

State-of-the-art in habitat modelling

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1 Introduction

This report describes the state-of-the-art in habitat modelling of the COST626 community in Europe. The report is based on a joint effort to describe the background theories of habitat modelling and the different modelling techniques. Furthermore, two inventories have been made of the models that are in use by the COST626 members and of the current research needs in habitat modelling.

2 Physical basis of habitat models

2.1 Introduction

This overview focuses on those stream models addressed to characterize the stream habitat. The expected output of this type of models can vary from being purely descriptive of the stream physical template to having some biological assessment applications. Physical descriptive models are developed to evaluate the degree of alteration of a given stream channel in relation to some reference conditions. Biologically based models are developed to infer the standing stock of a given species from the physical characteristics of a given stream. Nevertheless, in between these two extremes there is a range of habitat models addressed to obtain other outputs as shown in Figure 2-1.

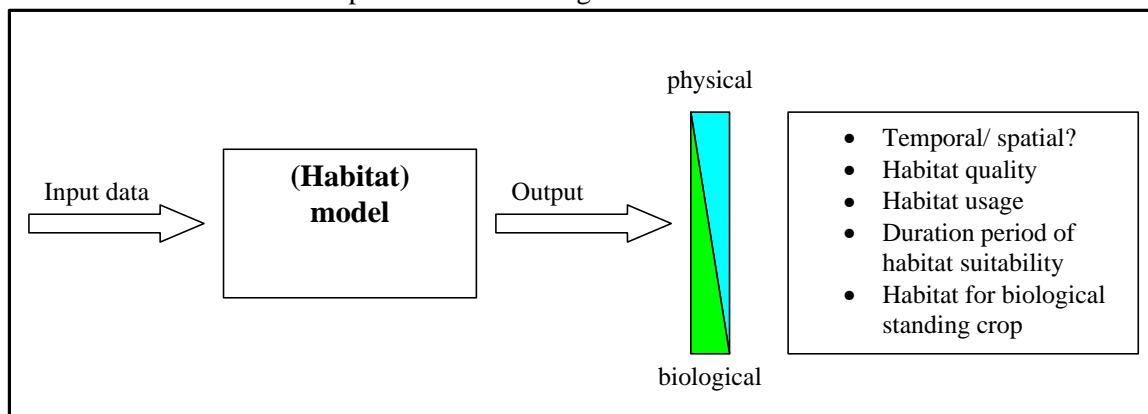


Fig. 0-1: Conceptual framework of physical habitat models

Based on this conceptual framework, habitat models (especially those having biological implications) are mostly based on hydrological, morphological and hydraulic parameters as the major factors influencing distribution and abundance of organisms in the streams (see Figure 2-2).

2.2 Key physical and hydrological parameters considered in habitat models

Habitat models can be developed at different spatial scales for different predictive purposes. Parameters used to describe hydrologic, morphologic and hydraulic aspects of the streams vary according to the selected scale used for the model. This fact is especially relevant to be considered in the development of the model to simplify the array of parameters and select those which are more suitable for the scale at which the model will operate. Table 2-1 summarizes some of the key parameters that should be/are considered at different scales to model the physical and hydrological stream template.

Scale effects strongly depend on the life-cycle and the home range of the target species and may change according to the target species considered.

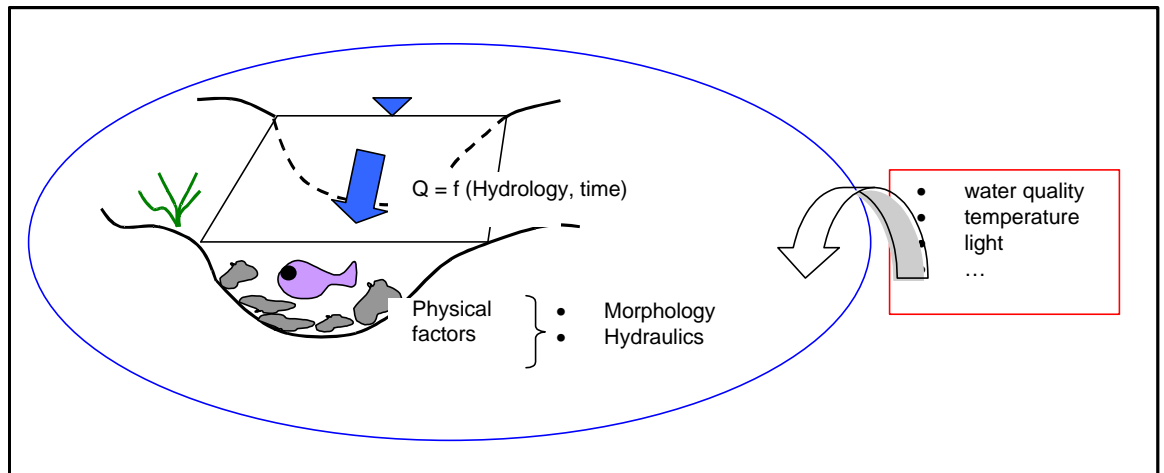


Fig.2-2: Main factors affecting distribution and abundance of organisms in running waters

Table 0-1: Key morphological and hydrological parameters considered in habitat models at different scales

Scope and scale		Parameters		
		Morphologic	Hydraulic	Hydrologic
“Pico”-habitat ~ cm	“Nose position” of fish	<ul style="list-style-type: none"> ▪ Substrate size, type, shape ▪ Substrate “quality” for biological purposes ▪ Motion/no motion ▪ k/d (roughness / depth) 	<ul style="list-style-type: none"> ▪ Shear stresses ▪ Laminar/turbulent near-bed boundary layer ▪ Local flow velocity (nose) 	<ul style="list-style-type: none"> ▪ Baseflow Q ▪ Maximum peak flow and duration ▪ Drought events
Micro-habitat ~ m	Section	<ul style="list-style-type: none"> ▪ Substrate size/type distribution ▪ Substrate stability ▪ Local elevation along cross-section (geometry) ▪ Roughness ▪ Sediment porosity ▪ Bathymetry ▪ Roughness r (height of protruding rock) ▪ Embeddedness ▪ Porosity ▪ armour layer ▪ particle shape ▪ Wentworth scale (1..15), dominant/subdominant ▪ Macrophytes ▪ Overhanging branches ▪ Cover (Rocks) ▪ Percentage of fines 	<ul style="list-style-type: none"> ▪ Wetted perimeter (water width and depths) ▪ Local velocities ▪ Vertical hydraulic gradient ▪ Water transient storage zone ▪ Surface-subsurface lateral linkages ▪ Cover (pools) ▪ “Broken” water ▪ Turbulences ▪ Splashwater 	<ul style="list-style-type: none"> ▪ Temporal variation of discharge: daily, seasonal, interannual ▪ Flood and drought regime: frequency, magnitude, evenness
Meso-habitat ~100 m	Reach	<ul style="list-style-type: none"> ▪ Topology ▪ Run/riffle/pool distribution ▪ Cross-section profiles ▪ Valley floor: constrained vs 	<ul style="list-style-type: none"> ▪ Mean cross-sectional velocity, water depths ▪ Spatial variance of velocity, shear stress, depth 	<ul style="list-style-type: none"> ▪ Mean annual flow ▪ Average duration of the floods and droughts ▪ Spatial variation of discharge

		<ul style="list-style-type: none"> ▪ unconstrained ▪ Channel stability ▪ Bank stability ▪ Plan shape: meander vs braided ▪ Description of morph. Patterns by shape and property ▪ Sinuosity ▪ Width/depth ratio ▪ Width/max. depth ratio ▪ Periphyton 		
Macro-habitat ~1000 m	Catchment	<ul style="list-style-type: none"> ▪ Drainage area: stream length ratio ▪ Frequency distribution of different stream orders ▪ Branching degree and distribution ▪ Longitudinal gradient ▪ Presence of barriers ▪ Land-use activity ▪ Number of pools/100m 	<ul style="list-style-type: none"> ▪ Mean water residence time ▪ Channel vs uphill position of water table (gaining or losing stream) 	<ul style="list-style-type: none"> ▪ Longitudinal variation of cumulative water yield ▪ Seasonal variability in runoff ▪ Surface or subsurface runoff ▪ Flow continuity
Ecoregion/Landscape		▪	▪	▪
Temporal Scale		<ul style="list-style-type: none"> ▪ Disturbance frequency <ul style="list-style-type: none"> ▪ Disturbance duration (draughts, suspended sediments e.g.) <ul style="list-style-type: none"> ▪ Dry periods versus draught events (disaster events) <ul style="list-style-type: none"> ▪ Wet periods versus flood events 		
Networking aspects		<ul style="list-style-type: none"> ▪ Characteristic patch diversity <ul style="list-style-type: none"> ▪ Residual pool depths ▪ Availability and location of refugia (from different threads) 		

Other factors that could be considered in the model and that are not so scale-dependent are:

- Temperature
- Light availability
- Water quality (oxygen, pH, conductivity, toxic substances, nutrient content, etc.)
- Amount and type of suspended particles
- Food resources availability

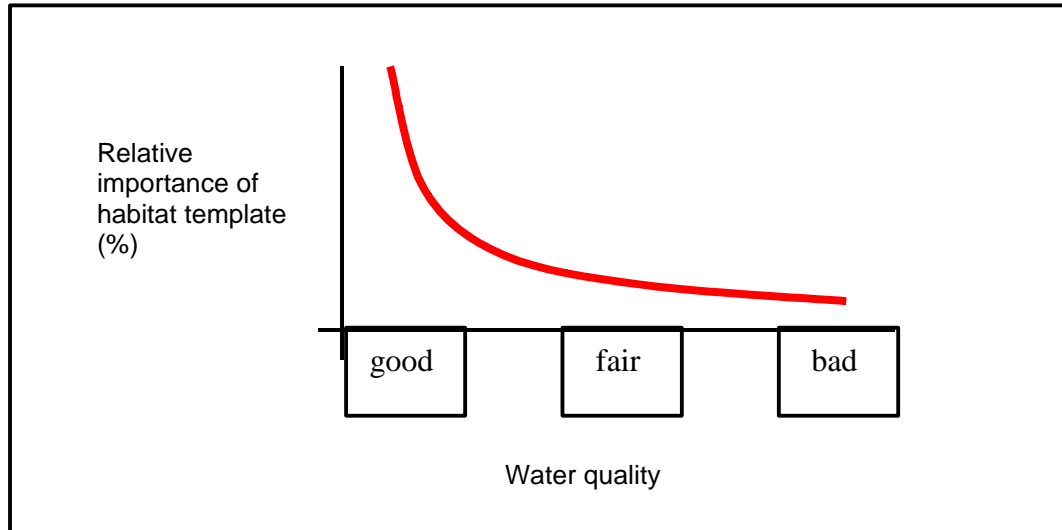


Fig. 2-3: Relative importance of the habitat template to limiting factors in relation to water quality

These factors may override the importance of the stream physical template under certain conditions; and thus, they can be considered as “limiting factors” for the habitat models when used to predict habitat suitability for biological standing stocks. For instance, the relative importance of the habitat template for predicting fish abundance can vary as a function of the water quality (see Figure 2-3).

2.3 Ecological Significance of key attributes

To understand why certain attributes or parameters are looked at within habitat models it is in some cases important to understand their secondary effects, that is how they act. For some attributes it is simply known from empirical experience that they influence habitat quality but it is not well understood why and in which manner.

An example for this is the hydrologic regime, which consists of the mean annual flow with temporal dynamics on top of that, the seasonality and the random characteristics of the discharge. It is common belief that it is important but no quantitative data can be found to specify this more clearly. One of the ways discharge dynamics influence habitats is that they determine when sediment transport occurs and which portion of the river bed is affected from sediment motion over a certain period. The regime determines how often and how long particles of a certain size move and how often and when incipient motion state is exceeded. For some bottom dwelling species this could also be expressed as disturbance frequency.

3 Interfaces with Ecology

Habitat models usually consist of a physical part that analyses hydraulic and/or morphologic attributes. Often these are considered as or linked with time series (e.g. of the discharge). The result of this part is the description of the physical environment that is available. Quality parameters or other information may be added.

In a second step these attributes are linked with or compared with what is called here “interfaces with ecology” which describe how these physical attributes correspond with the preference or the abundance (relative or absolute) of a certain specie. The result of this part is “habitat quality” which can be expressed in different terms. The traditional description (PHABSIM approach) for habitat quality is Weighted Usable Area (WUA) or Suitability Index (SI). Often different life stages (Spawning, larvae, juveniles and adult) and different seasons (summer/winter) are treated separately. Additionally, certain “activities” can be a criterion, such as feeding, resting, seeking shelter (“refuge”), rearing (salmonid fry still carrying their yolksacs that hide in the gravel), etc.

Table 0-2: Source of biological data used in habitat modelling

Correlation or process described	Numerical interface	Derivation from	Outputs from model
<ul style="list-style-type: none"> ▪ ‘Association’ functions; resource functions (This is data that records an organisms occurrence or ‘association’ with a resource or physical variable) 	<ul style="list-style-type: none"> ▪ Habitat Suitability Indices (HSI’s) (Use or Preferences) ▪ Regressionary models (univariate, multivariate, direct gradient analysis, fuzzy logic and artificial intelligence) 	<ul style="list-style-type: none"> ▪ Expert opinion ▪ Field measurement ▪ Biological knowledge 	<ul style="list-style-type: none"> ▪ Quantitative and qualitative measure of habitat quality for organism (usually used as a surrogate for population level) ▪ Index of habitat quality ▪ Probability of organism occurring
<ul style="list-style-type: none"> ▪ Biological processes 	<ul style="list-style-type: none"> ▪ Physiology (growth, digestion, accumulation of energy) ▪ Foraging behaviour ▪ Life-history strategies 	<ul style="list-style-type: none"> ▪ Experiment ▪ Observation 	<ul style="list-style-type: none"> ▪ Spatially explicit measure of habitat quality

The results of this type of approach usually is a pure prediction of habitat quality which is as a consequence of the modeling approach not linked with the population dynamics. However, often the results of these models are interpreted as a prediction of future species abundance.

The other type of interface between biological and physical attributes or processes are describing the growth of an individual animal or a certain group or species living under certain environmental conditions. This can include a large number of individual processes that are each controlled by environmental conditions, such as feeding, digestion, energy gain and consumption, reproduction. It also can be a simple description of the dynamics of a certain species' population under certain environmental conditions that are based on empirical data and integrate a large number of individual biological processes without understanding the mechanics of these. This part of biological modeling can be built upon the results of a pure physical habitat modeling approach or be independent from that.

The following chapters will describe both approaches in more detail.

3.1 Habitat preference criteria

The list of physical, chemical and biological variables that are related to an organisms presence or probability of occurrence or abundance / density is enormous but can be summarized as in table

Table 0-3: Attributes usually used for the description of probability of use or occurrence in habitat models.

Aspect	Attribute
Micro-habitat	Depth Velocity Substrate Threshold habitat size
Meso-habitat	Factors associated with channel shape and slope
Macro-habitat / Catchment	Riparian use Altitude Latitude Land –use Disturbance
Ecoregion/Landscape	Yann ?
Chemical	O2, toxicity
Biological	Traits, reproductive strategies

Mechanisms for dealing with the presentation of output vary according to the ecological reasoning behind the modeling. Thus it can include the

- Aggregation of data into one index
- Amount of habitat above a certain threshold
- Time series analysis
- Spatial distribution of the habitat quality

Validation of habitat models is problematic as there are many underlying assumptions which need to be tested and the output is often in units which are difficult to measure directly. Further, validation is often seen as unnecessary and is rarely funded. Most often attempts to validate habitat models relate the habitat quality to population numbers.

(give a crisp definition, figure, how these interfaces look and describe how you get them from field data)

3.1.1 Univariate preference functions

Biological models determine biological response to physical habitat. The models interpret the species abundance at areas with particular attributes (e.g. depth, velocity) as the measure of their suitability. Originally each attribute was analysed individually and a priori selected algorithms were used to combine this information. These are univariate functions, opposite to multivariate functions that will be discussed later. Three types are distinguished (Parasiewicz & Dunbar, 2001):

1. category 1: professional judgement
2. category 2: utilisation curves
3. category 3: preference curves

The first type of curves describes the suitability of a certain location based on expert knowledge and/or literature, the second type is based on measurements of the use of a location as habitat and the third category gives a combination of use and availability of habitat. These univariate preference functions are found by taking account of habitat available and converting habitat use functions into a simple ratio between use and available habitat (Figure 1).

There are two approaches to determining habitat available; one is to complete a random sampling across all habitats and the other is to sample in a proportional way across habitats. Using a random approach habitat available is sampled at random locations and data are pooled. The data resulting from this approach are highly comparable to point samples of habitat use. Proportional sampling of habitat available is the weighting of samples in each habitat type by the proportion that habitat type (i.e. riffle, pool) is present.

Univariate preference functions can be derived using a number of ratio formula or preference indices. The simplest is a simple ratio where preference (P) = Use (U) / Available (A). Other formulae include Jacobs Selectivity Index (Jacobs, 1974) calculated as:

$$D_i = \frac{r_i - p_i}{r_i + p_i - 2r_i p_i}$$

where r = the proportion of habitat used in class i and p = the proportion of habitat available in class i . Positive indices indicate selective use of that habitat class and negative values indicate avoidance of that habitat class.

Habitat preference scores are often subdivided into three regions:

1. Preferred habitat ($D > 0.2$)
2. Indifferent habitat ($-0.2 < D < 0.2$)
3. Avoided habitat ($D < -0.2$)

The preference functions can be delimited to take account of time of day, seasonal, life history and activity factors. For example, day time, feeding juvenile trout in the summer.

Frequently univariate preference functions are used in resolving conflicts over allocation of water resources in rivers using the Instream Flow Incremental Methodology (IFIM) and its component model Physical Habitat Simulation (PHABSIM). The habitat use and preference

functions (Figure 1) are converted into suitability indices (Figure 2) that range from 1 (optimal habitat) to 0 (where habitat has no value). These functions are then used to calibrate hydraulic models that describe the habitat to give an estimate of habitat value at different discharges and facilitate decision making for setting minimum discharges.

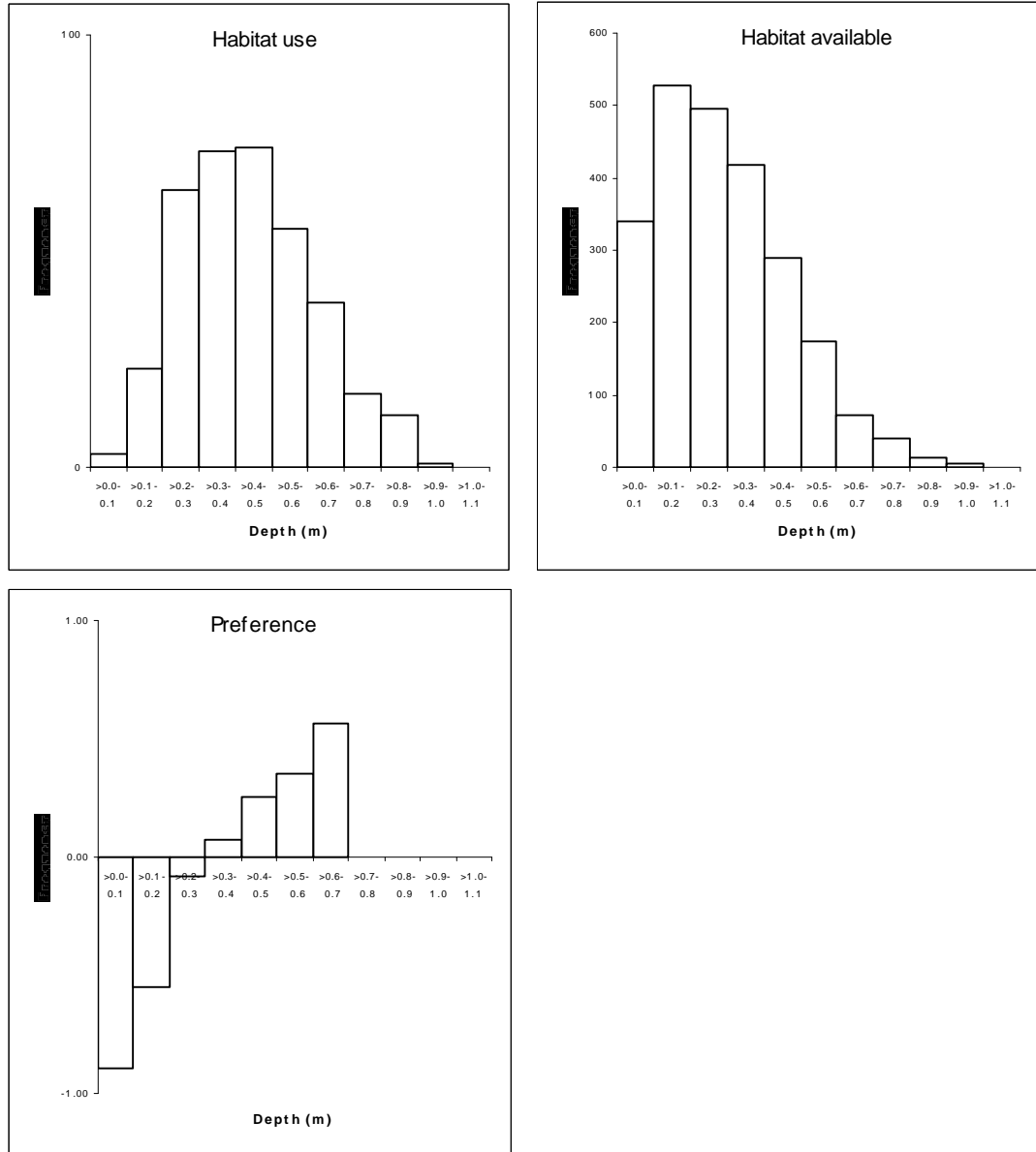


Figure 1. Frequency histograms of depth use by juvenile trout in Southern English rivers, habitat available to them and the resultant preference index.

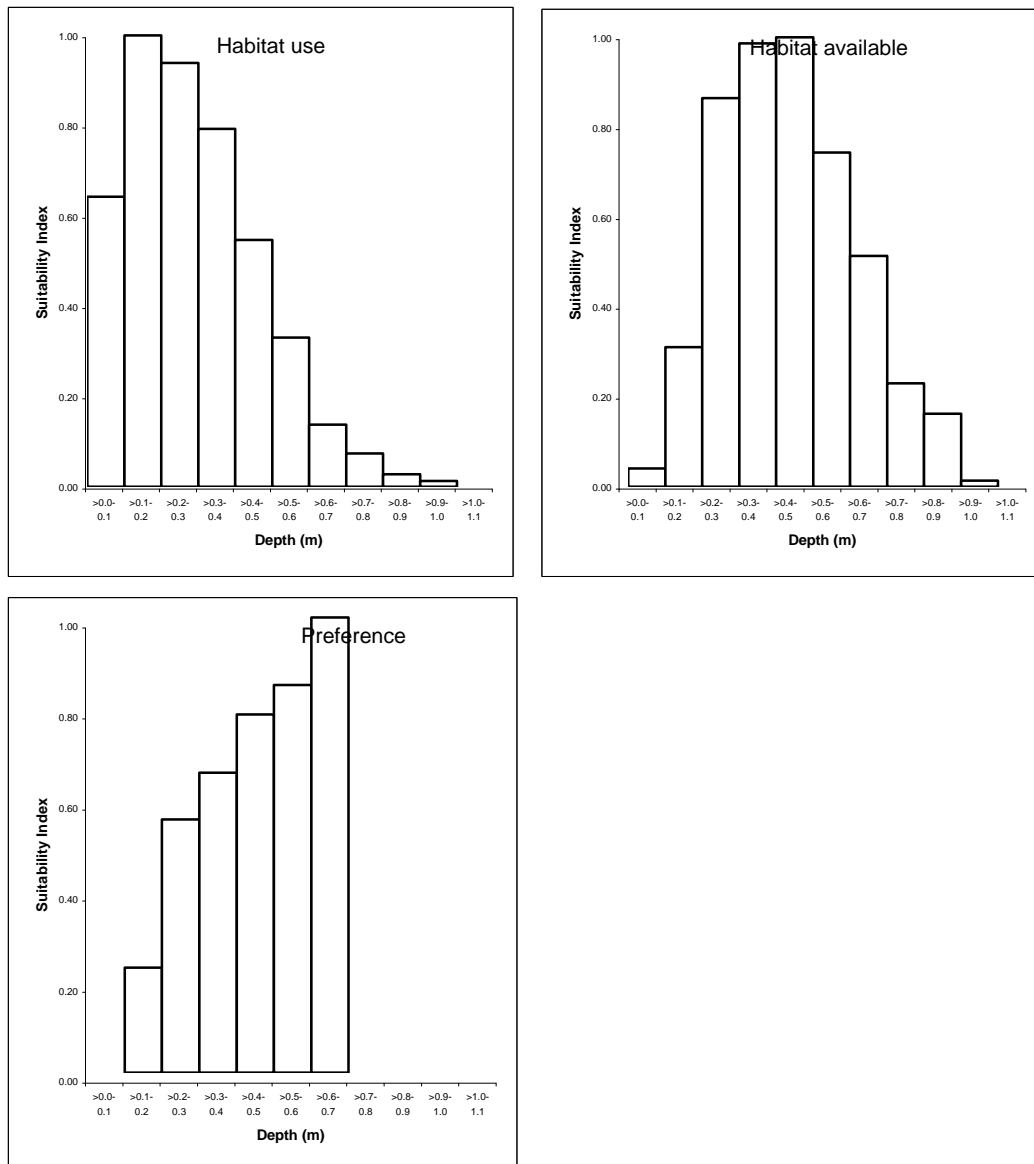


Figure 2. Depth use by juvenile trout in southern English rivers, depth available and preference from Figure 1 converted to Suitability Indices.

Jacob, J. 1974. Quantitative measurement of food selection: a modification of the forage ratio and Ivlev's electivity index. *Oecologia*. 14, 413-417.

Parasiewicz, P. & M.J. Dunbar, 2001. Physical habitat modelling for fish - a developing approach. *Large Rivers*, 12, 239-268.

3.1.2 Multivariate preference functions

Multivariate analysis takes into account the interaction of physical variables and determines species response to cumulative effect of number of environmental characteristics. A number of techniques are available:

1. Ordination techniques using indirect and direct gradient analyses, such as PCA;
2. Artificial Neural Networks;
3. Fuzzy rule-based functions;

4. Logistic regression.

(A) Ordination techniques: Indirect gradient analyses

Principal component analysis (PCA), correspondence analysis (CA) and detrended correspondence analysis (DCA) are ordination techniques which allow the detection of different types of underlying data structure. They construct synthetical gradients that explain the species data. Ordination analysis arrange sites along axes on the basis of data on species composition. The position of the sites (points) in the two-dimensional space is an indication of how similar or dissimilar they are in species composition. Extensive information about various ordination techniques in terms of community analysis is provided by Jongman et al. (1995).

Ordination techniques were applied to explore relationships between the species and the environment, for ecological analysis of all types of communities and environmental data, and for analyse of population-community responses to environmental change, either natural or anthropogenically induced.

PCA is an extension of fitting straight lines and planes by least-squares regression analysis. It extracts a set of eigenvectors, or theoretical variables, that minimize the total residual sum of squares after fitting straight lines to the species data. PCA relates to a linear response model in which the abundances of species either increase or decrease along environmental gradients. For example, PCA can be used for an analysis of spatial and temporal trends in stream water chemistry (Pardo 1994) or for an analysis of fish habitat preferences in streams. Raw data requirements: abiotic and biotic variables, species presence-absence and abundance data.

CA is an extension of the method of weighted averaging used in the direct gradient analysis of Whittaker (1967). DCA (Hill & Gauch 1980) is a heuristic modification of CA, designed to correct its major faults. Both techniques are related to a unimodal response model. The interpretation of the species points is different between PCA and CA/DCA. CA and DCA were used, for example, for analyses of longitudinal patterns of fauna and flora in streams (Armitage & Pardo 1995). Raw data requirements: Presence-absence and abundance species data.

General advantages of ordinations: Permit to work with big and complex data matrices, and to reduce and synthesize information. Indirect gradient analysis present some advantage over direct gradient analysis (see following section): species composition is easy to determine, while environmental conditions are difficult to characterise exhaustively. *General limitations of ordinations:* Possible subjectivity in the interpretation of the extracted theoretical axes. *CA limitations:* it is frequent that sites scores at the end of the first axis are closer together than those in the middle part of the axis, and the second axis frequently shows a systematic, often quadratic relation with the first axis, the arch effect, which reduces the expression of new information by the second axis. *DCA advantages* over CA, include the rescaling of CA axis to correct for the desired equal spacing of the site scores. Also eliminates the arch effect (a mathematical artefact) by 'detrending'. Detrending replaces the usual orthogonalization procedure, assuring the independence of the axes.

(B) Direct gradient analyses: canonical ordination methods

Canonical ordination techniques refer to direct gradient analyses; they combine the ordination with multiple regressions. Canonical correspondence analysis (CCA) and redundancy analysis (RDA) are the canonical forms of CA and PCA, respectively. The application areas are the same as for CA and PCA. In particular, these multivariate methods are used when one is interested in the effect of several environmental variables on the structure of taxon assemblages, for example for fish communities (Copp 1992). Because sample scores are constrained to be linear combinations of explanatory variables, canonical ordination is also called constrained ordination. The ordination diagram of canonical ordination, a triplot, provides information on the samples as points, species as points, and environmental variables as arrows.

As in regression, the environmental (=explanatory) variables can be continuous or nominal. The requirements for taxon data match the requirements for CA and PCA, which are described above. In most cases a transformation of the variables may be necessary, for example, when variables are analysed with different dimension or the distribution is skewed strongly (Legendre & Gallagher 2001).

A part of the limitations of CCA and RDA refers to the same as listed for CA and PCA. Furthermore, limitations are the same as to the limitations of multiple regression. PCA and RDA provide more quantitative information than CA and CCA. However, if the data are strongly non-linear the ordination diagram of PCA and RDA will be strongly distorted and the interpretation may lead to false conclusions. DCA contains some mathematical uncertainties, however, a DCA can be used to test, whether a CA or a PCA are more appropriate to analyse the data. Ordination length that are longer than 4 standard deviation units indicate non-linear data; in such a case, CA and CCA are more appropriate.

A use of ordination and canonical ordination can be helpful to test, if all important environmental variables were included in the canonical ordination. If the results do only differ slightly, probably all significant variables were included (or measured). But one has to be careful, similar to regression analysis, covariation of multiple variables may result in a substitution of functional variables. This is also the case for intercorrelations of environmental variables (problem of multicollinearity in multiple regression analysis). As CCA and RDA axes are linear combinations of environmental variables, significant noise in the environmental data can also distort the ordination.

(C) Artificial Neural Networks

Description with examples

Artificial Neural Networks (ANNs) are non-linear mapping structures which can be applied for predictive modelling, i.e. all the characters describing the unknown situation must be presented to the ANN, and the identification (prediction) is then given. Various types of neural networks exist, suitable to solve different kinds of problems. The choice of the type of network depends on the nature of the problem to be solved. The most popular ANNs are multi-layer feed-forward neural networks with the backpropagation algorithm, i.e. backpropagation networks (Rumelhart *et al.*, 1986; Hagan *et al.*, 1996) and Kohonen self-organizing maps, i.e. Kohonen networks (SOMs) (Kohonen, 1982).

Backpropagation networks

The backpropagation network is based on the 'supervised' procedure. The network constructs a model based on examples of data with known outputs. It has to build up the

model solely from the examples presented, which are together assumed to contain the information necessary to establish the relation. An example of a relation can be the abundances of a number of macroinvertebrate families (such as Gammaridae, Tubificidae, Chironomidae) which are being predicted based on a number of environmental variables such as flow velocity, percentages of clay, silt and sand in the sediment, river depth, dissolved oxygen, pH,... To make reliable predictions it is better to rescale the input variables, because they can have very different orders of magnitude. For example, the input variables can be rescaled to be included within the interval $[-1, 1]$ by using the following equation:

$$V_n = 2 \times \frac{(V_0 - V_{\min})}{(V_{\max} - V_{\min})} - 1$$

in which V_0 and V_n are, respectively, the old and new value of the variable for a sampling point, V_{\min} and V_{\max} are the minimum and maximum values of that variable in the original dataset. The architecture of the backpropagation network is a layered feed-forward neural network in which the non-linear elements, the neurons, are arranged in successive layers, and the information flows from input layer to output layer, through the hidden layer(s) (Fig.1). As can be seen in Fig. 1, nodes from one layer are connected to all nodes in the following layer, but no lateral connections within any layer, nor feed-back connections are possible. In the example mentioned above, each input neuron would represent one environmental variable and each output neuron the abundance of one macroinvertebrate family. With the exception of the input neurons, which merely connect one input value with its associated weight values, all neurons can be visualised with their connections as in Fig. 2. The inputs are indicated as x_1, x_2, \dots, x_n , each associated with a quantity called weight or connection strength $w_{j1}, w_{j2}, \dots, w_{jn}$ for the input to the j -th neuron. The net input for each neuron is the sum of all input values, each multiplied by its weight, and z_j a bias term which may be considered as the weight from a supplementary input equalling one:

$$a_j = \sum w_{ji}x_i + z_j$$

The output value, y_j , can be calculated by feeding the net input into the transfer function of the neuron:

$$y_j = f(a_j)$$

Many transfer functions may be used, e.g. a linear function or most often a sigmoid function. The number of input and output nodes depends on the number of the input and output objects.

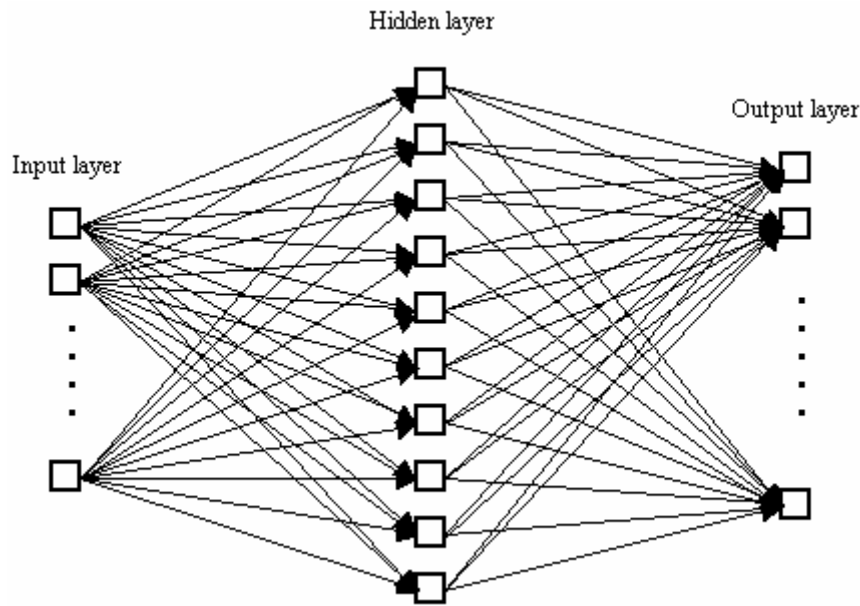


Fig. 1 Illustration of a three-layered neural network with input layer, one hidden layer with ten neurons and output layer.

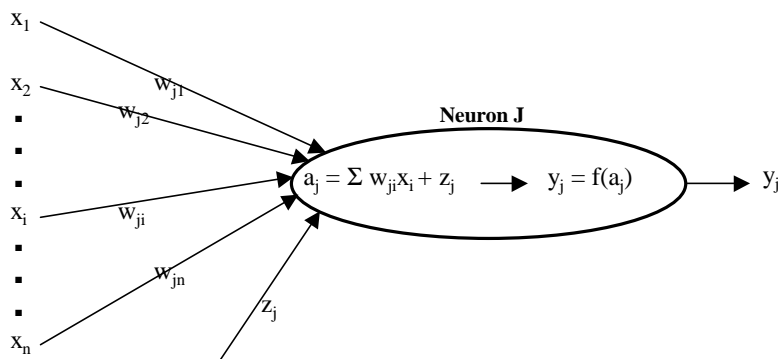


Fig. 2 Scheme of a neuron in a backpropagation network receiving input values from n neurons, each associated with a weight, as well as a bias z_j . The resulting output value y_j is computed according to the presented equations.

For determining the values of weights and biases in a backpropagation network, all the weights and biases are initially set to small random numbers. Subsequently, a set of input/output vector pairs is presented to the network. For example, the input vector can be a set of 15 environmental variables determined at 60 sampling sites and the output vector the abundances of Gammaridae and Asellidae (both Crustacea) sampled at these 60 sites. For each input vector, the output vector is calculated by the ANN, and an error term is calculated for the outputs of all hidden and output neurons, by comparing the calculated output vector and the actual output vector (the "target"). Using this error term, the weights and biases are updated in order to decrease the error, so future outputs are more likely to be correct. This procedure is repeated until the errors become small enough or a predefined maximum number of iterations is reached. This iterative process is termed "training". After the training, the ANN can be tested using independent data.

Self-organising maps

Kohonen self-organizing maps (SOMs) are based on the 'unsupervised' learning methodology, in which the relevant multivariate algorithms seek clusters in the data. Unsupervised learning allows the investigator to group objects together based on their perceived similarity. An important difference with the 'supervised' ANNs is that the training data consist of a set of input vectors, not associated with output vectors. Formally, a Kohonen network consists of two types of units: an input layer and an output layer (Fig. 3). The array of input units operates simply as a flow-through layer for the input vectors. The output layer is a multi-dimensional, usually two-dimensional, network of neurons. Each output neuron is connected to all input neurons. The set of weights associated with one output neuron represent the values of a set of variables ('pattern').

Initially, all weights are set randomly, so the neurons represent arbitrary patterns. During the training process, the data set, which consists of a large number of patterns, is presented to the SOM. The (usually Euclidean) distances between a pattern and all output neuron patterns are calculated. The weights of the output neuron which is the nearest to the pattern, and also of its neighbouring neurons, are modified so that it moves slightly closer to the input pattern. After an iterative training process, neighbouring output neurons will have more similar patterns than distant ones. In this way, a 'feature map' is obtained on which patterns can be plotted. The Kohonen network can as well be seen as a dimension reduction, because multi-dimensional data are projected on a array of neurons having a lower number (usually two) of dimensions.

For example, a set of 15 environmental variables sampled at a large number of river sites could be presented to a SOM. The result would be a map where each neuron represents values for each variables (a pattern) and adjacent neurons are characterised by more similar patterns than others. Each neuron can then be seen as the centroid of a river type, and the map as a classification of rivers based on the 15 variables. With the map, each new pattern will be assigned to one neuron, or river type. In this way, a SOM can be seen as a combination of classification and multi-dimensional ordination.

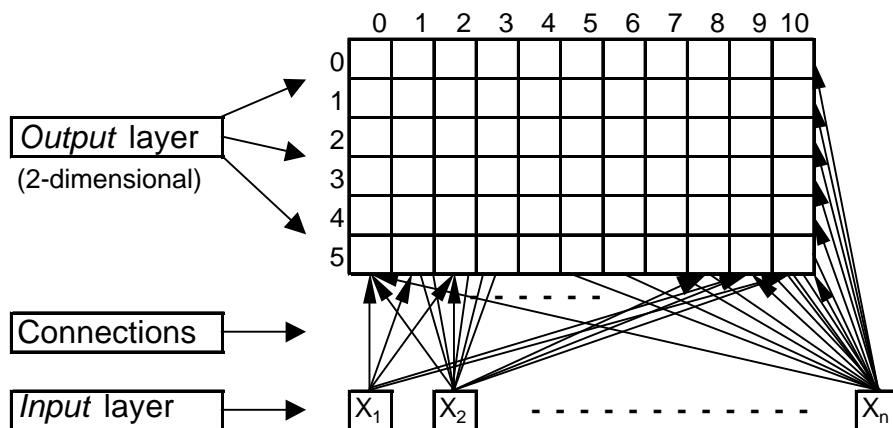


Fig. 3 Scheme of a two-dimensional Kohonen network, with 6 x 11 neurons in the output layer. Each neuron of the output layer is connected to each neuron in the input layer.

Raw data requirements

For the raw data, there are no specific requirements. In contrast to some other multivariate techniques, e.g. multiple regression, data do not need to be normally distributed. Any quantitative variable (e.g. the river depth expressed in meter) can be included as input or output variable. It is however recommended that input variables are rescaled, as mentioned earlier. Categorical variables (e.g. the stream velocity expressed in classes (stagnant, slow, moderate and fast)) can be used by expressing them as consecutive values (e.g. stagnant=0, slow=1, etc.). Nominal variables (e.g. water colour) may be used by defining each possible class as a separate variable, which can take the values zero and one (e.g. when the water is green, the variable "green" equals one and the other colour variables equal zero).

Application areas

ANNs are being increasingly used for predicting various water resource variables, such as rainfall, flow, water level and various water quality parameters (Maier and Dandy, 2000). Biological parameters of water quality are also increasingly modelled using ANNs, such as phytoplankton and fish (Lek & Guégan, 1998), but also macroinvertebrates (e.g. Walley & Fontama, 1998). Presence/absence as well as abundances can be predicted with an ANN, although when using abundances, they are usually transformed (e.g. by an $\log(n+1)$ transformation).

Currently, very few 'ready' ANNs are available, because each problem is usually approached with a specific set of training data and for each problem the optimal network architecture (number of neurons, transfer functions, etc.) differs.

Neural network users generally program their own network. Toolboxes exist for implementing neural networks, some of which are used within a specific modelling environment such as MATLAB. Some examples of these toolboxes can be found at websites (see [http-list](#) in references). However, some modellers prefer to program their neural networks 'from the bottom up'. This can be done with any existing programming language such as FORTRAN or C++.

Application of ANN in data-poor situations

A major limitation on the use of neural networks is that they require large amounts of data for training. This is a serious problem in most ecological applications, because data are usually very scarce. It is therefore essential to find ways of making the training of neural networks more efficient so that they can be used in situations where the number of data is small.

One of the reasons why neural networks are inefficient is that they are usually trained with raw data. This ignores the understanding and insight that a human expert can bring to bear. One way to interact with the training process is to pre-process the data before they are fed into a neural network (Silvert & Baptist 2000). The pre-processing transformation technique is a data aggregation method where usually orthogonal functions are used, such as Fourier components, Chebyshev polynomials, EOF's, Bessel or Laplace transforms. The transformation technique must be chosen with care and should be based on ecological knowledge of the system, so that the transformation represents best the ecological information. A pre-processing of data can reduce the number of input neurons and therefore reduce the problem of overtraining. It may also help to understand the process handling inside a neural network, making it less of a black box than it is when blindly applied to incoherent data sets. There exist several ways of doing this, including constraining the

system on the basis of prior information and the use of transformed variables to reduce the effective number of degrees of freedom. The more successfully we can integrate neural networks with other analytical procedures based on scientific understanding of how ecosystems function, the more effective neural networks will be in dealing with ecosystems for which only limited data are available.

Advantages & limitations

ANNs are able to process problems involving non-linear and complex data, even if the data are imprecise and noisy. They make powerful tools for predictive modelling, especially when the underlying data relationships are unknown. Hence they are ideally suited for the modelling of ecological data, which are known to be very complex and usually non-linear (Lek & Guégan, 1999).

A possible problem relates to the fact that ANNs require large amounts of data for training (Silvert & Baptist, 2000), and therefore they cannot always be applied. Furthermore, no standard methodology exists to decide upon the optimal ANN characteristics, such as transfer functions and number of hidden neurons, for a given problem (Maier, 1995). Moreover, an ANN is a black box method (Lek & Guégan, 1999). This is an important disadvantage for ecological applications, because the ANN does not provide insight in the underlying mechanisms of the problem studied.

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3.1.3 Fuzzy-rule based preference functions

A new approach to evaluate habitat quality is fuzzy rule-based modelling [1,2,3,4]. Fuzzy modeling allows to work with imprecise or „fuzzy“ information. This comes with the significant advantage that expert knowledge readily available from experienced fish biologists and supported by local investigations (electro fishing, observation) can easily be transferred into preference data sets by setting up check-lists. These lists or so called fuzzy-rule systems give the possible combinations of relevant physical criteria and let experts define if habitat quality is e.g. good, medium or low. Table 1 shows an extract of a set of fuzzy rules for adult brown trouts in an alpine region.

Table 1: Fuzzy rules for brown trout in alpine region (extract). Example line 2: If velocity is “medium” AND depth is “high” AND substrate is “large” AND cover type is 2 THEN suitability is “high”.				
velocity	local depth	substratum	cover type	suitability index
medium	high	large	0	Low
medium	high	large	2	High
medium	high	large	3,4,5	High
medium	high	large	6,9	High
medium	high	medium	0	Low
medium	high	medium	2	High

The parameters, that are contained in the criteria combinations are categorized by so called fuzzy sets (Figure 1). As a basic component of the approach they are described by so called membership functions [5]. In this way linguistic variables can be defined, i.e. “high”, “medium” or “small” flow velocity (Figure 1) and a fuzzy formulation of rules (Table 1) close to human way of communication is enabled. The rules define the relation between input or explanatory variables and consequence(in this case the habitat suitability).

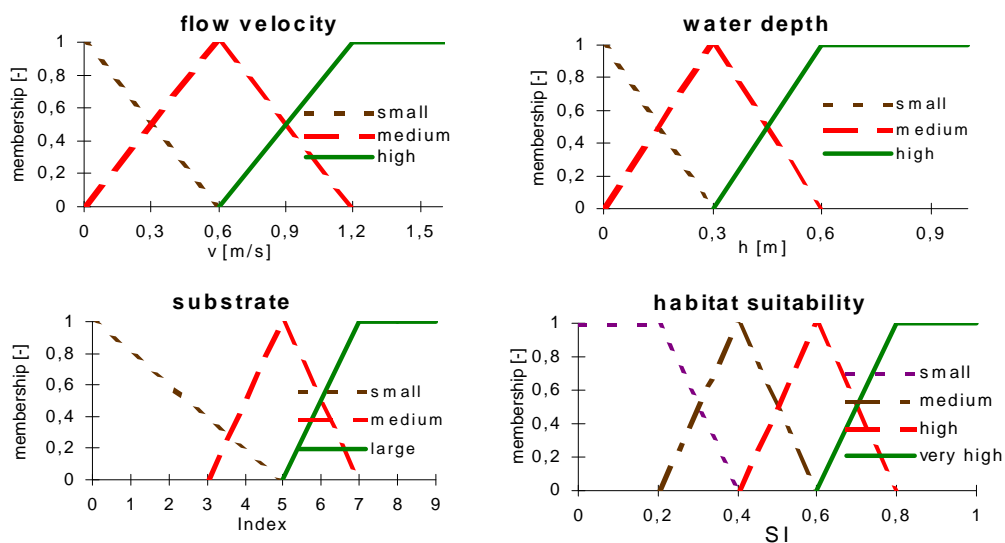


Figure 1: Fuzzy sets describing degrees of membership (membership functions) for input (velocity, depth, substratum) and output (suitability index)

Not only the input but also the output is „fuzzy“ (see Figure 1). The habitat suitability as output of the fuzzy model is derived by calculating so called degrees of fulfillment of all the rules in the rule system. These degrees of fulfillment or in other words levels of truth are then used for a „defuzzyfication“. Thus the result, which is still in the form of a fuzzy set, is transformed back into a standardized number between 0 and 1 to describe habitat quality.

Raw Data Requirements

The data requirements are similar to the definition of preference curves. Also there are different categories of rule generation. A rule system can be defined just by expert knowledge, experience or literature studies (category 1).

However the better way is to adapt the rule system to the local conditions and river type. The physical parameters at locations where fish was caught or observed have to be recorded. By comparing the parameter combinations and associated fish frequency with the fuzzy-rules and the defined rule consequences (habitat suitabilities) the category 1 rule system can be optimized to a category 2 system. If additionally the availability of the different parameter combinations is considered a category 3 rule system is derived.

Applications

In the last years the method integrated in the simulations model CASIMIR was tested and extended in various scientific and application-oriented projects and has proven its suitability for river types of different altitude, hydraulics, structure and dimension i.e.:

- Flow regulations and investigations of environmental integrity for hydroelectric power plants of different dimensions.
- Investigations of river sections influenced by hydropeaking.
- Contribution for the development of a standardized procedure for certifying hydroelectric power plants (assignment of Swiss "Oekostrom" label).
- Management strategies for river sections influenced by water diversion.
- Assessment and evaluation of ecological effects caused by river regulations.

- Contribution to the development of a model system for integrated watershed management (MIMAG).

Advantages & Limitations

The fuzzy-rule based method is very suitable for the formulation of ecological linkages, since these linkages rarely can be described by exact functions or crisp numbers. It is evident that the fuzzy rules are very close to the human way of communication and a convenient way to integrate expert knowledge. Additionally, using this approach the adjustment of the model to different river types is possible, since the physical parameters may be on different levels in different river types but the preferences of an organism within the system can be very similar.

Experiences in fish habitat modelling showed that the fuzzy-rules necessary for the numeric processing were formulated very similar by different experts. This seems to confirm the proximity of the approach to human thinking.

Summarised the method has got several advantages compared with other multivariate calculation procedures:

- Knowledge about the habitat demands of waters organisms is usually qualitative, by the fuzzy rule-based approach this knowledge can be numerically processed.
- Fuzzy logical calculations consider multivariate effects but no independence of the input parameters is required.
- A comparatively small number of measured or observed values is needed.
- New parameters can be included easily.
- The calculation is robust.
- Because of the fuzziness of the approach the demands on the accuracy of hydraulic calculations or observed physical parameters are lower than in conventional approaches.
- The calculation steps can be easily understood (no black box effect) and interactions within the system can be explained.

Limitations can be seen in the following facts:

- The number of fuzzy-rules is rapidly increasing the more parameters are considered.
- The rules close to human language can give the false impression, that they can easily be defined by any person regarding himself as an expert.

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3.1.4 Logistic regression

Logistic regression is a multivariate linear model. It requires field observations of characteristics of habitat available and utilised by indicator species. The habitat choice is described using a binary dependent variable for species occurrence. Logistic regression models use the following formula:

$$p = 1 / (1 + e^{-z})$$

Where p – probability of occurrence, e – constant,

$$z = b_1 * x_1 + b_2 * x_2 + \dots + b_n * x_n + a.$$

$x_{1..n}$ - significant physical variables, $b_{1..n}$ - regression coefficients, a - constant.

3.2 Biological process models

Biological process models are models that describe processes such as the dynamics of a population of a given species under certain environmental conditions. A simple model could be the growth of algae biomass in a lake under certain trophic conditions and light and temperature, based on empirical data. A more complex model would take individual processes within the species metabolism into account, such as feeding, digestion, reproduction, mortality etc. under given environmental conditions. These individual processes can be either mechanistic and based on physical processes or they can be empirical functions. A complex model can incorporate a number of individual processes and combine these to a life cycle model or a multi species community model.

These models can either be linked upon the results of a plain physical habitat model or be directly linked with certain data describing the physical and physiographic environment.

Bioenergetic models are a special type of biological process models where optimal fish location is based on energy budgets. These models compute how much energy a fish uses as a function of water velocity or turbulence and of food intake. The budget of energy intake and energy loss due to the current denotes the optimal location for fish.

3.3 Output of models

Interpretation of results.

Weighted useable areas, suitabilities, habitat quality and availability. Who can write something about this?

4 Models

4.1 Introduction

A model is a way of representing nature that should act like or describe processes and states in a controlled and simplified way to answer questions. A model can be anything from a very simple mathematical equation to very complex systems of algorithms incorporating a large number of individual processes and procedures. Models can be descriptive or predictive. Models can be divided roughly into several categories, however distinction may not always be very precise because complex models consist of a large number of distinct submodels which usually belong into different categories:

- Conceptual;
- Based on experience, expert model;
- Mathematical;
- Stochastic;
- Quantitative/semi-/non-quantitative;
- Fuzzy set based.
- Scale model/physical model

In this study a wide variety of models are inventoried and classified according to the following Table:

Table 0-4: State-of-the-art models

	Statistical, Stochastic	Mechanistic
Biological	<ul style="list-style-type: none"> ▪ Suitability index (BHABIM in CASIMIR) ▪ Multivariate statistics (multiple discriminant analysis, e.g. RIVPACS and logistic regression) ▪ Fuzzy-logic-suitability (FHABIM in CASIMIR, HARPHA, HABSCORE) ▪ Time series analysis ▪ Neural network ▪ Q_n-type models (flow duration curve based) 	<ul style="list-style-type: none"> ▪ PHABSIM type models (EVHA, RHEHAMSIM, CASIMIR, FISO...) ▪ Bioenergetic ▪ Multi-Agent (Moby Dick) ▪ Energy and substance models ▪ Growth-temperature based models ▪ 5M7 ▪ Population dynamics
Hydraulic	<ul style="list-style-type: none"> ▪ Frequency distribution based models (FSTRESS Lamouroux, TAUSIM in CASIMIR) ▪ Neural networks 	<ul style="list-style-type: none"> ▪ 1,2,3-dim steady state ▪ Time series of steady state conditions ▪ 1,2,3-dim unsteady state (SSIIM, MIKE, DELFT3D) ▪ Solute transport models (convection, advection, dispersion and diffusion) + reaction kinetics ▪ Ground water models

Water quality	<ul style="list-style-type: none"> ▪ Data processing techniques ▪ Neural networks 	<ul style="list-style-type: none"> ▪ > 600 processes & substances ▪ Dissolved Oxygen ▪ Temperature ▪ Light ▪ Nutrients (PO₄, NO₃, NH₄) ▪ Conductivity ▪ Acidity ▪ Carbonates ▪ BOD, COD ▪ Algae ▪ Toxics ▪ Sediment interface ▪ Passive/active (salinity or temperature changes physical properties of water)
Hydrology	<ul style="list-style-type: none"> ▪ Statistical hydrology ▪ Stochastic hydrology 	<ul style="list-style-type: none"> ▪ Precipitation-runoff models ▪ Distributed parameters ▪ Concentrated parameters ▪ Point vs. non-point sources (sediment and nutrients)
Morphodynamic	<ul style="list-style-type: none"> ▪ Classification & description based on data <ul style="list-style-type: none"> ○ Shear power ○ Bed forms ○ Plan forms ○ Shields number 	<ul style="list-style-type: none"> ▪ Stable channel conditions / Incipient motion ▪ Duration of motion related to particle size ▪ Loose boundary hydraulics, bedforms ▪ Suspended/bedload transport models ▪ Single vs. Multi-fraction models ▪ Armouring layer and sublayers ▪ Sediment transport in multiple layers ▪ Morphodynamic models
Spatial analysis	<ul style="list-style-type: none"> ▪ GIS based technologies ▪ Landscape Ecology <ul style="list-style-type: none"> • Contagion • Juxtaposition • Interspersion • Patch size • Minimum distance, area • Spatial analysis technique (integration of output from other models on a higher level) • • 	

4.2 State-of-the-art model inventory

The models used within the COST-626 network are not a complete list of available models in Europe, but represent only the ones in use by members of this group. Some of the models described are elementary modules that are components of more complex models or toolboxes. The complete overview is described in Appendix 1. Table ?? gives a summary of the names, general objective, typology and characteristics of the models.

Name	Objective	Typology	Characteristics
CASIMIR - BHABIM	Simulation of benthic habitat quality	▪ habitat model	▪ benthos
CASIMIR - FHABIM	Simulation of fish habitat quality	▪ habitat model	▪ fish <i>Links to Deflt3D, HEC, Mike11</i>
5M7	Fish habitat model for cyprinids	▪ habitat model	▪ cyprinids <i>Links to SSIM</i>
HARPHA	Minimum flow and habitat restoration	▪ habitat model	▪ fish
MesoHABSIM	Minimum flow and habitat restoration	▪ habitat model	▪ fish <i>multi-scale model: section to watershed</i>
MORRES	Habitat and ecotope quality and availability, and succession of ecotopes	▪ habitat model	▪ succession of vegetation
HABITAT	Aquatic habitat analysis	▪ habitat model	▪ fish and aquatic species <i>Links to SSIM and HEC</i>
ENERGI	Use energy gain in fish to simulate habitat quality	▪ habitat model	▪ fish energy budget
NORSALOMOD	modelling of population dynamics of Atlantic Salmon	▪ population dynamics	▪ Atlantic salmon
BIORIV	Growth of Salmon and Trout in rivers	▪ growth model	▪ fish
RIVPACS III	Biological assessment	▪ assessment model	▪ benthos
Saprob	Assessment of water quality by species indicators	▪ assessment model	▪ water quality indicators
Ecofuzz	Fuzzy set based reasoning system	▪ reasoning system	▪ fuzzy logic
FISU	Simulation of habitat quality for fish or other aquatic species	▪ hydraulic ▪ habitat model	▪ 2D ▪ fish and aquatic species
RHYHABSIM	1D hydraulic analysis and habitat evaluation	▪ hydraulic ▪ habitat model	▪ 1D ▪ fish
PHABSIM for Windows	Simulation of fish habitat quality	▪ hydraulic ▪ habitat model	▪ 1D/2D ▪ fish
BfG Habitat	Simulation of macrozoobenthos and fish habitat quality	▪ hydraulic ▪ habitat model	▪ 2D ▪ macrozoobenthos and fish
BfG ZooAuto	Simulation of fish habitat quality and population dynamics	▪ hydraulic ▪ habitat model ▪ population dynamics	▪ 1.5D ▪ fish ▪ fish
QUAL2E-IZH	1D river water quality model	▪ water quality	▪ 1D <i>Links to hydraulic modelRAGLA</i>
ALCON 3.0	Estimation of fish farming effluent	▪ water quality	▪ N/P fish farming
CORMIX 1-2-3	Water quality model	▪ water quality	▪ 1D/2D/3D
Decay rates	Prediction of in-stream leaf decay rates	▪ water quality	▪ leaf decay
LAKES	Water circulation in non-	▪ hydraulic	▪ 2D

	stratified lakes		
Hydrobiogeo-chemical model	Simulation of hydrobiogeochemical functioning	<ul style="list-style-type: none"> ▪ hydraulic ▪ water quality 	<ul style="list-style-type: none"> ▪ 1D ▪ NH4 + NO3
SWAN	Two-dimensional flow and transport model	<ul style="list-style-type: none"> ▪ hydraulic ▪ sediment transport 	<ul style="list-style-type: none"> ▪ 2D ▪ 2D
Delft3D	Two- and three-dimensional flow and transport model	<ul style="list-style-type: none"> ▪ hydraulic ▪ morphodynamic ▪ water quality 	<ul style="list-style-type: none"> ▪ 3D ▪ 2D ▪ 3D
SSIMM	Two- and three-dimensional flow and transport model	<ul style="list-style-type: none"> ▪ hydraulic ▪ morphodynamic ▪ water quality ▪ habitat model 	<ul style="list-style-type: none"> ▪ 3D ▪ 2D ▪ 3D ▪ fish

Application areas: what can they be used for?

What kind of commercial accessories we use?

Guide to people not familiar with models on how to act, ask questions, go to modeller to be answered.

Brainstorming:

Different categories in terms of

Approach

Scale

Target species

Userfriendliness

Data requirements

Scale-aspect

Ecoregion

Published, validated

Limitations

Make this a systematic overview

In a given situation, a certain question asked: with a given amount of time/money and a certain background experience, which is the choice between models you have.

First: simple screening type of models: How big is my problem, or don't I have a problem.

Then: more comprehensive techniques.

5 Research needs

An inventory of research needs within the modelling group of the COST626 initiative was conducted. The research needs were classified into five groups. An overview is given below, more elaborate descriptions are given in Appendix II

Physical habitats

- Physical habitat changes for various seasons;
 - summer droughts, for example nutrient concentrations as first step of trophic chain
 - physical winter habitat, ice-coverage, scour/erosion of ice and its effect on sediment transport and habitats, for example the spawning habitat.
- Interaction of habitat parameters and disturbance.
- Limitation of the habitat approach versus other relevant parameters (mortality / migration barriers).
- Artificial fluxes from reservoirs and its effects on habitats.
- Physical habitats and climate change

Model techniques

- Population dynamics linked to habitat modelling.
- Assessment of machine-learning methods for habitat models.
- Connecting different kinds of models; model tool box, hybrid modelling.
- Food web modelling.
- Combination of aquatic and terrestrial models to model the water body in combination with the floodplain

Processes and interactions

- Effects of vegetation cover on hydro- and morphodynamics; parameterisation of vegetation for models, use of remote sensing techniques or current measurements related to roughness.
- Hydrology and the interaction with instream habitats; ecosystem interactions between macrophytes, hydrodynamics, algae, oxygen, sediment, invertebrates, filter feeding.
- Physical processes on ice-formation and development of empirical or deterministic tools.
- Interaction between groundwater and channel flow.
- Food delivery to juvenile salmonids; drifting invertebrates and their sources.
- Transport phenomena models.
- Modelling the seston-macroinvertebrate trophic interactions in salmonid river to determine the availability of prey for fishes.
- Stability / erosion of rivers after river restoration and the sustainability of restored rivers.

Scales and classification

- Difference between catchment related models and geographical larger models.
- Minimum sample distance needed to determine habitats, for example distance between cross-sections.

- Influence of catchment uses and riparian corridors on organic matter budgets on a reach scale.
- Selection and definition of reference reaches as a basis for large-scale river models.
- River classification systems.
- Definition of dynamics on the basis of well-chosen criteria and parameters.

Data

- Defining benchmarking data for model validation.
- Prediction of reference states without any historical data.
- Assessment of the identification level of macro-invertebrates (genus, families, assemblages) with respect to detail needed for modelling.

6 Expected Results

To be discussed with end-user group.

Traditional fish habitat models take only the physical habitat into account. It is well known that population dynamics do in many cases not follow habitat availability because other factors might be limiting. There is a number of possible reasons for that:

Species interaction is neglected

Food availability is neglected

...

Mortality rates at different life stages are not well known and mechanisms are not well understood. What are physical habitat criteria to increase survival rates e.g. during the winter or in the transition phase from yolk-sac to fry (starvation problem)

....

Therefore it is clear that habitat models can only provide a limited perspective of the reasons for success or failure of a species community.

Aspects (Brainstorming):

- Predicted physical habitat for certain taxa/life stages
- Fish per usable area expected
- Predicted and measured populations dynamics
- Communities or taxa
- Results are scale dependent
- The scope is a function of the scale

7 Upscaling

Franz Kerle will send the results of the brainstorm session.

Some major aspects:

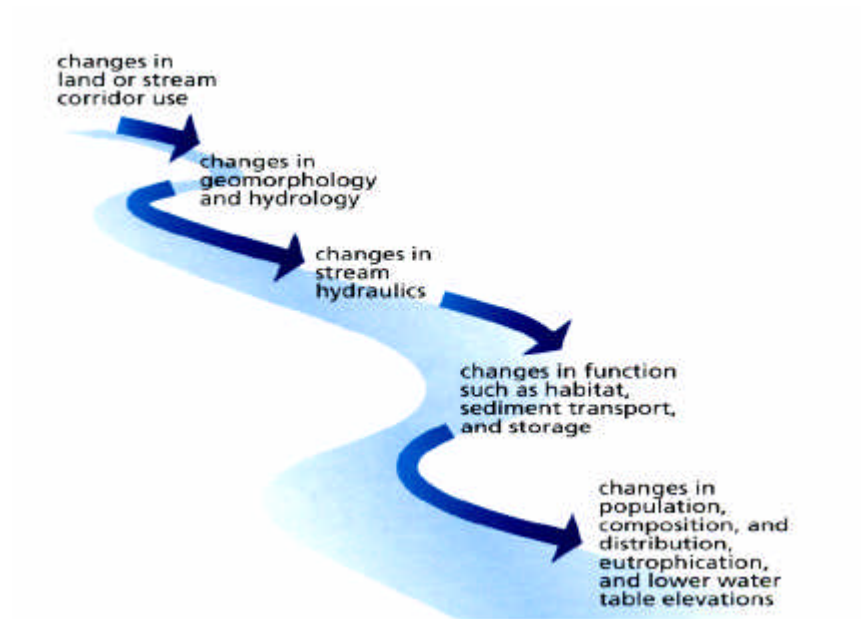


Fig. 0-1: Relevant aspects for floodplain ecological processes (Wentworth 2001)

Using a representative reach of a river (quantitative proof for this assumption?) for a modeling program and then transferring the results to other reaches of the river is not upscaling but simply working with random samples representing the entity.

Different models are applicable at certain scales only. A model must be able to represent its appropriate scale. The results of such models can be incorporated in larger scale management tools. This means that complex models can be used to directly generate generic information to be used within management + decision making tools to be given to basin managers or decision makers. This is important but not really upscaling.

Physical upscaling means to use results gained from a model with a certain (spatial) resolution on a certain scale, e.g. a river reach with a given length, and generate results that are applicable and valid to an area with a wider scale, e.g. a longer river reach or a higher organizational level (floodplain, other river reaches). **Does anyone do that?**

Multi-scale models include some principles from large scale models (e.g. temperature variability) into habitat models. Consider connectivity over space and time between small scale habitat units.

Is a direct upscaling needed or not

- Which are relevant parameters for an upscaling process (quantitative links across scales)
- Modeling approaches used for upscaling
- Is downscaling ever required?

Physical habitat modeling (small scale) aspect	Large scale aspect
<ul style="list-style-type: none"> • Static flow, time series • Precise, but inadequate scale • Single species/life stages approach • Static physical habitat • Non-disturbance condition 	<ul style="list-style-type: none"> • Many species, ecosystem approach • Holistic approach • Larger spatial scale • Theory based, dynamic • Disturbance • Large scale processes form physical habitat -> physical hierarchie • Dynamics = variation over time, natural flow regime • Baseflow stability and flood frequency • Importance of flow for shaping riverine ecological processes

8 Uncertainty

Uncertainty comes with model predictions. We need to quantify uncertainty to make decisions wisely, to account for natural variability in systems and to evaluate risk.

Uncertainty can be generated by different sources and therefore there are various ways of dealing with uncertainty. Five different sources of model uncertainty and possible strategies are (De Vriend, 2001):

1. Uncertainty inherent to inputs, e.g. due to weather. This kind of uncertainty we haven't to live with. The strategy is to quantify the effects as best as possible.
2. Uncertainty inherent to process, e.g. chaotic behaviour. The strategy here is to trace it and identify limits of prediction.
3. Uncertainty due to lack of data, e.g. long-term monitoring data. The remedy is to work on it and start or continue monitoring programs.
4. Uncertainty due to lack of knowledge. Remove this uncertainty by identifying and filling knowledge gaps.
5. Uncertainty due to lack of control, e.g. numerical process. The remedy is to reduce this, analyse the model and improve.

Habitat evaluation models rely heavily on data. A HEP model typically consists of sets of formalised relationships between measured abiotic parameters and biotic parameters. The predictive skill of a HEP model therefore often concerns the uncertainty embedded in data, viz. (1) the data that are used as inputs into the model (forcing factors, parameters), or (2) the data that serve as a reference for model validation. Here there are several pitfalls. By introducing too many calibration parameters, a model can be over-fitted, i.e. it fits the reference data set very well, but has little other predictive skill than extrapolation under the assumption of *ceteris paribus* (the conditions stay the same). Also, introducing more uncertain data may well be counterproductive, as the increase of uncertainty in the model may exceed the increase of information (De Vriend, 2001).

Anyhow, a modeller should include uncertainty in the outputs of the model. However, this is not easy. The modeller needs to know the sources of model uncertainty and must be able to quantify the total uncertainty as a result of the combination of the different sources. There are various ways for quantifying uncertainty. By evaluating simulations against measured data, the aberration in model outcome can be quantified. This is actually preceded by model calibration in which the aberration is minimised as best as possible. A Monte-Carlo simulation quantifies the probability of different model outcomes for variations in simulation parameters or options. This technique needs a lot of model runs and is therefore not practicable for long-lasting model simulations. Finally, benchmarking to international standards gives a quantification of model uncertainty.

Ultimately, modellers need to communicate uncertainty. This may imply that the models have to have acceptable levels of uncertainty before you communicate the outputs, because otherwise, the faith in the models is lost. Explaining and showing model uncertainty is in

itself a difficult part, because the results must be easily understood. A technique which is rather well-known are confidence intervals around the model results. Another technique for presenting uncertainty, but more difficult to understand, are probabilistic measures.

A final remark is that dealing with uncertainty should be a modeller's selling point, not something to hide!

Reference

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Appendix I MODEL INVENTORY

Name of model: MesoHABSIM
Contact (name, address, e-mail, phone, webpage etc.) Piotr Parasiewicz
 Instream Habitat Program
[\(http://www.dnr.cornell.edu/research/IHP/\)](http://www.dnr.cornell.edu/research/IHP/)
 Department of Natural Resources
 Cornell University
 306 Fernow Hall
 Ithaca, NY 14853
 tel: (607) 255 6578
 cell: (607) 227 5619
 fax and voice mail: (208)728-7305
 email : pp67@cornell.edu
<http://www.dnr.cornell.edu/facstf/parasiew.htm>
Ownership Cornell University, Department of Natural Resources
General objective: Instream flow model for river restoration planning
Spatial scale: Mesoscale: 100m
Temporal scale:

Physical (hydraulics,
 morphology, solid material)
 Hydrologic
 Biologic (Preference curves etc.)
 Water quality
 Interfaces available
 Preprocessors

Physical (hydraulics,
 morphology, sediment transport)
 Hydrologic
 Biologic: pure habitat, single
 species vs. communities, life
 cycle
 Biologic: prognoses of
 population dynamics
 Water quality

Physics
 Hydrologic
 Biologic
 water quality
Results presented as
 Interfaces available
 Postprocessors
 Applied studies
 (objective, ecoregion)
Validation
quantitative/qualitative
Platform (Windows/unix etc.)

Applicable model

User friendliness (0..10)

Source-codes *

**Handbooks & further
information**

Most relevant publications

Technical reports

available? (language?)

Name of model:	5M7
Contact (name, address, e-mail, phone, webpage etc.)	Yann Le Coarer eMail : yann.lecoarer@cemagref.fr CEMAGREF - Groupement d'Aix en Provence B.P. 31 - Le Tholonet – 13612 Aix en Provence Cedex 1 - FRANCE Telephone : 04 42 66 99 77 (ligne directe) 04 42 66 99 72 (secretariat) 04 42 66 99 10 (standard) Fax : 04 42 66 99 34 country phone number : 33 (e.g. 33 4 42 66 99 77) http://www.aix.cemagref.fr/htmlpub/divisions/Hyax/hyax.htm Hydrobiology reserach unit of Cemagref Aix en Provence
Ownership	Hydrobiology reserach unit of Cemagref Aix en Provence
General objective:	Fish habitat model for cyprinids
Spatial scale:	Usually reaches of one kilometer
Temporal scale:	Runs with steady flow comparisons of both physical and biological collected data. Time series of discharge implementation, in project
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Morphology by total station and stratified irregular sampling, velocity and roughness measurements. Utilisation of a special GIS for interpolation, Triangular Irregular Network,
Hydrologic	none
Biologic (Preference curves etc.)	electro fishing subunits, recording of their spatial localisation
Water quality	none
Interfaces available	For calculation of volume percentage of crossing clusters of depth and mean velocity : Transmeso (irregular sampling), Tranrepmeso (transects). 5M7 (under construction)
Preprocessors	Data input module included, alternatively ascii files
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	3-D digital river bed geometry, averaged flow velocities, local water depth, mapping of roughness /depth ratio, crossing clusters of depth and mean velocity mapping
Hydrologic	Comparison of volume/surface percentage of crossing clusters of depth and current velocity for different discharge.
Biologic: pure habitat, single species vs. communities, life cycle	Calculation of suitable indexes for taxa per crossing clusters of depth and current velocity Taxa Habitat quality maps.
Biologic: prognoses of population dynamics	Calculation of fish densities per suitable habitat that allows comparisons for different measurements campaign.
Water quality	none
<u>Numerical solutions:</u>	
Physics	River morphology: special interpolation program for depth Perform simple hydraulic calculations but the best way is to use results from external hydraulic programs (a special interface has been build for 3D SSIIM from SINTEF) .
Hydrologic	None
Biologic	Calculation of suitable indexes for taxa per crossing clusters of depth and current velocity
water quality	None

Results presented as	Figures, Maps, ascii files
Interfaces available	None
Postprocessors	None
Applied studies (objective, ecoregion)	instream flow studies
Validation quantitative/qualitative	Virtual simulations to assess the algorithm, first part of the model taxa length related to depth and velocity have been tested on a another data set.
Platform (Windows/unix etc.)	Windows
Applicable model	Free for scientific purpose and noncommercial projects
User friendliness (0..10)	1 for the GIS, 6 for the two little software transmeso & transrepmeso, 1 for 5M7 (under construction)
Source-codes *	Possibly yes for further joint development
Handbooks & further information	Under construction
Most relevant publications	Under construction
Technical reports available? (language?)	No (only confidential reports)

Name of model:	SWAN (Shallow Water Numerical Model)
Contact (name, address, e-mail, phone, webpage etc.)	Dr. Janos Jozsa, Budapest University of Technology and Economics, Muegyetem rkp 3, Kmf 5 H-1111 Budapest, HUNGARY, Phone: +36 1 463-1863 Fax: +36 1 463-1879 e-mail: kramer@vit.bme.hu web page: www.vit.bme.hu/kt/
Ownership	BUTE Department of Hydraulic and Water Resources Engineering
General objective:	Simulation of unsteady, free-surface flow and transport
Spatial scale:	Horizontal: km, vertical: m
Temporal scale:	Days, usually with 5-50 s time step
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	On equidistant Cartesian grids: terrain model, coverage map of hydraulic and sediment properties
Hydrologic	Time series of discharge, water level, wind, precipitation, water loss (infiltration+evaporation)
Biologic (Preference curves etc.)	None
Water quality	None
Interfaces available	ASCII (files or Windows Clipboard)
Preprocessors	Included in the application
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	2-D field of following: depth averaged flow velocities, water depth, wind and bottom shear stress, wave field, sediment concentrations of up to 5 size classes simultaneously
Hydrologic	Bed change, flood statistics. Time series of the grid-based physical information at selected locations.
Biologic: pure habitat, single species vs. communities, life cycle	None
Biologic: prognoses of population dynamics	None
Water quality	2-D residence time field
<u>Numerical solutions:</u>	
Physics	2-DH unsteady shallow water equations, giving depth and depth-averaged velocities. Sediment transport: advection-dispersion-(erosion-deposition). Explicit time stepping, finite difference approximation
Hydrologic	None
Biologic	None
Water quality	Residence time as advection-dispersion with zero-order reaction kinetics
Results presented as	Plane and axonometric figures, ASCII grids and time series
Interfaces available	None
Postprocessors	None
Applied studies (objective, ecoregion)	Wind-induced flow and suspended sediment transport in shallow lakes occasionally with reed cover. Flow in river reaches.
Validation	Against field measurements of current velocity and turbidity

quantitative/qualitative**Platform** (Windows/unix etc.) Windows**Availability of models****Applicable model** No**User friendliness** (0..10) 6**Source-codes** * No**Handbooks & further** User guide (no scientific background)**information****Most relevant publications** Working on it...**Technical reports** Yes, in Hungarian**available?** (language?)

Name of model:	SSIIM
Contact (name, address, e-mail, phone, webpage etc.)	Nils Reidar B. Olsen, www.bygg.ntnu.no/~nilsol/ssiimwin
Ownership	Nils Reidar B. Olsen
General objective:	Hydraulic simulations, especially with regards to sediment transport
Spatial scale:	1 mm to several km. Also suited for computation around physical constructions, such as intakes or bridge pillars.
Temporal scale:	Steady flow + time dependent flow with temporal scale from fractions of seconds to decades
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	coordinates of bed levels in the river, spatial variation of roughness, spatial variation of bed material size distribution and magnitude, water discharge, water level, sediment inflow
Hydrologic	water levels, discharge, sediment inflow
Biologic (Preference curves etc.)	Preference curve for fish habitat studies, algae growth parameters, parameters in algae sink/rise velocity formula, initial concentration of algae
Water quality	inflow concentration of water quality parameters, initial distribution of water quality parameters, parameters for the sink/source terms in the dispersion equations
Interfaces available	graphical user interface with interactive grid editor
Preprocessors	The model includes an interactive grid editor and a roughness editor. A surface modeling programme can be useful, such as Surfer, but is not required.
<u>Output data</u>	
Physical (hydraulics, morphology, sediment transport)	3D spatial variation of water velocity, sediment concentration, turbulence, pressure. 2D variation in bed level changes, water levels, bed sediment composition, bed form roughness, bed shear stress.
Hydrologic	Time series of water levels, bed levels, velocities, sediment concentration etc.
Biologic: pure habitat, single species vs. communities, life cycle	habitat quality maps, maps of algal concentration
Biologic: prognoses of population dynamics	algal growth and interaction with water quality parameters as oxygen concentration, nutrients etc.
Water quality	3D spatial and temporal variation in water quality concentrations (particle distribution, temperature and other parameters)
<u>Numerical solutions:</u>	
Physics	Solves the 3D Navier Stokes equations with the k-epsilon turbulence model. Algorithms for sediment movements, bed level changes, water level computations, flood waves, wetting/drying, dynamic movements of water body in vertical and horizontal directions.
Hydrologic	None
Biologic	computes habitat from preference functions and computed water velocities/depth. computes growth and movement of free-flowing algae in 3D
water quality	solves the convection-diffusion equation for multiple water quality constituents, including source/sink terms for interaction

Results presented as	between the variables.
Interfaces available	velocity vectors, contour plots, 3D OpenGL colour graphics
Postprocessors	Open GL, Excel
Applied studies (objective, ecoregion)	includes a post-processor with multiple graphics options. can also use Techplot A large number of instream flow studies for rivers in Norway. Dispersion of pollutants in lakes in Norway and the UK. Algae movements in lakes in the UK. Sediment studies of reservoirs in Costa Rica and Pakistan. A large number of tests against data from physical model studies, especially with regards to sediment transport.
Validation quantitative/qualitative	Predicted vs. observed: fish habitat, velocity vector fields, sediment concentration, bed level changes, changes in water depth, algae concentration, turbidity, temperature, radioactive tracer concentrations. ref.: http://www.bygg.ntnu.no/~nilsol/
Platform (Windows/unix etc.)	Windows NT4/98/ME/2K, OS/2
Applicable model	Downloaded from the web. Free for all purposes, but not recommended for commercial use
User friendliness (0..10)	6-8 (People have learned to use the model by no other help than reading the User's Manual)
Source-codes *	Some parts available for selected researchers for development and integration purposes
Handbooks & further information	120 page User's Manual. Several books covering the theory of the model.
Most relevant publications	User's Manual, books, a large number of international publications. See www.bygg.ntnu.no/~nilsol/cfd
Technical reports available? (language?)	several books on the web page www.bygg.ntnu.no/~nilsol/cfd

Name of model:	For the moment non name "Hydrobiogeochemical model"
Contact (name, address, e-mail, phone, webpage etc.)	Sabine Sauvage – CESAC (Ecological Center of Aquatic Ecosystems) : 29 rue Jeanne Marvig 31055 Toulouse Cedex 4 – France – E-mail : sauvage@cesac.cemes.fr Bernard Caussade – IMFT (Institut of Fluid Mechanics of Toulouse) E-mail : caussade@imft.fr
Ownership	1) IMFT (Institut of Fluid Mechanics of Toulouse) 2)CESAC (Ecological Center of Aquatic Ecosystems)
General objective:	Simulation of hydrobiogeochemical functioning
Spatial scale:	hundred kilometers
Temporal scale:	Runs with time series of discharge, usually a week with hourly discharge, it can run with mean daily discharge
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Cross section data, water table elevation, substratum, cover type, pool and riffle type, damming, overflow, confluence
Hydrologic	Discharge or time series of discharge or water table elevation
Biologic (Preference curves etc.)	(under construction)
Water quality	transport and transformation of Nitrogen
Interfaces available	none
Preprocessors	ascii files
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	1D hydraulic results : averaged flow velocities, water depth, bottom shear stress, wetted perimeter, Froude number, wetted section
Hydrologic	Steady state and unsteady state time series
Biologic: pure habitat, single species vs. communities, life cycle	none
Biologic: prognoses of population dynamics	none
Water quality	NH4 and NO3
<u>Numerical solutions:</u>	
Physics	resolution of the complete Saint Venant equations
Hydrologic	resolution of the complete Saint Venant equations
Biologic	none
water quality	uncoupled numerical resolution of the transport equation
Results presented as	
Interfaces available	none
Postprocessors	none
Applied studies (objective, ecoregion)	run of a great river , hydrobiogeochemical functioning during low water period, application for the management of Waste Water Treatment Plant (Garonne – South-West of France), optimisation of collected data, input data for a groundwater model applied to a wetland
Validation	from data
quantitative/qualitative	
Platform (Windows/unix etc.)	DOS
<u>Availability of models</u>	
Applicable model	Free for scientific purpose and noncommercial projects,
User friendliness (0..10)	5

Source-codes *	for further joint development
Handbooks & further information	Under construction, courses available
Most relevant publications	Scientific papers
Technical reports available? (language?)	Yes (in french)

Name of model:	RIVPACS III
Contact (name, address, e-mail, phone, web page etc.)	Software Sales and Support Institute of Hydrology Wallingford Oxfordshire OX10 8BB UK Tel: +44 (0) 1491 838800 Fax: +44 (0) 1491 692424
	E-mail: softdev@nwl.ac.uk WWW: http://www.nwl.ac.uk/ih
Ownership	Centre for Ecology & Hydrology (NERC)
General objective:	Biological assessment
Spatial scale:	Reach
Temporal scale:	Season to annual
Input data	
Physical (hydraulics, morphology, solid material)	Maps (distance from source), latitude, longitude. Substratum (4 size types).
Hydrologic	None
Biologic (Preference curves etc.)	Existing databases of invertebrates (family to species)
Water quality	Nutrients, alkalinity, chloride, etc.
Interfaces available	Multivariate analysis, Classification affinities
Preprocessors	Batch-mode data input from ASCII text files
Output data	
Physical (hydraulics, morphology, sediment transport)	None
Hydrologic	None
Biologic: pure habitat, single species vs. communities, life cycle	Site-specific predictions of the macroinvertebrate fauna based on environmental features, and sets a "target" of the fauna to be expected in the absence of environmental stress
Biologic: prognoses of population dynamics	None
Water quality	None
Numerical solutions	
Physics	None
Hydrologic	None
Biologic	Comparison of the target with the observed fauna at the site forms the basis of the biological assessment
water quality	None
Results presented as	Probability of occurrence of families and accompanying BMWP index
Interfaces available	None
Postprocessors	None
Applied studies (objective, ecoregion)	Numerous studies of biological assessment in Great Britain, Australia (with the derivative AusRivAs), Canada, Spain. Predictions on a Regional basis. Base-line data, water quality and pollution, River management, flow regulation, conservation.
Validation quantitative/qualitative	Predicted target fauna vs observed fauna.

Platform (Windows/unix etc.)	Windows
Availability of models	
Applicable model	License for commercial projects from the Centre for Ecology and Hydrology, UK.
User friendliness (0..10)	10
Source-codes *	10
Handbooks & further information	User manual, Booklet with practical sessions, procedures manual, video, courses.
Most relevant publications	Scientific papers
Technical reports available? (language?)	Yes. English.

Name of model:	RHYHABSIM
Contact (name, address, e-mail, phone, webpage etc.)	Ian Jowett, National Institute of Water & Atmospheric Research, PO Box 11-115, Hamilton, New Zealand. Phone: 64-7-8561793 Fax: 64-7-8560151 Email: i.jowett@niwa.cri.nz
Ownership	Ian Jowett
General objective:	1d Hydraulic Analysis and Habitat Evaluation
Spatial scale:	Cross-section/Reach/River
Temporal scale:	none
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Cross-section data (e.g., depth, velocity, and any other attributes), Section water level, location or weighting
Hydrologic	Calibration data (discharge and level either at each cross-section or at downstream section)
Biologic (Preference curves etc.)	Suitability curves for depth, velocity and attributes
Water quality	Water temperature modeling data
Interfaces available	
Preprocessors	Data input module included, alternatively ascii, excel, csv files
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	Hydraulic parameters at point, cross-section, reach, river scales. Particle tracking dispersion and deposition model. Flushing flow and sediment deposition
Hydrologic	Discharge water level rating curves
Biologic: pure habitat, single species vs. communities, life cycle	Areas of suitable habitat (WUA). Varying flow analysis of habitat suitability Fish passage analysis
Biologic: prognoses of population dynamics	none
Water quality	Downstream water temperatures
<u>Numerical solutions:</u>	
Physics	Calculation of water depth and velocity at points across the section using stage/discharge curves and conveyance with calibration for velocity distribution. Water surface profile modeling. Particle tracking dispersion model based on stream tubes
Hydrologic	Calculation of stage/discharge curves by hydraulic and curve fitting methods
Biologic	Habitat calculated from suitability curves.
water quality	Downstream water temperatures from heat budget. Numerical solution
Results presented as	Graphs, 2d maps, & tables
Interfaces available	
Postprocessors	Paste into windows applications, word, excel, powerpoint
Applied studies (objective, ecoregion)	Used extensively for flow regime assessments for water abstractions and hydro-electric operations in rivers of all size, including those with islands & braiding. Used to quantify habitat and stream morphology in research
Validation quantitative/qualitative	Mosley, M. P., and I. G. Jowett. 1985. Fish habitat analysis using river flow simulation. New Zealand Journal of Marine and Freshwater Research 19:293-309.

	Jowett, I. G. 1992. Models of the abundance of large brown trout in New Zealand rivers. <i>North American Journal of Fisheries Management</i> 12(3):417-432.
Platform (Windows/unix etc.)	Windows 98,2000,NT
Applicable model	Free for scientific purposes and noncommercial projects, for commercial projects licence available
User friendliness (0..10)	10
Source-codes *	No
Handbooks & further information	Help file with programme. Jowett, I. G. 1996: RHYHABSIM, river hydraulic and habitat simulation, computer manual. NIWA, Hamilton
Most relevant publications	Jowett, I. G. 1990. Factors related to the distribution and abundance of brown and rainbow trout in New Zealand clear-water rivers. <i>New Zealand Journal of Marine and Freshwater Research</i> 24(3):429-440. Jowett, I. G. 1992: River hydraulics and instream habitat modelling for river biota. In: Mosley, M. P. ed. <i>Waters of New Zealand</i> . pp. 249-263. Wellington, New Zealand Hydrological Society. Jowett, I. G. 1997: Instream flow methods: a comparison of approaches. <i>Regulated rivers</i> 13: 115-127.
Technical reports available? (language?)	Many (English)

Name of model:	PHABSIM for Windows
Contact (name, address, e-mail, phone, webpage etc.)	Mike Dunbar CEH Wallingford mdu@ceh.ac.uk +44 1491 692403
	Prof Thom Hardy Institute for Natural Systems Engineering Utah State University hardy@aaron.cce.usu.edu
Ownership	INSE group
General objective:	Simulation of fish habitat quality
Spatial scale:	Usually reaches of several hundred meters. Upscaling to sector scale using habitat mapping
Temporal scale:	Runs with time series of discharge, daily mean flows CEH time series module (MS-DOS) can handle any flow time-scale
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Cross section data, water table elevation, substratum (user defined size classes). Works in metric or imperial units
Hydrologic	Discharge or time series of discharge
Biologic (Preference curves etc.)	1) Univariate preference curves 2) Ability to use multivariate curves under development
Water quality	None
Interfaces available	PHABSIM for DOS files
Preprocessors	Import Ascii files.
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	Cross-section river bed geometry, local depth averaged flow velocities, local water depth, substratum
Hydrologic	Steady state time series
Biologic: pure habitat, single species vs. communities, life cycle	Weighted usable areas (WUA), for multiple species / life stages. Habitat time series, duration curves Can output hydraulic data in very user friendly form e.g. spreadsheet habitat calculations
Biologic: prognoses of population dynamics	None
Water quality	None
<u>Numerical solutions:</u>	
Physics	Three 1-D water surface elevation hydraulic models: Rating curve (self-calibrating) Mannings equation (user-calibrated) Water surface profile (step backwater) (user-calibrated) Two pseudo 2-D velocity models: Single velocity set + manning's equation (can produce hybrid models for different flow ranges) Three velocity sets: regression
Hydrologic	Uses input data
Biologic	Calculates habitat preferences (see input data)
water quality	None

Results presented as	Figures, graphs, ascii files
Interfaces available	None
Postprocessors	None
Applied studies (objective, ecoregion)	Numerous instream flow studies, some river restoration projects. Majority in UK for salmonid species in Chalk and upland streams. Some cyprinid applications. Many ongoing applications in USA, thousands of applications completed using PHABSIM for DOS.
Validation quantitative/qualitative	Major UK validation study completed in 2001. Contact MJD for details.
Platform (Windows/unix etc.)	Windows
<u>Availability of models</u>	
Applicable model	Free for scientific purpose and noncommercial projects, contact TBH for details
User friendliness (0..10)	8
Source-codes *	N/k
Handbooks & further information	Courses available
Most relevant publications	(Scientific papers)
Technical reports available? (language?)	Various (see below)

Name of model:	“NORSALMOD”
Contact	Atle Harby/Knut Alfredsen SINTEF Energy Research Sem Saelandsvei 11 7465 Trondheim NORWAY Phone +47 73 59 39 20 Fax + 47 73 59 72 50 knut.alfredsen@energy.sintef.no
Ownership	Norwegian Directorate of Nature Management
General objective:	Modelling of population dynamics of Atlantic salmon in Norwegian rivers
Spatial scale:	River, or part of river
Temporal scale:	Years. Seasonal studies based on daily input
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Water flow, water temperature, habitat data
Hydrologic	None
Biologic (Preference curves etc.)	Fish population dynamics, temperature based growth
Water quality	None
Interfaces available	Windows based interface
Preprocessors	Data preparation
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	None
Hydrologic	None
Biologic: pure habitat, single species vs. communities, life cycle	Results applies for taxa
Biologic: prognoses of population dynamics	Yes
Water quality	None
<u>Numerical solutions:</u>	
Physics	Hydrologic routing. Temperature
Hydrologic	Possible inflow computation
Biologic	Growth and mortality
water quality	None
Results presented as	Graphs and tables
Interfaces available	
Postprocessors	Excel
Applied studies (objective, ecoregion)	Testcase in Orkla
Validation	In progress (quantitative)
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows
<u>Availability of models</u>	
Applicable model	under construction
User friendliness (0..10)	2
Source-codes *	No
Handbooks & further	No

information

Most relevant publications Project report in Norwegian

Technical reports No

available? (language?)

Name of model:	MORRES
Contact (name, address, e-mail, phone, webpage etc.)	Harm Duel, Martin Baptist, Guda van der Lee. WL delft hydraulics, harm.duel@wldelft.nl
Ownership	WL delft hydraulics
General objective:	Availability of ecotopes, habitat availability and quality (vegetation, macrobenthos, fish, reptiles, amphibians, birds, mammals). Time-dependent succession of vegetation.
Spatial scale:	For river systems: from local level (floodplain, 1-5 km river reach) to regional level (river and floodplains up to 100 km reach)
Temporal scale:	Dependent on input parameters.
<u>Input data:</u>	Model requires spatial input from numerical models (1D or 2D).
Physical (hydraulics, morphology, solid material)	The parameter use is dependent on the application: velocity, water depth, flooding frequency and duration, salinity, temperature, turbidity, substratum, sedimentation / erosion rate and so on. Other information may be added, for example for ecotopes and vegetation modelling, vegetation management and grazing intensity.
Hydrologic	
Biologic (Preference curves etc.)	Univariate ecological optimum curves based on expert rules, monitoring data and field surveys. Sometimes based on statistical analyses (macrobenthos, vegetation). Combination of parameters through the minimum rule (most limiting factor).
Water quality	Water quality input is possible, model requires GIS-based (spatial) input on water quality parameters, kind of data is depending on the habitat requirements of the species selected
Interfaces available	Links to DELFT3D
Preprocessors	no
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	--
Hydrologic	--
Biologic: pure habitat, single species vs. communities, life cycle	Habitat availability and quality maps, weighted usable areas, hydraulic suitability indices, time series of vegetation cover maps
Biologic: prognoses of population dynamics	For fauna only independent single species habitat, no interactions, no population growth, mortality, migration.
Water quality	--
<u>Numerical solutions:</u>	
Physics	
Hydrologic	
Biologic	Minimum rule applied for combination of parameters
water quality	
Results presented as	Tables, maps
Interfaces available	Conversion to ArcView
Postprocessors	--
Applied studies (objective, ecoregion)	Numerous projects all over the world, not only related to river systems (rivers, lakes, wetlands, estuaries, coastal waters). The

Validation quantitative/qualitative	Netherlands; policy analysis on water management, environmental impact studies of river ecological rehabilitation measures or flood protection measures Comparison with field observations and monitoring data. Uncertainty analysis with respect to the quality of the data (input) and expert opinions on ecological optimum curves
Platform (Windows/unix etc.)	Windows.
Applicable model	At this moment the availability of the model is limited to main clients, user friendly versions will be available for commercial studies (license) within the next years
User friendliness (0..10)	7
Source-codes *	VB-code
Handbooks & further information	Handbook is available, Numerous publications, information is not on the web available yet
Most relevant publications	
Technical reports available? (language?)	

Name of model:	Saprob
Contact (name, address, e-mail, phone, webpage etc.)	Ciril Krušnik National Institute of Biology, Vecna pot 111, SI-1000 Ljubljana, Slovenia Ciril.Krusnik@uni-lj.si
Ownership	Ciril Krušnik National Institute of Biology
General objective:	ANALYSIS OF INDICATOR VALUES OF SOME FRESHWATER ORGANISMS FOR ASSESSING WATER QUALITY IN SLOVENIA
Spatial scale:	Area of the Republic of Slovenia
Temporal scale:	4 years, two sampling per year, more than 100 sites
Input data:	
Physical (hydraulics, morphology, solid material)	Temperature, pH, conductivity, suspended matter, hardness,
Hydrologic	Discharge
Biologic (Preference curves etc.)	Presence of E. coli
Water quality	BOD5, NO3, NO2, NH4, PO4, Cl, SO4, HCO3, Mg, Ca, K, SiO2, chemical oxygen demand (KMnO4, K2Cr2O7)
Interfaces available	CANOCO
Preprocessors	MS Excel
Output data:	
Physical (hydraulics, morphology, sediment transport)	Biplot with environmental (abiotic) and species (biotic) variables
Biologic: prognoses of population dynamics	Saprobic values (without detailed saprobic valence)
Biologic water quality	Saprobic values can be used for biological assessment of water quality
Results presented as	Tables, ascii files
Interfaces available	None
Postprocessors	None
Applied studies (objective, ecoregion)	Biological assessment of water quality
Validation	Comparison of values from literature with data from experiment
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows
Applicable model	
User friendliness (0..10)	1
Source-codes *	0
Handbooks & further information	No
Most relevant publications	Scientific paper
Technical reports available? (language?)	None

<u>Name of model:</u>	LAKES
Contact (name, address, e-mail, phone, webpage etc.)	Dr Ierotheos Zacharias National Centre for Marine Research Agios Kosmas, Hellinikon 166 04 Athens Greece Tel. 0030 10 9820213, Fax: 9811713 Email: thakis@ncmr.gr
Ownership	Dr Ierotheos Zacharias
General objective:	Water Circulation in Lakes during winter homogeneity
Spatial scale:	Any scale; depend on data grid
Temporal scale:	Hours
<u>Input Data:</u>	
Physical (hydraulics, morphology, solid material)	Wind stress at water level; river discharges; air pressure maps; surface heat fluxes
Hydrologic	
Biologic (Preference curves etc.)	
Water quality	Temperature distribution
Interfaces available	
Pre-processors	
<u>Output Data</u>	
Physical (hydraulics, morphology, sediment transport)	None
Hydrologic	Surface seiche; current direction and velocity; water level
Biologic: pure habitat, single species vs. communities, life cycle	None
Biologic: prognoses of population dynamics	None
Water quality	Temperature
<u>Numerical Solutions</u>	
Physics	Calculates water level set-up; current direction and velocity; surface seiche; temperature distribution; all output through a linear model so that during winter when the lake is not-stratified and both water levels and current amplitudes are proportional to wind stress
Hydrologic	
Biologic	
Water quality	
Results presented as:	Time Series
Interfaces available	
Post-processors	
Applied studies (objective, eco-region)	Lake circulation
Validation quantitative/qualitative	Comparison of time -series produced with observed time-series in the field
Platform (Windows/UNIX etc.)	DOS
<u>Availability of models</u>	

Applicable model	FORTRAN 77, 500 lines of code, 1MB on PC
User friendliness (0..10)	1
Source-codes *	7
Handbooks & further information	
Most relevant publications	Zacharias, I., and Ferentinos, G., 1997. A numerical model for the winter circulation in Lake Trichonis, Greece. <i>Environmental Modelling and Software</i> , 12(4), 311-321
Technical reports available? (language?)	

Name of model:	CORMIX 1-2-3
Contact (name, address, e-mail, phone, webpage etc.)	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY ENVIRONMENTAL RESEARCH LABORATORY 960 COLLEGE STATION ROAD ATHENS, GEORGIA 30605-2720 OFFICE OF RESEARCH AND DEVELOPMENT www.usepa.gov
Ownership	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
General objective:	CORMIX is a series of software subsystems for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. Its major emphasis is on the prediction of plume geometry and dilution characteristics within a receiving water's initial mixing zone so that compliance with regulatory constraints may be judged. The system also predicts the behaviour of the discharge plume at larger distances. The highly user-interactive CORMIX system is implemented on microcomputers (IBM-PC, or compatible), and consists of three subsystems: CORMIX1 for submerged single port discharges, CORMIX2 for submerged multiport diffuser discharges, CORMIX3 for buoyant surface discharges
Spatial scale:	Any scale; usually several km
Temporal scale:	Seconds; Minutes; Hours depending on hydrology and extend of prediction limits set by user
Input Data:	
Physical (hydraulics, morphology, solid material)	Ambient conditions (geometry, bounded or unbounded case); Outflow conditions (geometry, distance from banks, outflow angle, vertical and horizontal angle); roughness in Manning or Darcy-Weibach friction factor, distance of outflow from shore
Hydrologic	Ambient conditions (density, salinity, temperature currents and winds); Outflow conditions (density, salinity, temperature currents and winds; discharge volume)
Biologic (Preference curves etc.)	
Water quality	Pollutant concentration and characteristics at point of outflow
Interfaces available	
Pre-processors	
Output Data	
Physical (hydraulics, morphology, sediment transport)	
Hydrologic	(a) the date and time of the analysis section, (b) a complete echo of the input data, (c) the calculated flux, length scale and non-dimensional parameter values, (d) the flow classification used for predicting plume trajectory and mixing, (e) the coordinate system used in the analysis, (f) a summary of the near-field hydraulic mixing zone (HMZ) conditions, (g) the far-field locations where the plume becomes essentially fully mixed (i.e. uniform concentration) in the horizontal and vertical directions, (h) a summary of the toxic dilution zone (TDZ) conditions, and (i) a summary of the regulatory mixing zone (RMZ) conditions.
Biologic: pure habitat, single species vs. communities, life cycle	

Biologic: prognoses of population dynamics	
Water quality	Near-field bio-accumulation patterns, concentration of pollutant along the centerline
Numerical Solutions	
Physics	
Hydrologic	Equations of mixing between 2 different water systems
Biologic	
Water quality	
Results presented as:	Time Series with data analyses and auto-configured result explanation system and advisor; plots
Interfaces available	
Post-processors	
Applied studies (objective, eco-region)	Outflow of canals in rivers/lakes/sea; outflow of small streams/torrents in rivers/lake/sea
Validation quantitative/qualitative	
Platform (Windows/UNIX DOS etc.)	
Availability of models	
Applicable model	Free directly from EPA either from the website or as a free CD-rom containing all models used and approved by EPA for surface and groundwater, air, soil etc.
User friendliness (0..10)	10
Source-codes *	10
Handbooks & further information	Detailed User manuals either from website or with the software in WordPerfect 5.1 for DOS format
Most relevant publications	<p>Conides, A., and Zouganeli, P., 2000. Modelling the effects of Galatas city irrigation system on the adjacent Evinos river delta in Central-Western Greece. <i>J. Appl. Irrig. Science</i>, 35(1), 101-117</p> <p>Conides, A., Hunter, S.A., and Zouganeli, P., 2000. Modelling the effects of Ferres irrigation system (Evros river, North Greece) on the coastal lagoons. International Conference, (Tsihrintzis V.A., Korfiatis, G.P., Katsifarakis, K.L., and Demetracopoulos, A.C., Eds.), Protection and Restoration of the Environment V., Thassos Island, Greece, 3-6 July 2000, 203-211</p> <p>Jirka G. H. and R. L. Doneker (1991), "Hydrodynamic Classification of Submerged Single Port Discharges", <i>J. Hydraulic Engineering, ASCE</i>, Vol.117, HY9.</p> <p>Jirka G. H. and P. J. Akar, "Hydrodynamic Classification of Submerged Multipoint Diffuser Discharges," <i>J. Hydraulic Engineering, ASCE</i>, (117), HY9, 1991.</p> <p>Jirka G. H., "Multipoint Diffusers for Heat Disposal: A Summary," <i>J. Hydraulics Division, ASCE</i>, (108), HY12, pp. 1423-68, 1982.</p> <p>Fischer, H. B. et al., <i>Mixing in Inland and Coastal Waters</i>, Academic Press, New York, 1979.</p> <p>Chow, V. T., <i>Open Channel Hydraulics</i>, McGraw-Hill, New York, 1959.</p>
Technical reports available? (language?)	<p>Holley, E. R. and G. H. Jirka, "Mixing in Rivers," Technical Report E-86-11, U.S. Army Corps of Engineers, Washington, DC, 1986.</p> <p>"Technical Support Document for Water Quality-based Toxics Control," U.S. EPA, Office of Water, Washington, DC, September, 1991.</p> <p>"Draft: Management Plan for Puget Sound," Puget Sound Water Quality</p>

- Authority, Olympia, WA, 1989.
- "Draft: Assessment and Control of Bioconcentratable Contaminants in Surface Waters," U.S. EPA, Office of Water, Washington, DC, March, 1991.
- "Technical Support Document for Water Quality-based Toxics Control," U.S. EPA, Office of Water, Washington, DC, 1985.
- Doneker, R. L., and G. H. Jirka, "CORMIX1: An Expert System for Mixing Zone Analysis of Conventional and Toxic Single Port Aquatic Discharges (EPA 600/600/3-90/012)," U.S. EPA, Environmental Research Laboratory, Athens, GA, 1990.
- Akar, P. J. and G. H. Jirka, "CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Submerged Multiport Discharges," Technical Report of the DeFrees Hydraulics Laboratory, School of Civil and Environmental Engineering, Cornell University, Ithaca, N.Y. (Also in print as an NTIS report, USEPA, Environmental Research Laboratory Athens, Ga.), 1991.
- Jones, G. R. and G. H. Jirka, "CORMIX3: An Expert Sytem for the Analysis and Prediction of Buoyant Surface Discharges," Technical Report, DeFrees Hydraulics Laboratory, School of Civil and Environmental Engineering, Cornell University, Ithaca, N.Y., 1991.

<u>Name of model:</u>	ALCON 3.0
Contact (name, address, e-mail, phone, webpage etc.)	Dr Alexis J. Conides 130 Aristotelous str., GR-112 51 Athens Greece Tel & Fax ++30 10 8642944 conides@ncmr.gr, dac@aquabt.com, akoni@tee.gr
Ownership	Dr Alexis J. Conides Mr Vasilios Alexopoulos
General objective:	Estimation of fish farming effluent
Spatial scale:	Not in scale; the fish farm is considered as a point-pollution source
Temporal scale:	Annual and daily outputs during production
<u>Input Data:</u>	
Physical (hydraulics, morphology, solid material)	Form of farm; cages and utilized volumes; average depth
Hydrologic	None
Biologic (Preference curves etc.)	Stocked number of fry; marketable size target
Water quality	Natural concentration of nitrogen and phosphorus;
Interfaces available	None
Preprocessors	Data input sheet provided
<u>Output Data</u>	
Physical (hydraulics, morphology, sediment transport)	None
Hydrologic	None
Biologic: pure habitat, single species vs. communities, life cycle	None
Biologic: prognoses of population dynamics	None
Water quality	Production of nitrogen and phosphorus output on a daily or per production period basis (mg/L; kg); estimation of N/P ratio; total outputs and per category outputs (faeces, food waste, liquid excretion)
<u>Numerical Solutions</u>	
Physics	
Hydrologic	
Biologic	
water quality	Production of nitrogen and phosphorus output on a daily or per production period basis (mg/L; kg); estimation of N/P ratio; total outputs and per category outputs (faeces, food waste, liquid excretion)
Results presented as	Tables
Interfaces available	
Post-processors	The data usually are in numerical format and are used in the US EPA approved model CORMIX 1-2-3 so that after the estimation of the effluent amounts and concentrations, the use is able to evaluate dispersion, 3D fluxes and their geometry in full 3D, timing of dispersion, concentrations along the

<p>Applied studies (objective, eco-region) Validation quantitative/qualitative Platform (Windows/UNIX etc.) <u>Availability of models</u> Applicable model User friendliness (0..10) Source-codes * Handbooks & further information Most relevant publications</p>	<p>dispersion route, dilutions and bioaccumulations. CORMIX 1-2-3 requires information on the geometry of the flux (point of outflow as well as depth and currents in the area so that it estimates the flux geometry and other parameters. Since the CORMIX 1-2-3 exists, the ALCON 3 producers did not include such calculations in the ALCON 3 model so that it is more friendly, does not require complicated data and the output is readily validated if needed.</p> <p>Environmental impact of aquaculture; resolution of coastal area conflicts; production estimation Predicted vs. actual values obtained by spectrophotometry</p> <p>Windows all platforms (Visual Basic)</p> <p>Free; was in the Internet until some time ago 10 7 Help files available with details</p> <p>Conides, A., Anastasopoulou, K. and Fotis G., 1993. Application of standard procedure for forecasting the maximum possible environmental impact of sea bream cage culture in Greece. <i>Int. J. Env. Ed. and Inf.</i>, University of Salford, 12(1): 49-58</p> <p>Conides, A., and Zouganeli, P., 2000. Modelling the effects of Galatas city irrigation system on the adjacent Evinos river delta in Central-Western Greece. <i>Irrig. Science j</i>, 35(1), 101-117</p> <p>Klaoudatos, S.D., Conides, A., and Chatziefstathiou, M., 1995. Modern methods for the estimation of the impact of cage farms on the marine environment. <i>Proc. 2nd Panhellenic Conference "Aquaculture: Research and Production"</i>, Hellenic Maricultures Association, Aliia '95, October 1995, Thessaloniki, Greece (in Greek)</p> <p>Klaoudatos S., Conides A. and Chatziefstathiou M., 1996. Assessment of the impact of the floating cage culture systems on the marine environment. <i>Proceedings of International Symposium for the protection and rehabilitation of the environment, Crete Polytechnic/Stevens Institute of Technology/KRIKOS</i>, 28-30 August 1996, Chania, Crete, 396-404</p> <p>Conides, A., and Alexopoulos, V., 1997. The estimation of environmental impact of cage farms: the new model ALCON 4.0 for Windows 3.x. <i>Proc. of the 8th Conference of Ichthyological Association of the Greek Ministry of Agriculture</i>, September 25-28 1997, Thessaloniki, Greece. (in Greek)</p> <p>Conides, A., and Parpoura, A., 1996. Evaluation of a new tool in environmental impact assessment studies: Forecasting the maximum BOD output from a marine cage farm. <i>World Aquaculture 96</i>, World Aquaculture Society, Bangkok,</p>
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Thailand, 29/1-2/2/1996, 88-89

Klaoudatos S., Conides A. and Chatziefstathiou M., 1996
Environmental impact assessment (EIA) studies in floating
cage culture systems in Hellas. Partnership in coastal
management (Eds. J. Taussik and J. Mitchell), Proceedings
of LITTORAL 1996 Congress, Portsmouth, UK, 525-533

Conides A., and Alexopoulos V.Em., 1997. The estimation of
floating cage fish farming output: presenting the ALCON
3.0 for Windows routine. Martinique 97 Congress,
EAS/WAS/CAA/ADA/ ADAM Congress, Martinique, May
4-9, 1997, 95-96

Conides A., and Alexopoulos V.Em., 1997. ALCON 3.0 for
Windows: A Visual Basic™ routine for the estimation of
the environmental impact of fish farms. MESAEP 1997
Congress, (accepted abstract)

Koussouris, Th., Fotis, G., and Conides, A., 1995. Environment
and aquaculture. Agriculture Bank of Greece Publications,
187 pp. (in Greek)

Technical reports available?
(language?)

Klaoudatos, S., Conides, A., and Chatziefstathiou, M., 1997.
Study of the structure and function of the coastal ecosystem
of Kalloni Bay (Lesvos Island) for the estimation of the
environmental problems and the proposal of a management
system. Final Technical Report, Ministry of Environment,
pp., 135 (in Greek)

Klaoudatos, S., and Conides, A., 1997. Impact of fish farming
on the marine and coastal environment of Evoia Island
(Central Greece). Final Technical Report, Prefecture of
Evoia Island, pp. 103 (in Greek)

Klaoudatos, S., and Conides, A., 1998. EIA of the TRIENA-
EVOIKOS O.E." fish farm with annual capacity of 150
tonnes., pp. 20 (in Greek)

Conides, A., Klaoudatos, S., Parpoura, A., Bogdanos, K.,
Diapoulis, A., Chatziefstathiou, M., and Kougioufas, P.,
1998. The interaction between aquaculture and the
environment in Greece. Final Technical Report, PENED 94
Project 1577/96, Ministry of Development, pp. 185 (in
Greek)

Name of model:	QUAL2E-IZH
Contact (name, address, e-mail, phone, webpage etc.)	Asst.Prof. Boris Kompare, Univ. of Ljubljana, Inst. of Sanitary Engineering (IZH), Hajdrihova 28, POB 3422, SI-1001 Ljubljana, Slovenia. tel.: +386-1-421-74-80, e-mail: bkompare@fgg.uni-lj.si
Ownership	Univ. of Ljubljana, IZH
General objective:	1D river water quality model, written after USEPA QUAL2E up to 11 quality constituents
Spatial scale:	streams, rivers
Temporal scale:	coupled with hydraulic – if steady state then automatically optimized until results are stable (seconds to hours)
Input data:	
Physical (hydraulics, morphology, solid material)	coupled to hydraulic model
Hydrologic	
Biologic (Preference curves etc.)	initial concentrations of coliforms
Water quality	initial concentrations of quality constituents (up to 10)
Interfaces available	to hydraulic model
Preprocessors	RAGLA – our own hydraulic model
Output data:	
Physical (hydraulics, morphology, sediment transport)	
Hydrologic	
Biologic: pure habitat, single species vs. communities, life cycle	
Biologic: prognoses of population dynamics	time and space (profiles) dependent concentrations of coliforms
Water quality	dynamics of water quality constituents in selected profiles
<u>Numerical solutions:</u>	
Physics	
Hydrologic	
Biologic	integration of diff. eq. using Simpson's rule and bisection of time interval until solution is within prescribed accuracy
Water quality	integration of diff. eq. using Simpson's rule and bisection of time interval until solution is within prescribed accuracy
Results presented as	tables and graphs
Interfaces available	none
Postprocessors	none
Applied studies (objective, ecoregion)	rivers and streams within Slovenia (middle Sava, including impoundment Vrhovo)
Validation quantitative/qualitative	both
Platform (Windows/unix etc.)	all Windows – uses DOS window
<u>Availability of models:</u>	
Applicable model	for commercial and universities research
User friendliness (0..10)	around 5
Source-codes *	Turbo Pascal 5.5
Handbooks & further information	very limited info in Slovenian language – is based on USEPA manual
Most relevant publications	a few articles in journals and on conferences
Technical reports available? (language?)	use USEPA manual and reports (English)

Name of model:	BfG ZooAuto
Contact (name, address, e-mail, phone, webpage etc.)	Michael Kinder German Federal Institute of Hydrologie (BfG) Postfach 200253 D-56002 Koblenz Phone +49 261 1306 5482 Fax +49 261 1306 5374 Email kinder@bafg.de www.bafg.de
Ownership	Kinder/BfG
General objective:	Simulation of fish habitat quality and population dynamics
Spatial scale:	Reaches of 5 to 30 km in units of 100 m of large and shipable rivers
Temporal scale:	Series of mean values weekly or monthly
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Cross section data Ecomorphological assessment values
Hydrologic	Discharge or time series of discharge
Biologic (Preference curves etc.)	Univariate preference curves Specific rules for growth, reproduction and migration Rules for intraspecific and interspecific interaction as competition among space and nutrients and predator-prey relationships
Water quality	none
Interfaces available	
Preprocessors	
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	1,5d flow velocity water depth
Hydrologic	
Biologic: pure habitat, single species vs. communities, life cycle	Habitat suitability maps for fish species
Biologic: prognoses of population dynamics	prognoses of densities of individuals
Water quality	
<u>Numerical solutions:</u>	
Physics	
Hydrologic	1d simulation of flow velocity, and water depth for given discharge with an heuristic approximation of 2 nd dimension (1,5d)
Biologic	Calculates habitat suitability based on preference curves Combination of a cellular automaton with an individual based model approach (these rules are depending on habitat suitability)
water quality	
Results presented as	ascii files, coloured maps
Interfaces available	none
Postprocessors	none
Applied studies (objective, ecoregion)	Test application in river Moselle
Validation	none
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows

Applicable model	model under development
User friendliness (0..10)	1
Source-codes *	Fortran/MatLAB
Handbooks & further information	none
Most relevant publications	in preparation
Technical reports available? (language?)	none

Name of model:	BfG Habitat
Contact (name, address, e-mail, phone, webpage etc.)	Michael Kinder German Federal Institute of Hydrologie (BfG) Postfach 200253 D-56002 Koblenz Phone +49 261 1306 5482 Fax +49 261 1306 5374 Email kinder@bafg.de www.bafg.de
Ownership	Kinder/BfG
General objective:	Simulation of macrozoobenthos and fish habitat quality
Spatial scale:	Reaches of 5 to 30 km in units of 100 m of large and shipable rivers
Temporal scale:	Static or series of mean values weekly or monthly
Input data:	
Physical (hydraulics, morphology, solid material)	Cross section data Ecomorphological assessment values bottom substratum (previed)
Hydrologic	Discharge or time series of dircharge
Biologic (Preference curves etc.)	Univariate preference curves
Water quality	
Interfaces available	
Preprocessors	
Output data:	
Physical (hydraulics, morphology, sediment transport)	2d flow velocity 2d bottom shear stress water depth
Hydrologic	
Biologic: pure habitat, single species vs. communities, life cycle	Habitat suitability maps for single species
Biologic: prognoses of population dynamics	none
Water quality	
Numerical solutions:	
Physics	
Hydrologic	2d simulation of flow velocity, bottom shear stress and water depth for given discharge
Biologic	Calculates habitat suitability
water quality	
Results presented as	ascii files, coloured maps
Interfaces available	none
Postprocessors	none
Applied studies (objective, ecoregion)	Test application in river Rhine and Moselle
Validation quantitative/qualitative	none
Platform (Windows/unix etc.)	Windows
Applicable model	model under development
User friendliness (0..10)	1
Source-codes *	Fortran/MatLAb

Handbooks & further information	none
Most relevant publications	in preparation
Technical reports available? (language?)	none

Name of model:	HABITAT
Contact	Atle Harby / Karl Selanger SINTEF Energy Research Sem Saelandsvei 11 7465 Trondheim NORWAY Phone +47 73 59 39 20 Fax + 47 73 59 72 50 atle.harby@energy.sintef.no
Ownership	SINTEF Energy Research/ NTNU
General objective:	Fish habitat analysis, Habitat for any organism living in water
Spatial scale:	Usually reaches up to 1 km
Temporal scale:	Temporal habitat variation and habitat duration
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Distribution of water velocity, substratum, local depth
Hydrologic	Discharge time series
Biologic (Preference curves etc.)	Preference curves type II and type III.
Water quality	None
Interfaces available	Reads hydraulics from SSIIM (free 3D hydraulic model) or HEC-RAS/HEC-2 combined with measurements (IFIM-like approach).
Preprocessors	Measurement data processor
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	Map of distribution of depth, velocity, substrate etc. Depending on preference curves selected.
Hydrologic	None
Biologic: pure habitat, single species vs. communities, life cycle	Habitat quality maps, weighted usable areas, combined habitat quality, hydraulic suitability indices, Habitat-discharge time series, habitat duration curves
Biologic: prognoses of population dynamics	None
Water quality	None
<u>Numerical solutions:</u>	
Physics	None
Hydrologic	None
Biologic	Linking physical parameters to biological preferences. Habitat time series
water quality	None
Results presented as	Curves, maps and tables. Result files
Interfaces available	Ascii-files, link to HabPlot program
Postprocessors	
Applied studies (objective, ecoregion)	Numerous projects related to Instream Flow, River Restoration, Hydropeaking
Validation	Predicted habitat quality vs. fish findings,
quantitative/qualitative	Physical habitat (hydraulic conditions) validation done by hydraulic model
Platform (Windows/unix etc.)	Win NT
<u>Availability of models</u>	

Applicable model	Free/licenced depending on use
User friendliness (0..10)	7
Source-codes *	No
Handbooks & further information	User's Manual available. Training course manual available, numerous publications. Manual and information available on-line.
Most relevant publications	Scientific papers, habitat assessments/restoration
Technical reports available? (language?)	River System Simulator users manual.

Name of model:	FISU
Contact (name, address, e-mail, phone, webpage etc.)	Markku Lahti, Fortum Engineering, Rajatorpantie 8, 00048 FORTUM, Finland markku.lahti@fortum.com telep 358 +(0)10 4534539
	also: ari.huusko@rktl.fi timo.yrjana@vyh.fi
Ownership	Fortum Engineering, Helsinki, FIN North Ostrobothnia Regional Environment Centre, Oulu, FIN FGFRI, Kainuu Fisheries Research and Aquaculture, Paltamo, FIN
General objective:	Simulation of habitat quality for fish or other aquatic species
Spatial scale:	Modelled river reach can be from tens of meters to some kilometers, reasonable calculation cell size from 1*1 meter upwards
Temporal scale:	Time series of discharges can be calculated
Input data:	
Physical (hydraulics, morphology, solid material)	Spatially explicit topographical data (xyz) , river bed material (coarsest, the most dominant, the second dominant)
Hydrologic	Discharge, 2D flow modelling
Biologic (Preference curves etc.)	Univariate preference curves, multivariate preferences (surfaces)
Water quality	None
Interfaces available	
Preprocessors	Data input module included (Microsoft Excel-based)
Output data:	
Physical (hydraulics, morphology, sediment transport)	3-d digital riverbed geometry, local depth, local velocity, substratum
Hydrologic	
Biologic: pure habitat, single species vs. communities, life cycle	Habitat quality (univariate or WUA) maps for single species (life stages)
Biologic: prognoses of population dynamics	None
Water quality	None
Numerical solutions:	
Physics	Calculates local depth averaged velocities
Hydrologic	
Biologic	Calculates habitat preferences based on various approaches (see input data)
water quality	None
Results presented as	Maps, Graphs, ascii files
Interfaces available	None
Postprocessors	None
Applied studies	Several instream flow studies for restoration of dredged rivers,

(objective, ecoregion)	development of more ecological hydropower use and flow regulation.
Validation	Predicted local fish habitat vs. observed real fish location;
quantitative/qualitative	ongoing
Platform (Windows/unix etc.)	Windows
Applicable model	License from contact persons available
User friendliness (0..10)	5
Source-codes *	
Handbooks & further information	
Most relevant publications	Lahti, M. and Sinisalmi, T. 1998: A habitat model for aquatic environment. XX Nordic Hydrological Conference. Nordic Association for Hydrology, Helsinki, Finland. 10-13 August 1998. NHP report no. 44: 567-575
Technical reports available? (language?)	Lahti, M. 1999: A habitat model in planning of water system rehabilitations. Research Reports -Fortum. Fortum Power and Heat Oy. Vantaa. 153 pp. (in Finnish with English summary)

Name of model:	ENERGI
Contact (name, address, e-mail, phone, webpage etc.)	Anton Ibbotson, CEH Dorset, Winfrith Technology Centre, Dorchester, UK +44 1305 213500 ati@ceh.ac.uk
Ownership	CEH Dorset CEH Wallingford
General objective:	Use energy gain in fish to simulate habitat quality
Spatial scale:	100-200 m
Temporal scale:	None
Physical (hydraulics, morphology, solid material)	3d CFD modeling
Hydrologic	Discharge
Biologic (Preference curves etc.)	Process behavioural and physiological model, estimates of food delivery
Water quality	Temperature
Interfaces available	None
Preprocessors	None
Physical (hydraulics, morphology, sediment transport)	3d river bed geometry, 3d velocity and depth profiles all spatially represented
Hydrologic	None
Biologic: pure habitat, single species vs. communities, life cycle	Habitat quality maps for salmonid juveniles
Biologic: prognoses of population dynamics	Juveniles only
Water quality	None
Physics	3d CFD modeling of velocities and depth spatially represented
Hydrologic	None
Biologic	Spatially dependent swimming costs, gross energy intakes and net energy intakes
water quality	None
Results presented as	Figures, GIS, Graphs, ascii files
Interfaces available	None
Postprocessors	None
Applied studies (objective, ecoregion)	None
Validation quantitative/qualitative	Predicted habitat use against actual habitat use
Platform (Windows/unix etc.)	Windows
Applicable model	Not available yet as only being developed
User friendliness (0..10)	1
Source-codes *	Not available
Handbooks & further information	Not prepared
Most relevant publications	None
Technical reports available? (language?)	None

Name of model:	ECOFUZZ
Contact (name, address, e-mail, phone, webpage etc.)	Martin Baptist, WL delft hydraulics. Martin.Baptist@wldelft.nl
Ownership	WL delft hydraulics
General objective:	Fuzzy set based reasoning system. Ideal in situations where quantitative and qualitative data should be used together.
Spatial scale:	
Temporal scale:	
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Dependent on application. Can be output from numerical models, or expert rules. Input must be defined as fuzzy membership functions
Hydrologic	
Biologic (Preference curves etc.)	
Water quality	
Interfaces available	No, ascii input required
Preprocessors	
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	
Hydrologic	
Biologic: pure habitat, single species vs. communities, life cycle	Dependent on application. Can be biomasses, densities, suitabilities of groups or species.
Biologic: prognoses of population dynamics	
Water quality	
<u>Numerical solutions:</u>	
Physics	
Hydrologic	
Biologic	
water quality	
Results presented as	
Interfaces available	
Postprocessors	
Applied studies (objective, ecoregion)	<ol style="list-style-type: none"> 1. Expert system for the effects of climate change on the Wadden Sea ecosystem. Based on expert rules and climate change scenarios. 2. Fish habitat suitability in the river Waal, based on hydrodynamic model output. 3. Probability of occurrence of floating algae based on meteorological, hydrodynamic and expert data.
Validation	Validation is difficult due to the uncertain nature of the information
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows
Applicable model	
User friendliness (0..10)	8

Source-codes *

VB5-code

Handbooks & further information

Simple manual available

Most relevant publications

Baptist, M.J., M.W.M. van der Tol & M. Vonk, 2000. A fuzzy expert system for effects of climate change on the Wadden Sea ecosystem. Conference Proceedings of the Hydroinformatics 2000 Symposium, Cedar Rapids, Iowa, USA.

Technical reports**available?** (language?)

Name of model:	DELFT3D
Contact (name, address, e-mail, phone, webpage etc.)	Deepak Vatvani, WL delft hydraulics, P.O. Box 177, 2600 MH Delft, +31 15 2858585. Delft3d.info@wldelft.nl http://www.wldelft.nl/soft/d3d/index.html
Ownership	WL delft hydraulics
General objective:	2D and 3D hydrodynamic and transport model for non-steady flow on a curvilinear grid. Includes sediment transport, morphodynamics, water and sediment quality and waves. Consists of modules: flow, wave, mor, waq, eco, sed, part.
Spatial scale:	From streams to seas
Temporal scale:	From seconds (turbulence) to decades (morphology)
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Bathymetry, initial and boundary conditions.
Hydrologic	Discharges, water levels
Biologic (Preference curves etc.)	Input of habitat preference functions is foreseen in the near future.
Water quality	Initial concentrations, boundary conditions, loads, hydrodynamic inputs from the flow model.
Interfaces available	Interfaces with post-processing software and ArcView.
Preprocessors	Grid generator and bathymetry generator.
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	Flow, bed-shear stress, sediment transport (suspended and bedload), morphology, fate and transport of substances in water and sediment
Hydrologic	Discharge, water depth
Biologic: pure habitat, single species vs. communities, life cycle	Biochemical and ecological processes of algal growth is modelled dynamically. Direct coupling of physical output to preference curves is foreseen in the near future. Indirect coupling with MORRES is possible.
Biologic: prognoses of population dynamics	Not included
Water quality	Oxygen, nutrients, bacteria, temperature, salinity, organic and inorganic matter, dissolved matter, turbidity, heavy metals, organic micropollutants.
<u>Numerical solutions:</u>	
Physics	Implicit numerical scheme for flow
Hydrologic	--
Biologic	
water quality	Various explicit and implicit numerical integration schemes
Results presented as	
Interfaces available	Yes, ArcView
Postprocessors	General Post Processing Package (DELFT3D-software)
Applied studies (objective, ecoregion)	Numerous throughout the world
Validation	Quantitative validation via field data and experiments.
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows and UNIX
Applicable model	Available for commercial and non-commercial (universities) organisations.
User friendliness (0..10)	Some modules are more user friendly than others.
Source-codes *	Not available
Handbooks & further information	Available
Most relevant publications	
Technical reports	Yes, English.

available? (language?)

Name of model:	Decay rates
Contact (name, address, e-mail, phone, webpage etc.)	Isabel Pardo Area de Ecología Facultad de Ciencias Campus Lagoas-Marcosende 36200 Vigo Spain ipardo@uvigo.es Tel: +34 986 812585 Fax: +34 986 812556
Ownership	Isabel Pardo
General objective:	Prediction of in-stream leaf decay rates with abiotic and biotic variables
Spatial scale:	Usually reaches of 50 m
Temporal scale:	Months, season to annual
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Width, substratum type, depth
Hydrologic	Average flow velocities in section and discharge, water velocities point measurements
Biologic (Preference curves etc.)	Leaf mass loss with time. Invertebrate densities, percentage of functional feeding groups
Water quality	Nutrients, Oxygen, pH, electric conductivity, time series of temperature. Major water ions.
Interfaces available	Multivariate regression analyses
Preprocessors	Excel
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	None
Hydrologic	None
Biologic: pure habitat, single species vs. communities, life cycle	Modeling in –stream organic matter processing
Biologic: prognoses of population dynamics	None
Water quality	None
<u>Numerical solutions:</u>	
Physics	None
Hydrologic	None
Biologic	None
water quality	None
Results presented as	Figures, values
Interfaces available	None
Postprocessors	None
Applied studies (objective, ecoregion)	Evaluation of environmental impact caused by deforestation on in-stream OM dynamics. Application to stream management and stream functional restoration studies.
Validation	Predicted decay rates vs. findings.
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows
<u>Availability of models:</u>	
Applicable model	Not available yet as only being developed

User friendliness (0..10)	0
Source-codes *	Not available
Handbooks & further information	None
Most relevant publications	Scientific papers
Technical reports available? (language?)	None

Name of model:	CASIMIR - FHABIM
Contact (name, address, e-mail, phone, webpage etc.)	Matthias Schneider SJE Schneider & Jorde Ecological Engineering GmbH Viereichenweg 12 D-70569 Stuttgart Germany Phone +49-711-683436 Fax +49-711-6773436 e-mail: mailbox@sjeweb.de
	Klaus Jorde: jorde@uidaho.edu Franz Kerle: franz.kerle@iws.uni-stuttgart.de Frank Zoellner: frank.zoellner@iws.uni-stuttgart.de
Ownership	1) SJE Schneider & Jorde Ecological Engineering GmbH 2) Inst. of Hydraulic Engineering, University of Stuttgart
General objective:	Simulation of fish habitat quality
Spatial scale:	Several ten meters to several kilometers
Temporal scale:	Runs with time series of discharge, usually 1 year with mean daily discharge
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Cross section data, water table elevation, substratum (9 size classes), cover type, pool type
Hydrologic	Discharge or time series of discharge
Biologic (Preference curves etc.)	Alternatively 1) Univariate preference curves (PHABSIM type), 2) multivariate functions, 3) fuzzy-rule based habitat preferences
Water quality	None
Interfaces available	Hec-Ras, Delft 3D, Mike11, SMS (under construction)
Preprocessors	Data input module included, alternatively ascii files
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	3-D digital river bed geometry, local depth averaged flow velocities, local water depth, local bottom shear stress, substratum, cover, pools
Hydrologic	Steady state time series
Biologic: pure habitat, single species vs. communities, life cycle	Habitat quality maps, weighted usable areas (WUA), Habitat suitability indices, single species and life stages
Biologic: prognoses of population dynamics	None
Water quality	None
<u>Numerical solutions:</u>	
Physics	Calculates local depth averaged velocities from mean cross section velocities with a rule based geometry/roughness approach. Does not perform hydraulic calculations but uses measured water tables or results from external hydraulic programs.
Hydrologic	None
Biologic	Calculates habitat preferences based on various approaches (see input data)
water quality	None
Results presented as	Figures, graphs, tables, ascii files
Interfaces available	Generates bitmaps of the figures, tables can be copied to other windows applications
Postprocessors	None

Applied studies (objective, ecoregion)	Numerous instream flow studies, run-of river hydropower plants, alpine storage hydropower plants, river restoration projects, hydropeaking projects, lowland rivers to high alpine, small streams to larger rivers
Validation	predicted fish habitat vs. findings with integrated correlation analysis, ongoing
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows
<u>Availability of models</u>	
Applicable model	Free for scientific purpose and noncommercial projects, for commercial projects license from contact persons available
User friendliness (0..10)	7
Source-codes *	Possibly yes for further joint development
Handbooks & further information	Under construction, courses available
Most relevant publications	<p>SCHNEIDER, M. (2001): Habitat- und Abflussmodellierung für Fließgewässer mit unscharfen Berechnungsansätzen. – Dissertation, Mitteilungen des Instituts für Wasserbau, Heft 108, Universität Stuttgart, Eigenverlag, Institut für Wasserbau der Universität Stuttgart, Stuttgart.</p> <p>SCHNEIDER, M., K. JORDE, F. ZÖLLNER & F. KERLE (2001): Development of a user-friendly software for ecological investigations on river systems, integration of a fuzzy rule-based approach, proceedings Environmental informatics 2001, 15th International Symposium, Informatics for Environmental Protection, 2001, ETH Zurich, Switzerland</p> <p>JORDE, K., M. SCHNEIDER & F. ZÖLLNER (2000): Analysis of Instream Habitat Quality - Preference Functions and Fuzzy Models. Stochastic Hydraulics 2000, Wang & Hu (eds.), Balkema, Rotterdam, pp. 671 - 680.</p>
Technical reports available? (language?)	<p>“Hydraulisch-morphologische Simulation zur Habitatprognose in Fließgewässern“, Institut für Wasserbau der Universität Stuttgart, Abschlussbericht, Forschungsprojekt Az. 12245, gefördert durch Deutsche Bundesstiftung Umwelt (german)</p> <p>„Ökostrom Restwassersynthese“, EAWAG, Switzerland, 2001 (german)</p>

Name of model:	CASIMIR – BHABIM
Contact (name, address, e-mail, phone, webpage etc.)	<p>Klaus Jorde: Ecohydraulics Research Group University of Idaho – Boise 800 Park Blvd., Suite 200 Boise, ID 83712, USA Phone: +1-208-364-9907 Fax : +1-208-387-1246 e-mail: jorde@uidaho.edu</p> <p>Matthias Schneider: mailbox@sjeweb.de Franz Kerle: franz.kerle@iws.uni-stuttgart.de Frank Zoellner: frank.zoellner@iws.uni-stuttgart.de</p>
Ownership	<p>1) SJE Schneider & Jorde Ecological Engineering GmbH 2) Inst. of Hydraulic Engineering, University of Stuttgart</p>
General objective:	Simulation of benthic habitat quality
Spatial scale:	Several ten meters to several kilometers
Temporal scale:	Runs with time series of discharge, usually 1 year with mean daily discharge
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Series of FST-hemisphere measurements at the river bottom at different flows
Hydrologic	Discharge or time series of discharge
Biologic (Preference curves etc.)	Univariate preference functions: Species abundance vs. local FST-hemisphere measurement
Water quality	None
Interfaces available	Database with benthic species' preference functions
Preprocessors	Data input module included, alternatively ascii files
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	Temporal and spatial distribution of near bed hydraulic forces (e.g. bottom shear stress) as function of discharge
Hydrologic	Steady state time series
Biologic: pure habitat, single species vs. communities, life cycle	Habitat quality distribution, weighted usable areas (WUA), Habitat suitability indices, single species and life stages
Biologic: prognoses of population dynamics	None
Water quality	None
<u>Numerical solutions:</u>	
Physics	Statistical analysis of measured field data from FST-hemispheres, interpolations for flows between investigated flows
Hydrologic	None
Biologic	Links distribution of hydraulic forces with preference functions
water quality	None
Results presented as	Figures, graphs, ascii files
Interfaces available	Generates bitmaps of the figures
Postprocessors	None
Applied studies (objective, ecoregion)	Numerous instream flow studies, run-of river hydropower plants, alpine storage hydropower plants, river restoration projects, lowland rivers to high alpine, small streams to larger rivers
Validation quantitative/qualitative	Predicted benthic habitat vs. findings, ongoing

Platform (Windows/unix etc.)	Windows
<u>Availability of models</u>	
Applicable model	Free for scientific purpose and noncommercial projects, for commercial projects license from contact persons available
User friendliness (0..10)	7
Source-codes *	Possibly yes for further joint development
Handbooks & further information	Under construction, courses available
Most relevant publications	JORDE, K. & C. BRATRICH (1998): Influence of River Bed Morphology and Flow Regulations in Diverted Streams on Bottom Shear Stress Pattern and Hydraulic Habitat. In: Bretschko G. & Helesic J. (Eds.), Advances in River Bottom Ecology IV, Backhuys Publishers, 47-63.
Technical reports available? (language?)	Ökostrom Restwassersynthese, EAWAG, Switzerland, 2001 (german)

Name of model:	BIORIV (Part of the River System Simulator)
Contact	Atle Harby/Karl Selanger SINTEF Energy Research Sem Saelandsvei 11 7465 Trondheim NORWAY Phone +47 73 59 39 20 Fax + 47 73 59 72 50 atle.harby@energy.sintef.no
Ownership	SINTEF Energy Research
General objective:	Growth of salmon and trout in rivers
Spatial scale:	Catchment, river, or part of river
Temporal scale:	Seasonal studies based on daily input
<u>Input data:</u>	
Physical (hydraulics, morphology, solid material)	Water flow, water temperature
Hydrologic	None
Biologic (Preference curves etc.)	Growth parameters
Water quality	None
Interfaces available	
Preprocessors	
<u>Output data:</u>	
Physical (hydraulics, morphology, sediment transport)	None
Hydrologic	None
Biologic: pure habitat, single species vs. communities, life cycle	Results applies for taxa
Biologic: prognoses of population dynamics	Yes
Water quality	None
<u>Numerical solutions:</u>	
Physics	
Hydrologic	None
Biologic	Growth simulation based on temperature
water quality	None
Results presented as	Graphs
Interfaces available	
Postprocessors	
Applied studies (objective, ecoregion)	
Validation	
quantitative/qualitative	
Platform (Windows/unix etc.)	Windows and UNIX
<u>Availability of models</u>	
Applicable model	Available through River System Simulator
User friendliness (0..10)	4
Source-codes *	No
Handbooks & further information	River System Simulator users manual

Most relevant publications
Technical reports
available? (language?)

Name of model:	HARPHA
Contact (name, address, e-mail, phone, webpage etc.)	Stefan Schmutz University of Agricultural Sciences, Vienna (BOKU) Institute of Water Provision, Water Ecology and Waste Management Department of Hydrobiology, Fisheries and Aquaculture (HFA) Max Emanuelstr. 17, A-1180 Vienna, Austria
	http://iwgf-sig.boku.ac.at/fish/hfahome.htm Tel: +43-1-47654-5202 Fax: 43-1-47654-5217 schmutz@mail.boku.ac.at
Ownership	
General objective:	Minimum flow and habitat restoration
Spatial scale:	reaches of about 200 meters
Temporal scale:	3 to 4 different discharges
<u>Input data</u>	
Physical (hydraulics, morphology, solid material)	Cross section data, water table elevation, depth, mean column-, free flowing-, bottom velocity, substratum(choriotope, embedness), cover (broken water surface area, overhanging vegetation, underwater vegetation, surface vegetation, boulder, rip rap, undercut bank, visibility and velocity protection, shading)
Hydrologic	Different discharges
Biologic (Preference curves etc.)	multivariate preference functions
Water quality	none
Interfaces available	AUTOCAD, SPSS, EXCEL,
Preprocessors	
<u>Output data</u>	
Physical (hydraulics, morphology, sediment transport)	3-D digital river bed geometry, local depth, averaged flow velocities, local water depth, substratum, cover, mesohabitats
Hydrologic	Steady state time series
Biologic: pure habitat, single species vs. communities, life cycle	Habitat quality maps, probability areas for single species and life stages
Biologic: prognoses of population dynamics	None
Water quality	None
Numerical solutions	
Physics	Interpolation of multiple flow measurements
Hydrologic	
Biologic	Logistic regression analyses
water quality	
Results presented as	Figures, maps, graphs, Ascii files
Interfaces available	
Postprocessors	
Applied studies (objective, ecoregion)	Definition of low flow, 9
Validation	
quantitative/qualitative	

Platform (Windows/unix etc.)	Windows
Applicable model	Commercially available software (AUTOCAD, SPSS, EXCEL)
User friendliness (0..10)	
Source-codes *	
Handbooks & further information	
Most relevant publications	
Technical reports available? (language?)	Schmutz, S. and P. Parasiewicz, <i>Biotische Habitatmodellierung.</i> <i>Gewässerbetreuungskonzept Traisen.</i> , . 1999, HFA-BOKU & DonauConsult. Studie im Auftrag des BMLF, Wien. (German)

Appendix II Research needs

Physical winter habitat, ice-coverage, scour/erosion of ice and its effect on sediment transport and habitats, for example the spawning habitat.

We know that winter represent the part of the year with largest mortality rate. We think the mortality can be explained by understanding the physical habitat, which is dominated by ice and cold water. A research project will focus on short-term effects of variable winter habitat conditions in order to find relationships between physical factors and winter habitat use. This will also be used to identify possible bottlenecks and long-term effects on salmon populations and explain mortality of juvenile Atlantic salmon linked to physical processes. The main objective of a research project is to better understand the response of juvenile Atlantic salmon to changes in physical conditions during winter. A project will focus on habitat and behavioural studies at low temperatures and variable ice conditions for juvenile Atlantic salmon, and the results will be applied to expand the available habitat assessment methods to utilise low temperature and ice conditions in quantifying habitat conditions for Atlantic salmon during winter in northern climates.

As sub-objectives a project will evaluate methods for fish sampling to obtain fish preferences for cold water and ice conditions, and study the dynamics of habitat selection. A project intends to determine the importance of various ice formations, water temperature and light conditions for juvenile Atlantic salmon. Further a project will integrate the latest tools for hydraulic and ice modelling into the physical habitat simulation system, and thereby provide a solid foundation for a future seasonal habitat analysis. A project will also develop field methods for monitoring physical habitat changes during winter with special emphasis on ice cover, frazil ice generation and anchor ice, and also break-up of the ice with related dynamic effects, such as river bank morphodynamics and substrate changes.

Seasonal variability of physical habitats with emphasis on the worst period of the year (e.g. summer droughts in the Mediterranean region).

Physical habitats of rivers and streams change considerably across seasons. Indeed, water flow is one of the most important seasonal factors; in the Mediterranean regions these flow changes can be particularly important. On one side of the range of variability, are end of summer or fall floods, while on the other, are summer droughts. These changes in water flow modify the river morphology and features (i.e. river section and slope, roughness, transport of sediment, submersed macrophytes, ...). The communities of rivers under these variable regimes are only adapted to natural changes and not to those changes which are an effect of human activity. For instance, some macroinvertebrate species first develop in the upper part of the freatic zone and can subsequently colonise the river very fast after a flood. In summer, many macroinvertebrates finish their development and, as adults, colonise terrestrial environments. Species which cannot leave the water, such as algae species and some insects, worms or molluscs, develop diapause stages, while fishes migrate towards river sources or remain in deep pools.

Although large seasonal variability is a widespread feature of rivers and streams, in the Mediterranean region changes are much more pronounced and have effects on the biomass, abundance and diversity of their fish populations. The modelling of the physical habitat for fishes should take into account extreme annual fluctuations as a factor strongly influencing the development of important fish populations.

Limitation of the habitat approach versus other relevant parameters (mortality / migration barriers).

Problem: The application of habitat models or the interpretation and validation of results gained from habitat models is meaningless if habitat is not a limiting parameter in a specific case. It is well known that in many cases species abundance does not follow habitat availability. Examples for this could be difficult maritime conditions for anadromous species resulting in a low smolt-adult-return ratio, a small number of fish surpassing difficult upstream migration conditions or missing connectivity between different metapopulations for genetic exchange. Usually habitat modelers apply their models without examining in advance if habitat is actually limiting, and therefore an increase in quality and availability would be beneficial, or if other restrictions apply and therefore habitat conditions need no immediate improve.

Research objective: Define criteria or methods that allow to specify if habitat is a limiting criteria or not. This question must be answered in most cases before habitat modeling starts

Research approach: I don't know, discuss with biologists.

Interaction between groundwater and channel flow.

Problem: The interaction between groundwater and channel flow has multiple influences on habitat conditions, some salmonids and other fish are known to spawn in "upwelling" zones. These zones might be in terms of temperatures, oxygen content, water quality, hydraulic conditions and substrate composition locally quite different from surrounding areas. Our habitat models are unable to describe these attributes.

Research objective: Specify spawning habitats as related to upwelling zones and develop preference criteria as they could be included in habitat models. Define specific capacities that need to be integrated that need to be integrated in habitat models to be able to describe these preference functions. (groundwater-streamflow interaction modeling is probably the high end of this, but are there simpler approaches ?)

Research approach: First, find out from literature if this is really important and what the mechanisms behind the phenomenon are.

Selection and definition of reference reaches as a basis for large-scale river models.

Problem: Very often habitat models are applied to answer questions related to a river reach of a greater length than can actually be modeled (temporal and financial restrictions) or even watersheds with different running waters. Modelers usually define "reference reaches" then. However, criteria according to which reference reaches or sites are chosen are rather undefined. Very often they are close to a bridge or the next bar....Few exceptions exist (Piotrs approach).

Research objective: Establish rules and criteria how reference reaches or sites are to be chosen in order to be representative for the entire river reach in question. Number and/or length of reference reaches or sites required to be "representative" .

Research approach: Literature review, could also be a separate small COST subproject.

Definition of ‘dynamics’ on the basis of criteria and parameters.

Problem: It is well documented that “dynamics” play an important role within the ecological integrity of most running water ecosystems. However, if decisions e.g. in instream flows are to be made, it is difficult to specify the “dynamics” required for the systems, because dynamics is an abstract term that needs physical description in order to be applicable. It is not very clear which physical attributes are the relevant ones. Examples could be length of time, time to occur, recurrence periods etc. when sediment transport takes place, number of times when incipient motion is reached, occurrence of certain flood events (which are the important ones, is it the peak or the volume or the duration or the geomorphological consequences? What are the biological criteria (patch dynamics, disturbance..)

Research objective: Define physical and/or biological criteria for different levels of dynamics in river systems link the with ecosystem integrity.

Research approach: I’d like to have a PhD student working on it.

Artificial fluxes from reservoirs and their effects on habitats.

One of the most important factors in the management of a river located in an area with intense human activity relates to how can we combine river use as an energy source and the development of fish communities. Damming the river deeply modifies water flow and, thus, provokes deep changes in the physical habitat of many species.

While reservoirs can eliminate the negative direct effects of large floods, they reduce flow variability of intermediate floods, which contributed to the dynamics of the river section (i.e. bankfull flows and related discharges).

In addition to changes in the water flow downstream of the reservoir, reservoirs also decrease physical variables such as water temperature, and loads (i.e. all dissolved, suspended and bed loads). Changes are not always negative because reservoirs may allow the development of alluvial plains and braided reaches. The latter may lead to the development of rich fish communities not found before and increase the diversity and biomass of the community.

It is important that artificial fluxes below reservoirs maintain a certain "naturalness" in their fluctuations. Historical records can help in determining what can be considered natural flow variability.

Population dynamics and habitat modelling

The main problem with habitat models is that they actually use environmental parameters (physical and chemical characteristics, morphological characters etc.) as indicators and descriptors of the habitat preferences of various species (not only salmonids or a certain species) since they have good adaptability. In addition, the functionality of habitat models over a few kilometers of rivers may or may not describe sufficiently the distribution range of a certain population or may describe the habitat of certain life stages (larvae, fry, juveniles, young, adults, mature adults). The dynamics of the fish populations, however, are not incorporated in full in these models in order to adapt the model results for the specific stock condition. Fish stock condition is a much more complicated issue and not always

dependant on the habitat quality. Example for this case is the problems of natural salmonid stocks due to the accidental release of cultivated salmon or GM salmon. In that case, the habitat can be assumed unharmed from the environmental and morphological point of view, while the natural stock receives an acute ecological pressure.

The objective of such work would be the incorporation of basic (initially) and complicated (later) stock dynamics parameters in the habitat models which would be included in the initial data feeding process. Population parameters that would be of major interest and are descriptive for the state of a population can be:

- ? Food Conversion of the population (Q/B)
- ? Condition Factor
- ? Growth factor (K from VBGF studies)
- ? Natural Mortality
- ? Yield per Recruit or Yield function

Food web modelling in habitat models

The main problem with habitat models is that they actually use environmental parameters (physical and chemical characteristics, morphological characters etc.) as indicators and descriptors of the habitat preferences of various species (not only salmonids or a certain species) since they have good adaptability. An important aspect of a fish population is the availability of food both in quantity and quality. Therefore when we actually look and describe a population, we actually are looking also on the resources that this population utilizes in order to reach that certain state. The information that are fed in habitat models, however, involve the habitat characters (physical and chemical quality, description and morphology etc.) as well as some ecological indicators for abundance, distribution and biodiversity which are then analysed to produce habitat preference indicators for the populations. For this reason, we believe that the incorporation of food web information in habitat models will serve 2 objectives:

- ? Increase substantially the accuracy of the model. This will be achieved through the inclusion of more parameters in the same model (or by binding together 2-3 models) despite the fact that the modelling process will become more complicated;
- ? Improve substantially the capacity of a model to describe a population. This will be achieved through the inclusion of information on the local resources and resources-related links of the particular population. The overall objective to increase the predicting capacity of a model will always be

The research approach would be first to identify food web parameters, as well as their measurement/calculation methods, which can be used as raw data for habitat models. These parameters should be certainly habitat-related (per area, per length, per flow regime etc.) so that their incorporation in the mathematics will be possible.

Transport phenomena models (sediment transport in stratified regions)

The problem of transport phenomena in Greece and several Mediterranean countries is of major importance. Numerous ecosystems depend on the transportation of sediments (and

other substances) along the main river flow. The sediment transportation process (in Greece) is interrupted by various reasons such as:

- ? Hydroelectric power dams
- ? Uncontrolled or illegal irrigation dams made by farmers
- ? Interrupted flow (river flow that changes from surface to underground due to fissures, earthquake cracks etc.)
- ? Seasonal complete dry out of the river (more than 75% of the Greek rivers dry completely - 0 flow - during summer)
- ? Alteration of river banks and landscape formation for the development of settlement and agriculture

The above processes have caused the elimination of traditional fish habitats along the Greek rivers and the river deltas and therefore, this affects not only freshwater species but also marine and brackish water species. Such habitats not only include areas for certain species but also areas utilised by fish during certain life stages (egg laying, larvae, fry, juveniles, young, adults or mature adults).

The objectives of research should be the adaptation of existing models in the particular conditions of flow and river morphology in Greece in order to be able both to describe and predict transport phenomena and flow regimes under those conditions. There exist numerous models (research and marketable products) that are intended to analyse transportation phenomena without, however, the capability to account for these specific characteristics. This is expected, since most originate from countries (such USA or North Europe) where the characteristics of the river are completely different from those in the Mediterranean region.

Parameter selection in ecological modelling

When developing models to predict community structure from environmental variables, an important problem is the selection of a limited number of environmental variables which will be used as predictors, because determining a large number of variables in the field is cost-inefficient, and furthermore, some variables may be redundant.

The objective of this research topic is to define a limited number of environmental variables which can be used as input variables for a particular problem. These variables need to be relevant and it must be realistic to obtain reliable data. Alternatively, a selection procedure could be proposed which can be applied to identify the most important variables.

For this purpose, a wide range of techniques could be applied, such as correlation analysis, regression-analysis, a senso-net (a special variant of a backpropagation network), Monte Carlo simulations and genetic algorithms.

Assessment of machine-learning methods

Due to their high predictive performance, machine learning techniques such as Artificial Neural Networks (ANNs) are increasingly applied in ecological modelling. The problem with ANNs in comparison with other methods, e.g. multiple regression, is that they are 'black boxes'. In this way, the disadvantage of ANNs is their lack of explanation regarding the relative importance of each independent variable considered. In ecology however, it is

useful to know the magnitude of impacts of each variable. In addition, there is no theoretical or practical way of accurately interpreting the weights in an ANN.

Regarding to the given problem, the objective is to look for methods, which allow the determination of the impact of variables initially applied to the model and the interpretation of the weights in the neural network.

To determine the response of the model to each of the input variables separately, an experimental approach can be suggested by applying a typical range of variation of a single 'free' variable to the model, while the other are held constant, called a sensitivity analysis. Also sensitivity analysis and Monte Carlo simulations could help to obtain insight in the functioning of ANNs. Garson (1991) has proposed some methods to interpret neural network connection weights.

Garson, G.D. (1991). Interpreting neural-network connection weights. *Artif. Intell. Expert* 6: 47-51.

Difference between catchment-related models and geographically larger models

Models describing river characteristics are often developed based on information gathered in the field. This data may cover very large ecoregions, but also a very small catchment. Small-scale models may be more accurate since they use very specific information for that area, while models developed using information from a large area may be more robust as a wider range of possible situations is covered.

When a large amount of information is available for a large geographical region, the question arises whether one model which is developed for the whole region, or rather a number of parallel models, each covering a subregion, will be more reliable.

To solve this problem, models should be compared which were developed for different subregions as well as for the whole region for which information is available. One should however be aware that dividing the region into subregions not only makes the data more specific, but the number of data available will decrease dramatically. Furthermore, this question probably has more than one answer, varying for each specific topic addressed.

Prediction of reference states without any (historical) data

An important challenge in river ecology is related to the assessment of ecosystem health. The European Water Framework Directive (EU, 2000) for example states that the reference community for watercourses should be identified. However, in many European countries, no sampling points are available where the biological community can be considered unimpacted.

The aim of this research topic is to be able to identify the reference, or "target" community based on a number of environmental variables characterising the ecosystem. These variables should be independent of human impact, e.g. stream velocity, substrate type, river width and river depth.

Several approaches are currently under investigation throughout Europe, including the use of paleolimnological data, data from ecologically similar regions and the use of expert knowledge. If none of these approaches is possible, a pragmatic selection could be made of sampling points which represent the best ecological status possible. Subsequently, the available data can then be used to calibrate models which predict ecosystem state based on a number of environmental variables characterising the ecosystem.

EU, 2000. Directive of the European Parliament and of the council 2000/60/EC establishing a framework for community action in the field of water policy. Rep. No. PE-CONS 3639/1/00 REV 1. European Union, Luxembourg

Assessment of the identification level of macro-invertebrates (genus, families, assemblages) with respect to detail needed for modelling

Models built to predict assemblage composition may be developed using biological data described at different taxonomic levels. However, identifications at species-level, e.g. for macroinvertebrates, are costly and time-consuming. On the other hand, identification at higher taxonomic levels, such as family, may give rise to less reliable models, as different species within a family will prefer different environmental conditions.

The question is which taxonomic level is sufficient when developing a model predicting aquatic communities. This is very dependent on the aim of the model and the financial resources available.

For answering this question, one should compare different strategies, and consider the specific aim of the model, the time and financial resources involved, as well as the level of model reliability required.

Stability/erosion of rivers after river restoration and the sustainability of restored rivers

The improvement of river habitat means very often construction of “new” riverbed. The new riverbeds should be constructed in a way that rebuilding should not be necessary due to damages caused by flooding, erosion or sedimentation. Evidence continues to accumulate indicating that the majority of river restoration projects are unsuccessful with respect to erosion and sedimentation if fluvial geomorphology is not taken into account. (Kellerhals and Miles (1996)) This means that the restoration work has to be repeated in order to maintain good habitat for the preferred species. Better design practice may improve performance.

Research objective

Developing of new guidelines or if possible adaptation of existing guidelines for training of rivers to make sure that habitat improvement will be sustainable.

Research approach

Adaptation of classical river training methods and fluvial geomorphology to habitat improvement works in order to make it sustainable.

Kellerhals R. and Miles M.: Fluvial geomorphology and fish habitat: Implications for river restoration. In Leclerc M, Capra H, Valentin S, Boudreault A and Cote Y: Ecohydraulics 2000. Proceedings 2th International Symposium on Habitat Hydraulics Quebec 1996. INRS-Eau Quebec, Canada.

Physical processes on ice-formation and development of empirical or deterministic tools.

It is generally assumed that the winter condition with very low water temperature and ice conditions is the critical season for fish survival in northern rivers. Data from biological studies of fish also show that winter conditions may have severe impacts on fish population. Despite of that, very few studies have been made of winter conditions even for commercially important species such as salmon.

Adding to the stress caused by the seasonal loss of habitat and the associated migration, are the changes that take place in the habitat quality under ice: reduced light transmission and reduced fluxes through the ice covered boundaries. Decreased metabolism, and oxygen

rejected when water freezes to ice, provides limited survival opportunities even when the habitat is sealed off from the atmosphere by an ice cover.

Currently models of ice and ice impacts on physical fish habitat are seldom used in habitat assessments, and in cold climate countries this neglect may cause the critical winter periods to be missed out in the habitat assessment process.(Alfredsen and Tesaker (2002))

Research objective

The objective is to increase the knowledge of the interaction of physical, biological and ecological factors in rivers with ice-formation: anchor ice, frazil ice etc.

Research approach

A monitoring program should be established for a first approach to the problem. Relevant parameters are temperature, discharge variations, flooding effect, river bed and bank changes, ice conditions etc. Based on the monitoring, new models and methods will be developed.

Alfredsen K and Tesaker E: Winter habitat assessment strategies and incorporation of winter habitat in Norwegian habitat assessment tools. To be published in Hydrological processes 16, 2002. John Wiley & Sons Ltd.

Defining benchmarking data for model validation.

Through the recent years we have witnessed that a large number of software packages to be used in ecohydraulic modeling have been developed. Computational models of complex system are increasingly available to a large and very varied group of users. A great deal of knowledge and skill is and will be transferred from experts in various disciplines to new users with different professional background. Flexible and easy to use interfaces encapsulate the models. The results are that the theoretical basis and details of the models are hidden. This stresses the need to examine and describe the validity of a model and the results from the model. A validation document should describe the following: (IAHR 1994)

- ? In which situations can a particular model be justifiably applied.
- ? How well do computational results represent the actual system
- ? To what extent has the model been tested
- ? What are the estimated accuracy of the prediction and what is the basis for these estimates
- ? Which are the inherent uncertainties in the model calculation and how can they be controlled

The validation of a model should give the answers to these questions.

To perform a validation it is necessary to have appropriate data.

Research objective

The objective of this work is to identify and make available to model developers and users set of data that could be used to validate models.

Research approach

The following step might be followed:

- ? Review of the need for data in the different models
- ? Definition of a structure for a database
- ? Identification of exciting set of data to be used in the validation of models
- ? If necessary: identification of new study sites appropriate for collection of validation of data.
- ? Storage of data in a database for easy access for different users.

Alfredsen K and Tesaker E: Winter habitat assessment strategies and incorporation of winter habitat in Norwegian habitat assessment tools. To be published in Hydrological processes 16, 2002. John Wiley & Sons Ltd.

Kellerhals R. and Miles M.: Fluvial geomorphology and fish habitat: Implications for river restoration. In Leclerc M, Capra H, Valentin S, Boudreault A and Cote Y: Ecohydraulics 2000. Proceedings 2th International Symposium on Habitat Hydraulics Quebec 1996. INRS-Eau Quebec, Canada.

IAHR: Guidelines for documenting the validity of computational modeling software. IAHR, June 1994.

Hydrology and the interaction of instream compartments or habitats

In the lowland river Spree (Germany) the discharge has been reduced continuously since 1990 and reached nearly zero values in summer 2001, because of water abstractions. Natural mean annual discharge would be about 25m³/s. The concomitant investigations revealed interactions between ecological compartments of the river depending on the discharge level. These interactions resulted in cascade effects, which are difficult to predict. The outcome of the cascade is of importance for the ecological integrity of the river and thus for management decisions.

Probably the cascade effects will transform the river in an other state: Eutrophic intercalated lakes export high plankton loads into the flowing sections (lengths about 20 to 30 km). Phytoplankton competes for nutrients and light with submerged macrophytes and strongly influences the oxygen budget and sedimentational processes. Along the flowpath phytoplankton concentration is reduced by sedimentations in dead zones and macrophyte stands and by filtration by dense populations of filter feeders (*Dreissena* and unionid mussels, amphipods). The reduction in discharge and hydrodynamics effect via the interaction of the compartments high depositions of decaying plankton, very low oxygen concentrations, and changes in mesohabitats composition as defined by substratum types. In consequence the diversity of mesohabitats is reduced as significant parts of the river bottom are covered by a fluffy mud layer consisting of decaying phytoplankton. This endangers species, for examples unionid mussels, which in turn could reduce phytoplankton density. The hypothetical endpoint of the reduced discharge and the interactions between the instream compartments could be a river that consists of only two compartments: muddy sediment and macrophytes. However other scenarios are conceivable.

For management decision and predictions it seems essential to combine hydrological and biological models that focus on single abiotic and biotic processes. For example, hydraulic models need to be connected to a sedimentation model and to a biological process models of phytoplankton growth and decay. This would be relevant for river sections which are influenced by lake outflows, epilimnic releases of reservoirs, or high autochthonous production.

Effects of vegetation cover on flow, parameterisation of vegetation for models, use of remote sensing techniques for hydraulic roughness or current measurements related to roughness coefficients.

Aims of the project

? To carry out controlled experiments in streams and artificial channels in order to determine the modifying nature of macrophytes on the physical habitats in streams.

? To set-up and evaluate an empirical stream habitat model based on physical and plant parameters from undisturbed streams.

Questions which are to be answered by this project (hypotheses)

- ? How are physical habitats influenced by the presence of macrophytes and how can this influence be quantified?
- ? How does macrophyte characteristics such as structure, density and coverage affect the physical habitats in the stream?
- ? Is it possible to determine the influence of macrophytes from controlled experiments with natural and artificial plants?

Interactions between stream plants and the physical habitats.

The modifying influence of the macrophytes on the physical stream habitats is studied through a series of more or less controlled experiments:

To study interactions between plants and physical habitats controlled experiments using artificial plants are carried out. All macrophytes are harvested from the stream and the artificial plants are planted in different patterns and densities on the stream reaches. The effects on substrate and the physical conditions (velocities, depth, sediment dynamics etc.) are studied.

In a number of streams semi-controlled experiments of the effects of different macrophyte patterns are carried out. Macrophytes are harvested and then replanted in different patterns and densities on the stream reaches. The effects on substrate and the physical conditions (velocities, depth, sediment dynamics etc.) are studied. Experiments concerning the effects of different kinds of weed cutting patterns on physical parameters are also carried out.

Modelling the seston-macroinvertebrate trophic interactions in salmonid river to determine the availability of prey for fishes.

Salmonid production depends on many variables including food conditions. A large part of the salmonid prey items (Ephemeroptera, Trichoptera,...) feed on seston and the associated microbial components (bacteria, protists, fungi, algae)¹. The activity of the microbial components will determine the fate of the seston produced in the upper part of the river or in a dam, and finally determine the food availability for macroinvertebrates.

The research objectives are therefore (1) to determine the fate of seston in relation to the microbial activity and (2) to determine the transfer efficiency of carbon from seston to macroinvertebrates.

Models exist for determining the fate of seston in rivers (MARCIE model², HSB model³,...) but there are not coupled to trophic models and cannot therefore reach the second objective.

In the seston-microbe-macroinvertebrate food chain, ectoenzymatic hydrolysis of complex sestonic molecules by microbes is the first rate-limiting step and size-dependent ingestion rates of seston by macroinvertebrates is the second rate-limiting step. A trophic model of benthic macroinvertebrate production must therefore include equations describing these two steps and the associated equations (enzyme diffusion in seston for example).

¹ Edwards RT, 1987. *Limnol Oceanogr* 32: 221-234.

² Sinsabaugh RL et al, 1997. *Limnol Oceanogr* 42 : 29-38.

³ Billen G, 1991. Protein degradation in aquatic environments. In: Chrost R. (Ed): *Microbial Enzymes in Aquatic Environments*, Springer Verlag: 122-142.

Influence of catchment uses and riparian corridors on organic matter budgets on a reach scale.

Agricultural activities generate environmental impacts on land and water not commonly assessed during initial land transformation and posterior functioning of agriculture fields or tree plantations. Streams in land-transformed watersheds are affected by excess sediments, nutrients and forestry waste products causing direct physical impact on riparian zones and disturbance of essential ecosystem processes, leading to deterioration of water quality and flow dynamics in downstream areas. Scientific evidence of the great impacts land transformation have on stream water quality and quantity calls for a better incorporation of mitigation measures and monitoring in agriculture practices.

Scientific knowledge and research are needed to generate a sound scientific basis for developing ecologically based methodologies for mitigation of impacts on streams and to incorporate these into land use and environmental legislation.

To relate variables at the landscape scale (watersheds) with variables at the section/reach scale (stream) in order to identify forestry impacts through local impact, which e.g. cause changes in the riparian corridor, and impacts through the impacts in the watersheds, which are transferred down-stream. Evaluation on stream structure and function at high ecological status (reference conditions) and forestry impacted watersheds. The functional approach should allow the identification of impacts, which do not affect structure as such e.g. at the level of population or species diversity but which nevertheless drives changes in essential dynamics such as OM-processing or nutrient recycling.

River classification system

Classification methods used in Denmark are mainly determined by biological objectives. It is therefore useful to try to set up some kind of hierarchical river classification system that takes hydrologic and geomorphic characteristics into account.

A physically river characterisation/classification could help or be a useful knowledge dealing with the following issues:

- ? What is the state of Danish Rivers – how many river kilometres of a certain quality/character – ex. reference reaches in connection with Water Framework Directive
- ? Transferability of knowledge (restoration, management, water abstraction, etc.) from one river to another. In how many watercourses can the results from an investigation be applied
- ? Selection of study objects for research purpose
- ? monitoring station programme

At the moment no standardised river classification system based on hydrology and geomorphology are applied in Denmark. But the first step has been taken with a system based on the equations of the hydraulic geometry for river channels (Leopold and Maddock, 1953). Temporary investigation comparing the equations (constants and exponents) of the hydraulic geometry for a natural and a modified river in the same catchment indicate a potential use of those equations for evaluating the river state/condition. Equations of the hydraulic geometry for specific geological catchment can maybe be used as a measurement of the degree of regulation of a river (ex. in respect to its reference conditions).

Before any standardised classification system can be applied some research needs has to be taken. Creating equations of the hydraulic geometry by determine the exponents, for a broad range of rivers of varied state for different landscape and landuse.

Leopold, L.B. and Maddock, T. (1953) "The hydraulic geometry of stream channels and some physiographic implications", Geol. Survey Prof. Paper 252, USGS, Washington, DC.

Food delivery to juvenile salmonids; drifting invertebrates.

The density of drifting invertebrates is spatially and temporally highly variable. This makes the prediction of their delivery to drift feeding stations very difficult. In general, the amount of drift passing a point in a river will be dependent on the benthic sources upstream, hydraulic conditions and distributions and will be mediated by the invertebrates ability to swim and move about in the current. Not much is known about the effects of any of these determinants.

The research objective would be to predict quantities of invertebrate animals passing a point in the river once the source has been quantified and the hydraulic conditions between the source and the point of measurement are known.