondary channels will be positively related to habitat quality (as calculated from the RHS data for the site by the Habitat Quality Score 'HQS', Raven *et al*. 1998b) and negatively related to anthropogenic physical habitat alteration (quantified using the Habitat Modification Score 'HMS', Raven *et al*. 1998b) but this relationship will be confounded by river size effects and will not be relevant for every river type.

(ii) The ratio between estimated channel width and estimated wetted width (main + secondary channels) is expected to differ greatly between sites and is expected to be a useful descriptor of river type in South Europe. This ratio, once its natural range is established for a river type, may be developed as an indicator of low flows due to excessive abstraction.

(iii) The total number of substrate types found per site will be greater with the recording of secondary substrate types for each transect.

(iv) The total number of flow types found per site will be greater with the recording of secondary flow types for each transect.

(v) The presence of a secondary channel is expected to bring a greater range of physical habitats, especially through the creation of areas of slower water and finer substrate, either in the secondary channel itself, or in the main channel. Associated with this is the hypothesis that, where there is more than one channel, the number and type of aquatic instream macrophytes, will be on average higher (river type dependent).

(vi) Typical pairs of flow types and substrate types will be found which occur more frequently than can be explained by chance. The occurrence of these pairings will be related to river type.

The developing of relationships between RHS data and biological data has only recently started and at the moment the results of studies point to the 'potential for development' rather than definitive answers. In the next few years we expect such studies to flourish and answers to be produced. For example, there are plans, within the UK, to link RHS data with invertebrate data from RIVPACS to better understand the cases where the invertebrate fauna is impoverished due to physical habitat modification (Wright *et al*. 1998). With the AQEM project and the recently started STAR project, RHS will now be used to link biology and physical habitat internationally, hence the need for RHS addenda for South European rivers.

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