Departament d'Ecologia
Universitat de Barcelona

Ter River influence on Sau Reservoir limnology
Empirical and watershed-scale modeling

La influència del riu Ter en la limnologia de l'embassament de Sau
Modelització empírica i a escala de conca

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Part III

APPENDIXES

Appendix A

Neuro-fuzzy load estimation: MATLAB codes, usage, and examples

This appendix details the MATLAB files used to implement the neuro-fuzzy nutrient load estimation, and includes an informal *User Manual* with example files to help applying the method in other situations. All these materials are also provided in a digital support attached to this book. The *Numerical Example.ppt* file has no printed equivalent in this appendix, because its multimedia features are incompatible with the paper support. An alternative source is `http://www.aslo.org/lomethods/free/2004/0342_numerical_example.ptt`.

A.1 User Manual

A.1.1 Introduction

As stated in the *Introduction* of *Chapter 1*, fuzzy logic are little used in limnology, and almost completely ignored by classical statistics textbooks, and by standard statistical packages. The contents in Appendix A want to fill this gap, providing all tools needed to calculate loads with the method presented in the paper. The only pre-requisite is to have access to the MATLAB basic package plus the MATLAB Fuzzy Logic Toolbox, but no expertise with this software is required.

The complexity of the algorithms needed to apply ANFIS discouraged the authors from writing the codes in a free-access language, to give stand-alone executables. Instead, we wrote codes in MATLAB language, to take advantage of the ANFIS functions present in the MATLAB Fuzzy Logic Toolbox. Since MATLAB is not free software, use of the codes presented here limits to people having access to MATLAB. However, the authors will update this Appendix as soon as free access, powerful ANFIS functions appear (nowadays, only very limited ANFIS functions are available outside the MATLAB Fuzzy Logic Toolbox).

The following sections explain how to use the MATLAB m-files included in the Appendix to calculate constituent annual loads. But it should be stressed that not only loads, but also any regression problem can be analyzed with our procedure, even problems with more than two inputs (i.e. independent variables). However, only one output (i.e. dependent variable) is accepted by our method, and missing values are not allowed.

A.1.2 MATLAB files management

Despite we wrote our codes to be used without any MATLAB training, some basic guidelines on MATLAB files management will be given here, because this MATLAB feature frequently disorients beginners.

To work with our m-files and data, we have to place all files in a folder included in the MATLAB working path. The working path is a collection of folders where MATLAB searches files when these are called. Any file located outside this path will be invisible to MATLAB. The working path is accessible clicking the *Path Browser* button in the MATLAB command window, or typing *path* in the prompt. The most practical solution for beginners is to place files in the folder ... `/MATLAB/Work`, usually the default current directory (i.e. the folder where MATLAB preferentially loads or saves data). If after a run with our m-files the expected output files are not in ... `/MATLAB/Work`, it means that the current directory is not that folder (but we will find the output files in the folder defined as the current directory, of course!).

The MATLAB working path is easily edited with the *Path Browser* tool. But we recommend beginners to work with the ... `/MATLAB/Work` folder as the working directory, and only edit the MATLAB working path if either this folder is absent or it is not the current directory.

Remember that MATLAB is case sensitive. Thus, any data file or m-file should be named properly when requested (e.g. *Data.dat* but NOT *data.dat*).

A.1.3 Data preparation

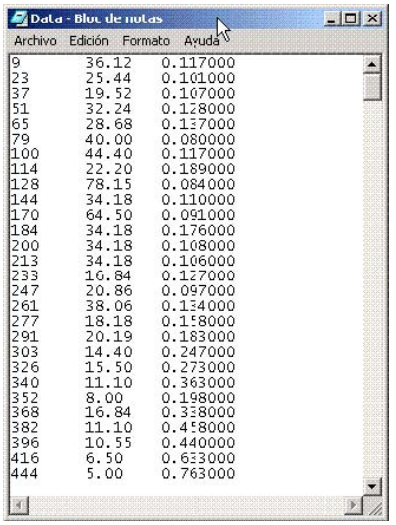
Two data files are needed to run the m-files provided in this Appendix. **It is of great importance placing the input variables in the same column order in these two files. Failing to do so will cause nonsense results, or a general collapse during computation**.

A convenient format to work with MATLAB is ASCII. Our experience is that pasting data from a spreadsheet in the Windows Notepad and saving from this application has no conflicts with MATLAB. Remember that all data and m-files should be placed in a folder included in the MATLAB working path.

Main data file

We have to arrange our basic data in a file with three columns: day number, daily flow [$m^3\ s^{-1}$], and mean daily nutrient concentration [$mg\ constituent\ L^{-1}$] (e.g. Data.dat). The day number must be assigned considering the January 1^{st} of the first year in the database as the day one. Take account of leap years! !

It is of great importance to place the output (nutrient concentration) in the last column, as MATLAB functions expect so. Units should be as above to maintain units coherence in the output files. Any missing value should be present.



Continuous input file

We have shown in the paper that after a relationship (i.e. a FIS) is established between the inputs and the output, we use this fuzzy relationship to obtain a continuous output (i.e. daily constituent concentration) from a continuous input (i.e. daily flow and day number). Thus, we need a file to feed the method with such a continuous input. In the case of annual load calculations, the file must contain a column with daily flows, and a column with day

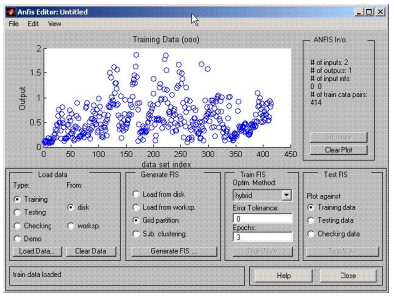
numbers. The day number column will consist in a column covering from January 1^{st} of the first year present in the database to December 31^{st} of the last year in the database. For example, for a database containing data from two non-leap years, the day number column will take values from 1 to 730. The flow column should consist in a continuous daily record corresponding to the days in the day number column. The file *Coninput.dat* is an example. For applications different than nutrient load calculations, this file could be the *Main data* file without the dependent variable, or other appropriate collection of inputs.

A.1.4 Structure identification

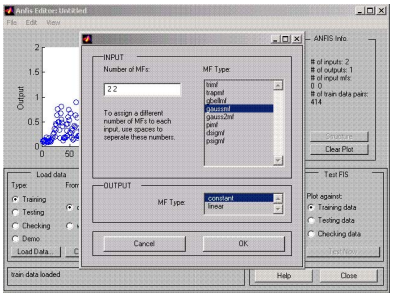
In this section we explain how to use a graphical user interface included in the MATLAB Fuzzy Logic Toolbox to solve the structure identification. The basic purpose is to answer the question: *How many MFs are necessary for each input variable?*

1. Launch MATLAB and type *anfisedit*. A graphical interface to work with ANFIS starts.

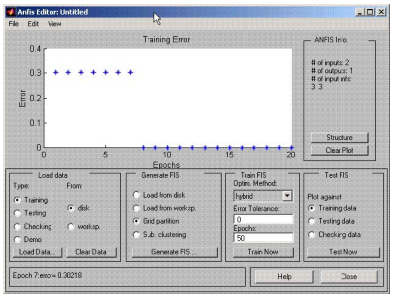
2. Click *Load data...* with the *Training* option active. Load the *Main data* file (e.g. Data.dat). The output variable appears plotted on the screen.



3. Click *Generate FIS...* with the *Grid partition* option active. A new window appears. In the *Input MF Type* box choose *gaussmf*, and in the *Output MF Type* box choose *constant*. In the *Number of Input MFs* box type a number of membership functions for each input separated by a space (e.g. start with 2 2). Here the inputs are ordered as in our files. Click *OK*. A graphical diagram of the generated zero-order Sugeno-type model is available clicking the button *Structure*

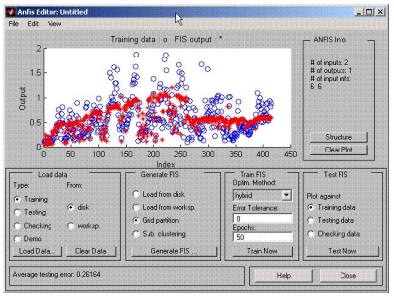


4. Set the *Optim. Method* to *hybrid*, and the *error tolerance* to 0. Write a number of *epochs* for the training process (e.g. 50). Click *Training Now*. A picture of the evolution of the Mean Square Error between modeled and observed values is displayed. If evidence exist that more epochs will significantly decrease the Error, click the *Train Now* button again.



5. When a reasonably stable Error value is achieved, click *Test Now* with the *Training data* option active. Record the Average Testing Mean Square Error displayed in the box at the bottom of the window, and also the total number of epochs used to achieve a stable Error value.

6. Repeat steps 3 to 5 with different number of Input MFs, until a decision can be taken. This



step includes some subjectivity, because in addition to the Mean Square Error, the total number of parameters should also be considered as a criterion. Each gaussian MF has two parameters, and the total output parameters are the product of the number of MF in each input. Total number of parameters should not exceed 1/6 the number of cases present in the Main data file.

This procedure works with gaussian input MFs and constant output MFs. We purposely omitted a discussion about the many options included in the ANFIS package, because this is beyond the scope of the Appendix. Although we encourage researchers to change these options if enhanced performance is expected, alternative ANFIS configurations usually gave poor results or an unacceptable amount of parameters. Researchers should consult the MATLAB Fuzzy Logic Toolbox documentation if they want to use alternative configurations.

A.1.5 Parameter estimation

When the structure identification problem is solved, the next step is to assign values to input and output MFs parameters. Once such values are assigned, we can use the generated FIS to calculate loads. This section explains how to obtain nutrient loads with the Monte-Carlo analysis explained in the paper.

Generating Training and Checking files

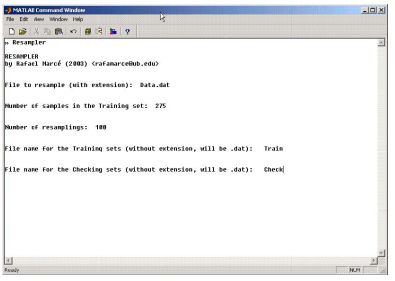
For computational convenience, we first randomly generate the different training and checking data files, which will be used during the Monte-Carlo ANFIS estimation. The m-file `Resampler.m` is the code that performs this action. Launch MATLAB and type *Resampler*. The application request some information:

1. First we have to type the name of the *Main data* file to be resampled (e.g. Data.dat).

2. Then, the amount of samples desired in the *Training* set should be specified. We assigned 2/3 of the cases in the *Main data* file. All cases not included in the *Training* set go to the *Checking* set.

3. The number of resamplings refers to the amount of *Training* and corresponding *Checking* data files we want to generate. We used 1000 in the paper (this generates 2000 files). We recommend generating few more sets than we need (*see* subsection 8).

4. Next, the desired name for the *Training* and *Checking* data files is requested. These are a prefix, because the complete file name is this prefix plus an automatically added number and extension. For example, if we answer *Train* and *Check*, the generated files will be T*rain1.dat*, T*rain2.dat*, ..., and *Check1.dat*, *Check2.dat*,...

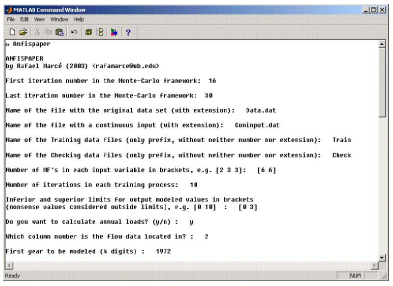


Calculating loads

When *Training* and *Checking* data files have been generated, the last step to obtain the desired annual loads is to run `Anfispaper.m`. Type *Anfispaper* in the MATLAB prompt. As above, a number of questions should be answered:

1. First and last iteration number in the Monte-Carlo framework. This is to specify the amount of Monte- Carlo iterations. These numbers are related to the index in the *Training* and *Checking* files generated through `Resampler.m`, so we cannot go beyond the number of resamplings generated in the preceeding section. We can start with a small number of iterations (e.g. answering 1–100), and repeat calculations with different *Training* and *Checking* files (e.g. answering 101–200, 201–300,) until loads and variances are stable (the program does NOT calculate this, the researcher should collect results after each run). This is very useful, because there is no a priori method to know how many iterations are needed to attain stable results. Typing 1000 or 10000 iterations will result in a very time-consuming computation (several hours), whereas 100 iterations could take only few minutes.

2. The four next questions refer to the names of the different working data files (*Main data* file, *Continuous data* file, *Training* and *Checking* files).



3. The information we collected during the *Structure Identification* trial-and-error procedure is incorporated through the seventh and eighth questions. First we have to type the number of MFs we have considered optimal for each input. Then, the number of training epochs needed during the ANFIS training. This number is actually an approximation, and it is better to place this limit beyond the minimum number of epochs needed during the trial-and-error step.

4. Inferior and superior limits for output modeled values. All values beyond these limits will be considered as nonsense values, as explained in the paper. Researcher expertise and/or information in the *Main* database could help answering this question.

5. If annual loads are considered, two more questions should be answered. First we have to type the column number where the flow input is placed in the *Main* and *Continuous data* files. The last question is the first year sampled in the *Main data* set. This number will be used to deal with leap years, so it is NOT and option.

After answering these questions, the computer will calculate during several minutes, depending on the number of Monte-Carlo iterations and the velocity of the processor. When calculations end, the time elapsed (in seconds) is showed on the screen. Some warning messages could also be present on the prompt. These messages can be completely ignored. Results are stored in ASCII files located in the MATLAB working folder, which can be opened by standard spreadsheets and statistical packages. Bear in mind that *Anfispaper* will overwrite results files generated during previous runs. Place valuable results outside the working folder.

A.1.6 Results files

loadsanual.dat

Annual load data in *Kg* constituent per year. There is one row for each Monte-Carlo iteration, and one column for each year modeled (the first column is the first year modeled). From this data we can calculate mean annual loads and variances, as well as test the normality of distributions. This file will be missing if annual loads are not considered during calculations.

nonsensevalues.dat

This file includes all the information about nonsense values detected during daily nutrient concentration prediction. This file contains a row for each

value modeled during the evaluation of the *Continuous input* file, and a column for each Monte-Carlo iteration (it could be a very large file! !). Each cell in this file contains a number:

0. The value was not considered as a nonsense value. No action was taken.

1. Nonsense value considered. The modeled value was smaller than the user-defined inferior limit. The value was replaced by the preceding modeled output.

2. Nonsense value considered. The modeled value was higher than the user-defined superior limit. The value was replaced by the preceding modeled output.

3. Nonsense value considered. One or more input values were beyond the limits of the collection of inputs present in the *Main data* file. The ANFIS function in the MATLAB Fuzzy Logic Toolbox does not model such values (i.e. it do not extrapolate, simply assigns an statistical value to this output). The value was replaced by the preceding modeled output.

fitandresiduals.dat

This file includes information about several diagnostic analysis implemented in *Anfispaper*. There is a row for each Monte-Carlo iteration. The number of columns will vary depending on the number of inputs (n) (34 columns in a two input problem):

Col. 1. Training Mean Square Error between observed and modeled concentration values plus Checking Mean Square Error.

Col. 2. Coefficient of determination of the regression between modeled and observed concentration values. Only *Training* data set considered.

Col. 3. Coefficient of determination of the regression between modeled and observed concentration values. Only *Checking* data set considered.

Col. 4. P-value of the Kolmogorov-Smirnov test for normality of the residuals. If p-value > 0.05 residuals are normal.

Col. 5. Mean value of the residuals.

Col. 6. Variance of the residuals.

Next $(2+n)$. Residuals Lag-1 autocorrelation. The first column refers to the model residuals. Then, there is a column for residual series sorted by each input, and a final column for residuals sorted by modeled values.

Next $(2+n)$. P-value of the Kendall rank coefficient test for presence of trends in the residuals. If p-value $>$ 0.05 a trend is present. The first column refers to the model residuals. Then, there is a column for residual series sorted by each input, and a final column for residuals sorted by modeled values.

Next $(2+n)$. P-value of the coefficient of determination (r^2) of the regression between residuals and an independent variable. If p-value > 0.05 the slope of the regression is not zero. Thus, a linear trend is present in the series. The first column refers to the model residuals. Then, there is one column for a regression with each input, and a final column for a regression with modeled values.

Next $(2+n)$. Runs test T statistic . If T statistic is < 1.96 no trend is present (no difference between observed and expected runs). The first column refers to the model residuals. Then, there is a column for residual series sorted by each input, and a final column for residuals sorted by modeled values.

Next $(2+n)$. Expected runs if residuals were random.

Next $(2+n)$**.** Observed runs. The first column refers to the model residuals. Then, there is a column for residual series sorted by each input, and a final column for residuals sorted by modeled values.

Next $(2+n)$**.** Runs interval. If observed runs $>$ (expected runs + interval) there is a cyclic trend. If observed runs $<$ (expected runs + interval) there is a monotonic trend.

parametersanfis.dat

This file includes information about the parameters fitted during ANFIS estimation. There is a row for each Monte-Carlo iteration. The columns will vary depending on the number of inputs and MFs:

Col. 1. Standard deviation of the first gaussian curve (MF) of the input 1 (the input order is the order in the data files).

Col. 2. Mean of the first gaussian curve (MF) of the input 1.

Col. 3. Standard deviation of the second gaussian curve (MF) of the input 1.

Col. 4. Mean of the second gaussian curve (MF) of the input 1.

(...) MF parameters of Input 2 are placed next, and so on.

Output MFs parameters follow the input parameters. Remember that output MFs are constants. Thus, there is only one parameter for each output MF. To understand how output constants are sorted in this file we have to bear in mind that each output parameter is the consequent of an *if-and-then* rule. Indeed, the output constants are sorted following an *if-and-then* rule order. The order of the output parameters are:

Column 1 after input parameters:

If $Input$ 1 is MF 1 and $Input$ 2 is MF 1 ,

then $Output$ is $Constant$ 1

Column 2 after input parameters:

If $Input$ 1 is MF 1 and $Input$ 2 is MF 2 ,

then $Output$ is $Constant$ 2

Etc...

Remember that we can draw the gaussian MFs from the parameters in this file. A gaussian curve is defined by the equation:

$$f(x) = e^{\frac{-(x-c)^2}{2\sigma^2}} \tag{A.1}$$

where c is the mean parameter and σ the standard deviation. x is the value of the input variable (flow or time).

outputseries.dat

This file includes all modeled values during simulation (i.e. daily nutrient concentration). Here, the nonsense values are already processed. This file contains a row for each value modeled from the evaluation of the *Continuous input* file, and a column for each Monte-Carlo iteration. Take in mind that this file can be very large.

A.1.7 Performance analisys

The m-file `Performance.m` implements the performance analysis explained in *Chapter 1*. If annual loads are not considered, the comparisons between modeled and observed values are between sums of outputs instead of between sums of loads. Other possibilities can be easily programmed. Contact the author for assistance.

1. Launch MATLAB and type *Performance*. A number of questions should be answered.

2. *First subsampling frequency*: The performance analysis is repeated for *Training* and *Checking* sets of different sizes (always maintaining the 2/3–1/3 ratio). The frequency refers to the number of samples in the first *Training* + *Checking* sets. Then, calculations are repeated with 2×frequency cases in these sets, then with 3×frequency cases, and so on (until the total number of cases in the *Main data* file are reached).

3. *Number of calculations in each sampled frequency*: Inside each frequency, calculation will be repeated several times (i.e. a Monte-Carlo framework for each frequency). This number is also the index to call *Training* and *Checking* files (e.g. if we answer 100, *Training* and *Checking* files numbered from 1 to 100 will be used to built new *Training* and *Checking* sets according to the defined frequency, as well as the *Evaluation* sets).

4. Following questions are equivalent to that present during *Anfispaper* run. See above.

After answering these questions, the computer will calculate during several minutes, depending on the number of Monte-Carlo iterations, number of different frequencies, and the velocity of the processor. The output consists in two files for EACH frequency (*freq*):

- PerfLoad*freq*.dat: This file contains the loads (or other result if annual loads are not considered) calculated through evaluation of inputs present in the different *Evaluation* sets, and the actual load calculated from the outputs present in these sets (nonsense values excluded, see explanations in *Chapter 1*). There is a row for each Monte-Carlo iteration. The first column is the observed load, the second is the modeled load. From these files we can calculate mean bias and variance, and we can also test the significance of this bias.

- PerfNonSense*freq*.dat: This file is equivalent to the *Nonsensevalues.dat* file above. We calculated the mean number and variance of nonsense values in each frequency from these files.

A.1.8 Special error message

In very rare occasions, an *Anfispaper* or a *Performance* run crashes, displaying an error message of the type:

> ANFIS FUNCTION CANNOT WORK WITH THE CHECKING FILE NUMBER 134. THIS FILE SHOULD BE MODIFIED.
>
> (*Anfispaper* run)

> ANFIS FUNCTION CANNOT WORK WITH THE CHECKING FILE NUMBER 456 IN FREQUENCY 300. THIS FILE SHOULD BE MODIFIED.
>
> (*Performance* run)

This is due to a *bug* in the anfis MATLAB Fuzzy Logic Toolbox function. Usually, if the anfis function finds an input space in the *Checking* data beyond the limits of the input space in the corresponding *Training* set, this *Checking* case is not modeled, and a statistical output is assigned. But if a *Checking* input value is really far beyond the limits defined in the *Training* set, anfis could fail evaluating rules including this input, and the run crashes.

In practice, we never found this error during *Anfispaper* runs. Only in one occasion a *Performance* run crashed. However, we included this error message to help researches in other situations. When an error of this type appears, the *Checking* file named in the error message and its corresponding *Training* set should be eliminated, and replaced by other combination of *Training* and *Checking* sets. This is way we recommended to generate more *Training* and *Checking* files than needed. For example, if we want to work with 1000 *Training* and *Checking* sets, we generate more (e.g. 1010). Then, if any error of this type appears, we can discard the problematic files and replace it with one of the pairs not in use

(i.e. we have to rename the files). Remember that the collection of *Training* and *Checking* files should be numbered without gaps. Otherwise, the applications will crash.

A.2 MATLAB codes and example files

MAIN MATLAB APPLICATIONS

Anfispaper.m
Performance.m
Resampler.m

OTHER MATLAB FUNCTIONS

acorf.m
acovf.m
kendallrank.m
komogorov.m
normcdf.m
stdncdf.m
regressr.m
runsrf.m

EXAMPLE DATA

Data.dat
Coninput.dat

A.2.1 `Anfispaper.m`

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                          ANFISPAPER                                          %
%   by Rafael Marce <rafamarce@ub.edu>                                         %
%   Written in May 2003 at the USACE Environmental Laboratory,                 %
%              Waterways Experiment Station, Vicksburg (MS).                   %
%   Help and software from Carlos E. Ruiz is greatly appreciated               %
%==========================================================================%
%       Permission is granted to modify and re-distribute this code          %
%       in any manner as long as this notice is preserved.                   %
%==========================================================================%
%--------------------------- DISCLAIMER: -------------------------------%
%          This code is provided as is with no guarantees.                 %
%--------------------------------------------------------------------------%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   ANFISPAPER.  Applies ANFIS in a Monte-Carlo framework                      %
%   Any number of inputs can be modeled but only one output                    %
%   Also, the input MF's must be gaussian, and the output MF constants%
%   Other configurations need changes in the line 75 and 216-229               %
%   As the core of the procedure is the anfis function from                    %
%   the Matlab Fuzzy Logic toolbox, consult documentation in this              %
%   toolbox to change anfis options.                                           %
%   Four files are saved as outputs. Consult the Appendix A for                %
%   details.                                                                   %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear

fprintf ('\nANFISPAPER')
fprintf ('\nby Rafael Marce (2003) <rafamarce@ub.edu>')
```

```
inisample=input('\n\nFirst iteration number in the Monte-Carlo framework:  ');

finsample=input('\nLast iteration number in the Monte-Carlo framework:  ');

originaldata=input('\nName of the file with the original data set (with extension):   ','s');

continuinput=input('\nName of the file with a continuous input (with extension):   ','s');

mostrejats=input('\nName of the Training data files (only prefix, without neither number nor extension):   ','s');

remanents=input('\nName of the Checking data files (only prefix, without neither number nor extension):   ','s');

numeroMF=input('\nNumber of MF''s in each input variable in brackets, e.g. [2 3 3]:   ');

numberiter=input('\nNumber of iterations in each training process:   ');

nullimits=input('\nInferior and superior limits for output modeled values in brackets\n(nonsense '   ...
                                        ...      values considered outside limits), e.g. [0 10]  :   ');
%the last break is illegal, must be recomposed to avoid errors
loadsq=input('\nDo you want to calculate annual loads? (y/n) :   ','s');

if loadsq=='y'
   flowloc=input('\nWhich column number is the flow data located in? :   ');
   firstyear=input('\nFirst year to be modeled (4 digits) :   ');
else
   fprintf ('\nAnnual loads will NOT be calculated')
end
tic
extensio='.dat';
%%%%%%%%%%%%%%%%%%%%%%%ANFIS in a Monte-Carlo framework%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

conterror=0; %Error message. See the text document included in the Appendix
for i=inisample:finsample
numero=int2str(i);
   arxiu=strcat(mostrejats,numero,extensio);
   trainingdata=load(arxiu);
   arxiu2=strcat(remanents,numero,extensio);
   checkdata=load(arxiu2);

   %Generating a fuzzy inference system with the user-defined options
   fismat=genfis1(trainingdata,numeroMF,'gaussmf','constant');

   [ard,ardd]=size(trainingdata);
   numberinputsee=ardd-1;

   seriept=evalfis(checkdata(:,1:numberinputsee),fismat);
   if any(seriept~=0)
   fprintf ('\nANFIS FUNCTION CANNOT WORK WITH THE CHECKING FILE NUMBER %d.\nTHIS FILE SHOULD BE REPLACED\n',i)
   conterror=conterror+1;
   else
   end
end
if conterror>0
   return
else
end

for i=inisample:finsample

   %Loading the training and checking data
   %This loading procedure explains why we label the training and cheching data with a number
   numero=int2str(i);
   arxiu=strcat(mostrejats,numero,extensio);
   trainingdata=load(arxiu);
   arxiu2=strcat(remanents,numero,extensio);
   checkdata=load(arxiu2);

   [ak,akk]=size(trainingdata);
   numberinputs=akk-1;

   %Generating a fuzzy inference system with the user-defined options
   fismat=genfis1(trainingdata,numeroMF,'gaussmf','constant');

   %Adaptive neuro-fuzzy inference. Anfis function is the core of the procedure
   [fistraining,etraining,ss,fischeck(i),echeck]=anfis(trainingdata,fismat,numberiter,[0 0 0 0],checkdata);

   %%%Error and fit evaluation of the parameterized FIS structure%%%

   %Looking for the training iteration with minimum mean squar error between the observed data and the checking set
   %Remember that the parameter values during this iteration are the final values considered for the current iteration
   minimoerrorchk=min(echeck);
   posicion=find(echeck==minimoerrorchk);

   %Global error, calculated as the sum of the errors from the training and cheching sets
   sumaerror(i,1)=minimoerrorchk+etraining(posicion);

   %Least squares regression for the training and checking sets
   seriefit=evalfis(trainingdata(:,1:numberinputs),fischeck(i));
   seriefit2=evalfis(checkdata(:,1:numberinputs),fischeck(i));
```

```
[pvalue,rsquare]=regressr(trainingdata(:,akk),seriefit);
sumaerror(i,2)=rsquare;

[pvalue,rsquare]=regressr(checkdata(:,akk),seriefit2);
sumaerror(i,3)=rsquare;

%Residuals observed-modeled values
matriu_obs = cat(1,trainingdata,checkdata);%concatenation
valors_predits = cat(1,seriefit,seriefit2);
valors_obs = matriu_obs(:,akk);
residus = valors_obs - valors_predits;

%Residuals and different inputs and predicted values in one matrix
matriu_resiuds(:,1) = residus;
for lk=2:(akk)
   matriu_resiuds(:,lk) = matriu_obs(:,(lk-1));
end
matriu_resiuds(:,(akk+1)) = valors_predits;

%Kolmogorov-Smirnov test (normality of the residuals)
mean_residus(1:length(residus),1) = mean(residus);%Needed for a subrutine in kolmogorov.m
var_residus(1:length(residus),1) = var(residus);
[statistic, pvalue, H]=kolmogorov(residus,0.05,'norm_cdf',mean_residus,var_residus);

%%%%%%%%%% model residuals statistics

%Lag-1 autocorrelation
residust=transpose(residus);
parmtr=length(residus)-1;
autocorr_fx = acorf(residust,parmtr);
lag1_residus(1) = autocorr_fx(1);

%runs test
[Tstat(1),expectedruns(1),nombreruns(1),intervalo(1)]=runsrf(residus);

%kendall rank coefficient for trends
[mu,h,pvalken(1)]=kendallrank(residus);

%Least squares regression (zero slope significance)
contadorx=(1:length(residus))';
[pvalreg(1),xxxx]=regressr(residus,contadorx);

%%%%%%%%%% input variables residuals statistics

for ii=1:numberinputs
   residus_ordenats = sortrows(matriu_resiuds,ii+1);%residuals sortet by inputs

   %Lag-1 autocorrelation
   residust=transpose(residus_ordenats(:,1));
   parmtr=length(residus_ordenats(:,1))-1;
   autocorr_fx = acorf(residust,parmtr);
   lag1_residus(ii+1) = autocorr_fx(1);

   %runs test
   [Tstat(ii+1),expectedruns(ii+1),nombreruns(ii+1),intervalo(ii+1)]=runsrf(residus_ordenats(:,1));

   %kendall rank coef
   [mu,h,pvalken(ii+1)]=kendallrank(residus_ordenats(:,1));

   %Least squares regression (zero slope significance)
   [pvalreg(ii+1),xxxx]=regressr(residus_ordenats(:,1),residus_ordenats(:,ii+1));
end

%%%%%%%%%% predicted values residuals statistics

residus_ordenats = sortrows(matriu_resiuds,akk+1);

%Lag-1 autocorrelation
residust=transpose(residus_ordenats(:,1));
parmtr=length(residus_ordenats(:,1))-1;
autocorr_fx = acorf(residust,parmtr);
lag1_residus(akk+1) = autocorr_fx(1);

%runs test
[Tstat(akk+1),expectedruns(akk+1),nombreruns(akk+1),intervalo(akk+1)]=runsrf(residus_ordenats(:,1));

%kendall rank coef
[mu,h,pvalken(akk+1)]=kendallrank(residus_ordenats(:,1));

%Least squares regression (zero slope significance)
[pvalreg(akk+1),xxxx]=regressr(residus_ordenats(:,1),residus_ordenats(:,akk+1));


%%%%%%%%%% collecting results. Programmed for any number of input variables

sumaerror(i,4)=pvalue;%Kolmogorov pvalue
sumaerror(i,5)=mean(residus);%mean of the residuals
sumaerror(i,6)=var(residus);%variance of the residuals

for iii=7:(7+numberinputs+1)
   sumaerror(i,iii)=lag1_residus(iii-6);
```

```
   end

   for iii=(7+numberinputs+2):((7+numberinputs+2)+numberinputs+1)
      sumaerror(i,iii)=pvalken(iii-(7+numberinputs+1));
   end

   for iii=((7+numberinputs+2)+numberinputs+2):(((7+numberinputs+2)+numberinputs+2)+numberinputs+1)
      sumaerror(i,iii)=pvalreg(iii-((7+numberinputs+2)+numberinputs+1));
   end

   for iii=(((7+numberinputs+2)+numberinputs+2)+numberinputs+2):((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)...
                                                                  +numberinputs+1)
      sumaerror(i,iii)=Tstat(iii-(((7+numberinputs+2)+numberinputs+2)+numberinputs+1));
   end

   for iii=((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2):(((((7+numberinputs+2)+...
                    numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+1)
      sumaerror(i,iii)=expectedruns(iii-((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+1));
   end

   for iii=(((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2):...
               ((((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+1)
      sumaerror(i,iii)=nombreruns(iii-(((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)...
                                                              +numberinputs+2)+numberinputs+1));
   end

   for iii=((((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)...
                               :(((((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)+...
                                                              numberinputs+2)+numberinputs+2)+numberinputs+1)
      sumaerror(i,iii)=intervalo(iii-((((((7+numberinputs+2)+numberinputs+2)+numberinputs+2)+numberinputs+2)...
                                                                  +numberinputs+2)+numberinputs+1));
   end

end

%%%%%%%%%%%ANFIS parameters. It is only possible with gaussian MF in the inputs and a constant parameter as output MF
%For other options this code must be modified. See the Fuzzy logic toolbox pdf help for other options and
%associated number of parameters

for i=inisample:finsample
   ww=-1;
   for qq=1:numberinputs
      for qqq=1:numeroMF(qq)
         ww=ww+2;
         parmetresanfis(i,ww:ww+1)=getfis(fischeck(i),'input',qq,'mf',qqq,'Params');%function that collects the fis parameters
                                                                                    %(the inputs in this case)
      end
   end
   ppp=0;
   for zz=ww+2:(ww+1+prod(numeroMF))
      ppp=ppp+1;
      parmetresanfis(i,zz)=getfis(fischeck(i),'output',1,'mf',ppp,'Params');
   end
end

%%%%%%%%%%%%Now we model the output with all the Fuzzy Inference Systems we have parameterized,
                                                                  %with an input file specifief by the user

serieevaluar=load(continuinput);
serieoriginal=load(originaldata);

if loadsq=='y'

   for h=inisample:finsample
      seriept=evalfis(serieevaluar,fischeck(h));

      %Nonsense values substitution
      overl=0;
      for tt=1:numberinputs
         overli=find( (serieevaluar(1,tt) < min(serieoriginal(:,tt))) | (serieevaluar(1,tt) > max(serieoriginal(:,tt))) );
         if any(overli)
            overl=overl+1;
         else
         end
      end
      if overl>0 %no-trained inputs give an average output. A little disaster!!!
         seriept(1)=serieoriginal(1,akk);%The probability of applying this is minimal!!
         contadordepurats(1,h)=3;
      elseif seriept(1)<nullimits(1)
         seriept(1)=min(serieoriginal(:,akk));
         contadordepurats(1,h)=1;
      elseif seriept(1)>nullimits(2)
         seriept(1)=max(serieoriginal(:,akk));%maximum in the database
         contadordepurats(1,h)=2;
      else
         contadordepurats(1,h)=0;
      end
      for k=2:length(seriept)
         overl=0;
         for tt=1:numberinputs
            overli=find( (serieevaluar(k,tt) < min(serieoriginal(:,tt))) | (serieevaluar(k,tt) > max(serieoriginal(:,tt))) );
```

```
            if any(overli)
               overl=overl+1;
            else
            end
         end
         if overl>0
            seriept(k)=seriept(k-1);
       contadordepurats(k,h)=3;
         elseif seriept(k)<nullimits(1)
        seriept(k)=seriept(k-1);
        contadordepurats(k,h)=1;
         elseif seriept(k)>nullimits(2)
        seriept(k)=seriept(k-1);
        contadordepurats(k,h)=2;
         else
       contadordepurats(k,h)=0;
         end
      end

      seriesoutputs(:,h)=seriept;

      %%%%%%%%%%%%%Annual load calculation

      numeroanys=length(serieevaluar)/365;%Only false for aprox 1400 years!!
      serieloads=seriept.*serieevaluar(:,flowloc)*3.6*24;%Kg/day
      contadordedies=1;
      leapyears=[1848 1896 1948 1996 2044 2092
                 1852 1904 1952 2000 2048 2096
                 1856 1908 1956 2004 2052 2104
                 1860 1912 1960 2008 2056 2108
                 1864 1916 1964 2012 2060 2112
                 1868 1920 1968 2016 2064 2116
                 1872 1924 1972 2020 2068 2120
                 1876 1928 1976 2024 2072 2124
                 1880 1932 1980 2028 2076 2128
                 1884 1936 1984 2032 2080 2132
                 1888 1940 1988 2036 2084 2136
                 1892 1944 1992 2040 2088 2140];
      for g=firstyear:(firstyear+numeroanys-1)
         leaps=find(g==leapyears);
         if any(leaps)
            load(h,g-firstyear+1)=serieloads(contadordedies);
            for dia=1:365
               load(h,g-firstyear+1)=load(h,g-firstyear+1)+ serieloads(contadordedies+dia);
            end
            contadordedies=contadordedies+366;
         else
            load(h,g-firstyear+1)=serieloads(contadordedies);
            for dia=1:364
               load(h,g-firstyear+1)=load(h,g-firstyear+1) + serieloads(contadordedies+dia);
            end
            contadordedies=contadordedies+365;
         end
      end
   end
   save loadsanual.dat load -ascii

else

   for h=inisample:finsample
      seriept=evalfis(serieevaluar,fischeck(h));

      %Nonsense values substitution
      overl=0;
      for tt=1:numberinputs
         overli=find( (serieevaluar(1,tt) < min(serieoriginal(:,tt))) | (serieevaluar(1,tt) > max(serieoriginal(:,tt))) );
         if any(overli)
            overl=overl+1;
         else
         end
      end
      if overl>0
         seriept(1)=serieoriginal(1,akk);
         contadordepurats(1,h)=3;
      elseif seriept(1)<nullimits(1)
         seriept(1)=min(serieoriginal(:,akk));
         contadordepurats(1,h)=1;
      elseif seriept(1)>nullimits(2)
         seriept(1)=max(serieoriginal(:,akk));
         contadordepurats(1,h)=2;
      else
         contadordepurats(1,h)=0;
      end
      for k=2:length(seriept)
         overl=0;
         for tt=1:numberinputs
            overli=find( (serieevaluar(k,tt) < min(serieoriginal(:,tt))) | (serieevaluar(k,tt) > max(serieoriginal(:,tt))) );
            if any(overli)
               overl=overl+1;
            else
            end
```

```
          end
          if overl>0
             seriept(k)=seriept(k-1);
        contadordepurats(k,h)=3;
          elseif seriept(k)<nullimits(1)
         seriept(k)=seriept(k-1);
         contadordepurats(k,h)=1;
          elseif seriept(k)>nullimits(2)
         seriept(k)=seriept(k-1);
         contadordepurats(k,h)=2;
          else
        contadordepurats(k,h)=0;
          end
       end

       seriesoutputs(:,h)=seriept;
    end
end

%%%%%%%%%%Saving data

save nonsensevalues.dat contadordepurats -ascii
save parametersanfis.dat parmetresanfis -ascii
save fitandresiduals.dat sumaerror -ascii
save outputseries.dat seriesoutputs -ascii
toc
```

A.2.2 Performance.m

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                          PERFORMANCE                                       %
%   by Rafael Marce <rafamarce@ub.edu>                                       %
%   Written in May 2003 at the USACE Environmental Laboratory,               %
%              Waterways Experiment Station, Vicksburg (MS).                 %
%   Help and software from Carlos E. Ruiz is greatly appreciated             %
%============================================================================%
%       Permission is granted to modify and re-distribute this code          %
%       in any manner as long as this notice is preserved.                   %
%============================================================================%
%--------------------------- DISCLAIMER: -----------------------------------%
%          This code is provided as is with no guarantees.                   %
%----------------------------------------------------------------------------%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   PERFORMANCE. Performance analisys as explained in the Appendix.          %
%   Applications different than load calculations or mathematicaly           %
%   equivalent need substantial modifications.                               %
%   Contact the authors for specific cases.                                  %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear

fprintf ('\nPERFORMANCE')

fprintf ('\nby Rafael Marce (2003) <rafamarce@ub.edu>')

freqcy=input('\n\nFirst subsampling frequency :  ');

numsamples=input('\nNumber of calculations in each sampled frequency:  ');

mostrejats=input('\nName of the Training data files (only prefix, without neither number nor extension):   ','s');

remanents=input('\nName of the Checking data files (only prefix, without neither number nor extension):   ','s');

numeroMF=input('\nNumber of MF''s in each input variable in brackets, e.g. [2 3 3]:   ');

numberiter=input('\nNumber of iterations in each training process:   ');

nullimits=input('\nInferior and superior limits for output modeled values in brackets\n(nonsense values ...
                                                                  considered outside limits), e.g. [0 10]  :   ');
%The above break is illegal. Must be recomposed to work with the code
loadsq=input('\nIs it an annual load problem or equivalent? (y/n) :   ','s');

if loadsq=='y'
   flowloc=input('\nWhich column number is the flow data located in? :   ');
   else
   fprintf ('\nAnnual load NOT considered')
end

tic
extensio='.dat';
numero=int2str(1);
arxiu=strcat(mostrejats,numero,extensio);
trainingdata=load(arxiu);
arxiu2=strcat(remanents,numero,extensio);
checkdata=load(arxiu2);
totalfile=cat(1,trainingdata,checkdata);
numberfreqcies=fix(length(totalfile)/freqcy);
[ak,akk]=size(trainingdata);
numberinputs=akk-1;

conterror=0; %Error message. See the text document included in the Appendix
for f=1:numberfreqcies
   for i=1:numsamples
      %Loading the training and checking data
      %This loading procedure explains why we label the training and cheching data with a number
      numero=int2str(i);
      arxiu=strcat(mostrejats,numero,extensio);
      trainingdata=load(arxiu);
      arxiu2=strcat(remanents,numero,extensio);
      checkdata=load(arxiu2);

      totalfile=cat(1,trainingdata,checkdata);
      numerotrains=round((f*freqcy)*2/3);

      trainingdata=totalfile(1:numerotrains,:);
      checkdata=totalfile((numerotrains+1):(f*freqcy),:);
      evaldata=totalfile(((f*freqcy)+1):end,:);

      %Generating a fuzzy inference system with the user-defined options
      fismat=genfis1(trainingdata,numeroMF,'gaussmf','constant');
      seriept=evalfis(checkdata(:,1:2),fismat);

      if any(seriept~=0)
         fprintf ('\nANFIS FUNCTION CANNOT WORK WITH THE CHECKING FILE NUMBER %d IN ...
                                          FREQUENCY %d.\nTHIS FILE SHOULD BE MODIFIED\n',i,f)
```

```
        %The above break is illegal. Must be recomposed to work with the code

        conterror=conterror+1;
      else
      end
   end
end
if conterror>0
   return
else
end

%%%%%%%%%%%%%%%%%%%%%%%%ANFIS in a Monte-Carlo framework%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for f=1:numberfreqcies
   contadordepurats=zeros( (length(totalfile)-(f*freqcy)),numsamples);
   for i=1:numsamples

      %Loading the training and checking data
      %This loading procedure explains why we label the training and cheching data with a number
      numero=int2str(i);
      arxiu=strcat(mostrejats,numero,extensio);
      trainingdata=load(arxiu);
      arxiu2=strcat(remanents,numero,extensio);
      checkdata=load(arxiu2);
      totalfile=cat(1,trainingdata,checkdata);
      numerotrains=round((f*freqcy)*2/3);
      trainingdata=totalfile(1:numerotrains,:);
      checkdata=totalfile((numerotrains+1):(f*freqcy),:);
      evaldata=totalfile(((f*freqcy)+1):end,:);
      %Generating a fuzzy inference system with the user-defined options
      fismat=genfis1(trainingdata,numeroMF,'gaussmf','constant');
      %Adaptive neuro-fuzzy inference. Anfis function is the core of the procedure
      [fistraining,etraining,ss,fischeck,echeck]=anfis(trainingdata,fismat,numberiter,[0 0 0 0],checkdata);
      seriept=evalfis(evaldata(:,1:numberinputs),fischeck);
      loads(i,1)=0;
      loads(i,2)=0;
      serieoriginal=cat(1,trainingdata,checkdata);
      %Nonsense values substitution and calcul
      for k=1:length(seriept)
         overl=0;
         for tt=1:numberinputs
            overli=find( (evaldata(k,tt) < min(serieoriginal(:,tt))) | (evaldata(k,tt) > max(serieoriginal(:,tt))) );
            if any(overli)
               overl=overl+1;
            else
            end
         end
         if overl>0
            contadordepurats(k,i)=3;
         elseif seriept(k)<nullimits(1)
          contadordepurats(k,i)=1;
         elseif seriept(k)>nullimits(2)
          contadordepurats(k,i)=2;
         else
            contadordepurats(k,i)=0;
            if loadsq=='y'
               loadobs=evaldata(k,akk)*evaldata(k,flowloc)*3.6*24; % Kg/day
               loadmod=seriept(k)*evaldata(k,flowloc)*3.6*24;
               loads(i,1)=loads(i,1)+loadobs;
               loads(i,2)=loads(i,2)+loadmod;
            else
               loadobs=evaldata(k,akk);
               loadmod=seriept(k);
               loads(i,1)=loads(i,1)+loadobs;
               loads(i,2)=loads(i,2)+loadmod;
            end
          end
      end
   end
   numero=int2str((f*freqcy));
   arxiu3=strcat('PerfLoad',numero,extensio);
   arxiu4=strcat('PerfNonSense',numero,extensio);

   [casos,columnes]=size(contadordepurats);
   formato='%d';
   for u=2:columnes
   formato=strcat(formato,' %d');
   end
   formato=strcat(formato,'\n');

   if exist(arxiu3)==2;
      delete(arxiu3);
   else
   end
   if exist(arxiu4)==2;
      delete(arxiu4);
   else
   end
      [fid, message] = fopen(arxiu3,'a');
   if fid==-1
   disp (message)%Error
```

```
   else
   end
   fprintf(fid,'%d %d\n',loads);
   fclose(fid);
      [fid, message] = fopen(arxiu4,'a');
   if fid==-1
   disp (message)%Error
   else
   end
   fprintf(fid,formato,contadordepurats);
   fclose(fid);
end
toc
```

A.2.3 Resampler.m

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                              RESAMPLER                                      %
%   by Rafael Marce <rafamarce@ub.edu>                                        %
%   Written in May 2003 at the USACE Environmental Laboratory,                %
%             Waterways Experiment Station, Vicksburg (MS).                   %
%   Help and software from Carlos E. Ruiz is greatly appreciated              %
%=============================================================================%
%       Permission is granted to modify and re-distribute this code           %
%       in any manner as long as this notice is preserved.                    %
%=============================================================================%
%--------------------------- DISCLAIMER: -------------------------------------%
%          This code is provided as is with no guarantees.                    %
%-----------------------------------------------------------------------------%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   RESAMPLER. Random resample the rows of a matrix.                          %
%   The m-file has been built for non-experienced users.                      %
%   However, a function-like m-file is easily obtained with                   %
%   minor changes.                                                            %
%   The program randomly divides a matrix (row indexed) into                  %
%   two subsets of data (Training and Checking sets). The proportion          %
%   of samples in each subset is user-defined.                                %
%   The random sampling is repeated as many times as wanted.                  %
%   The output is an array of files, named individually with a                %
%   user-defined prefix and an automatically assigned suffix, e.g.:           %
%             Training1.dat, Training2.dat, etc...                            %
%             Checking1.dat, Checking2.dat, etc...                            %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


clear

fprintf ('\nRESAMPLER')
fprintf ('\nby Rafael Marce (2003) <rafamarce@ub.edu>')

entrada=input('\n\n\nFile to resample (with extension):  ','s');
matriu=load (entrada);

numsamples=input('\n\nNumber of samples in the Training set:  ');

conjunts=input('\n\nNumber of resamplings:  ');
mostrejats=input ('\n\nFile name for the Training sets (without extension, will be .dat):   ','s');

remanents=input ('\n\nFile name for the Checking sets (without extension, will be .dat):   ','s');
tic
[casos,columnes]=size(matriu);
formato='%d';
for u=2:columnes
   formato=strcat(formato,' %d');
end
formato=strcat(formato,'\n');

for i=1:conjunts
   sampling=randperm(casos);%Random rearrangement of the raw index
   extensio='.dat';
   enumeradordarxiu=int2str(i);%transforms a number into a word

   arxiu=strcat(mostrejats,enumeradordarxiu,extensio);
   if exist(arxiu)==2;
      delete(arxiu);
   else
   end
   [fid, message] = fopen(arxiu,'a');
   if fid==-1
   disp (message)%Error
   end
   for j=1:numsamples
   fprintf(fid,formato,matriu(sampling(j),:));
   end
   fclose(fid);

   arxiu=strcat(remanents,enumeradordarxiu,extensio);
   if exist(arxiu)==2;
      delete(arxiu);
   else
   end
   [fid, message] = fopen(arxiu,'a');
   if fid==-1
   disp (message)%Error
   end
   for j=(numsamples+1):casos%The remaining samples form the checking set
   fprintf(fid,formato,matriu(sampling(j),:));
   end
   fclose(fid);
end
toc
```

A.2.4 acorf.m

```
function [ACF,stderr,lpq,qpval] = acorf(Z,N);
% Autocorrelation function
%  Calculates autocorrelations for multiple data series.
%  Also calculates Ljung-Box Q stats and p-values.
%
%    [ACF,stderr,lpq,qpval] = acorf(Z,KMAX);
%  If mean should be removed use
%    [ACF,stderr,lpq,qpval] = acorf(detrend(Z',0)',KMAX);
%
% INPUT
%  Z is data series for which autocorrelations are required
%       each in a row
%  KMAX is the number of autocorrelations to be calculated
%
% OUTPUT
%  ACF      nr x KMAX matrix of autocorrelations
%  stderr   nr x KMAX matrix of (approx) std errors
%  lpq      nr x KMAX matrix of Ljung-Box Q stats
%  qpval    nr x KMAX matrix of p-values on Q stats
%
% All input and output parameters are organized in rows, one row
% corresponds to one series

% Version 2.44
% last revision 19.06.1998
% Copyright (c) 1997, 1998 by Alois Schloegl
% e-mail: a.schloegl@ieee.org

% calculating lpq, stderr, qpval from
% suggested by Philip Gray, University of New South Wales,

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% License along with this library; if not, write to the
% Free Software Foundation, Inc., 59 Temple Place - Suite 330,
% Boston, MA  02111-1307, USA.

[nr,nc]=size(Z);
ACF=acovf(Z,N);
ACF = ACF(:,2:N+1) ./ ACF(:,ones(1,N));

if nargout > 1

stderr=ones(nr,N)*sqrt(1/nc);
lpq=zeros(nr,N);
qpval=zeros(nr,N);

cum=zeros(nr,1);
for k=1:N,
        cum=cum+ACF(:,k).^2/(nc-k);
        lpq(:,k)=nc*(nc+2)*cum;                % Ljung box Q for k lags
        qpval(:,k)=1-chi2cdf(lpq(:,k),k); % p-value of Q stat
end;
end;
```

A.2.5 acovf.m

```
function [ACF,WACF] = acovf(Z,KMAX);
% Autocovariance function for multiple channels
% [ACF,WACF] = acovf(Z,N);
%
% Input: Z    Signal (one channel per row);
% N+1  # of coefficients
% Output: ACF  autocovariance function
% WACF weighted autocorrelation function

% Version 2.40
% last revision 27.04.1998
% Copyright (c) 1997, 1998 by Alois Schloegl
% e-mail: a.schloegl@ieee.org

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% Free Software Foundation, Inc., 59 Temple Place - Suite 330,
% Boston, MA  02111-1307, USA.

[lr,lc]=size(Z);

if (nargin == 1) KMAX = lc-1;
elseif (KMAX >= lc-1) KMAX = lc-1;
end;

if (10*KMAX > lc) & (lr==1),      % use fast Built-in function
ACF = filter(Z(lc:-1:1),1,Z);
ACF = ACF(lc:-1:1+lc-KMAX);
else
        ACF=zeros(lr,KMAX+1);
        for L=1:lr,
for K = 0:KMAX,
ACF(L,K+1) = Z(L,1:lc-K) * Z(L,1+K:lc)';
% fprintf(1,'%05.1f %i %08.8f\n',toc,K,ACF(K+1));
end;end;

end;
ACF=ACF/lc;
WACF=ACF*lc./ACF(:,ones(1,KMAX+1));
```

A.2.6 kendallrank.m

```
function [mu,h,sig]= kendallrank (x)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                              KENDALLRANK                                    %
%   by Rafael Marce <rafamarce@ub.edu>                                        %
%   Written in May 2003 at the USACE Environmental Laboratory,                %
%              Waterways Experiment Station, Vicksburg (MS).                  %
%   Help and software from Carlos E. Ruiz is greatly appreciated              %
%=============================================================================%
%       Permission is granted to modify and re-distribute this code           %
%       in any manner as long as this notice is preserved.                    %
%=============================================================================%
%------------------------- DISCLAIMER: ------------------------------------%
%          This code is provided as is with no guarantees.                    %
%-----------------------------------------------------------------------------%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   KENDALLRANK.  Kendall's rank correlation coeficient                       %
%   The coeficient is calculated for the vector (x) and the same              %
%   vector but sorted.                                                        %
%   Output variables are:                                                     %
%   'mu'  Kendall mu beta statistic                                           %
%   'h' Determine if the actual significance exceeds                          %
%       the desired significance (0.05)                                       %
%   'sig' p value for trend. If <= 0.05 there is a trend                      %
%   For details see Legendre & Legendre 1998 Numerical Ecology.               %
%   2nd English edition. Elsevier Science BV, Amsterdam.                      %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

ordenada=sort(x);
n = length(x);
parejas=nchoosek(n,2); %Number of elements (2 a 2)
i=zeros(1,parejas);

contador=0;
for dd=1:n
   for k=1:(n-dd)
      contador=contador+1;%Indexing all combinations of elements
      i(contador)=dd;
   end
end
j=zeros(1,parejas);
contador=0;
for dd=1:n
   for k=(dd+1):n
      contador=contador+1;%Idem
      j(contador)=k;
   end
end
sdex=sign(x(i)-x(j));
sdeordenada=sign(ordenada(i)-ordenada(j)); %Calculation of S
s1=(sdex.*sdeordenada);
S=sum(s1);

clear sdex;
clear sdeordenada;
clear s1;
clear i;
clear j;

un=unique(x);
ties=zeros(1,length(un));
for index2=1:length(un)
temp=find(x==un(index2));%Tied values. As is the same series but diferently sorted, it is like a simetric contingency table
if length(temp)>1
ties(index2)=length(temp);
end
end

i=1:length(ties);
L1=(sum(ties.*(ties-1)))/2;%Calculation of L

mu= S / ((sqrt((n*(n-1)-L1)/2))*(sqrt((n*(n-1)-L1)/2)));%Calculation of Kendall mu beta

%Significance

zval=(abs(mu) * sqrt((9*n*(n-1))/(2*(2*n+5))))- sqrt(18/(n*(n-1)*(2*n+5))); %Statistic z (Legendre)

sig = 0.5 * erfc( - (zval) ./ (sqrt(2)));% the significance just found is for the  tail = -1 test
if (sig > 1)
    sig=1;
end
sig = 1 - sig;%Transformation for the alternative tau>0
h = 0;% Determines if the actual significance exceeds the desired significance
if sig <= .05,
    h = 1;
end
```

```
if isnan(sig),
    h = NaN;
 end
```

A.2.7 kolmogorov.m

```
function [statistic, pvalue, H]=kolmogorov(x,size,dist,varargin)
% PURPOSE:
%     Performs a Kolmogorov-Smirnov test that the data are from a specified distribution
%
% USAGE:
%     [statistic, pvalue, H]=kolmorgorov(x,size,dist,varargin)
%
% INPUTS:
%  x        -  A set of deviates from a garch process OR a ser of deviates suspected of having GARCH
%  size     -  The size for the test.  The test is a two tailed test with Size/2 probability in each tail.
%  dist     -  A char string of the name of the CDF, i.e. 'normcdf' for the normal, also use 'unifcdf' if you want to
%              only pass already probability integral transformed data to the funtion, and set the varargin at to 0,1.
%  varargin -  Arguements passed to the CDF, such as D.F. for a T-dist
%
% OUTPUTS:
%  statistic - The KS Statistic, D=max(abs(u-i/n)) where u is the ith sorted CDF point
%  pval      - The asymptotic probability of signifigance
%  H         - 1 for reject the null that the distribution is correct, 0 otherwise
%
%
% COMMENTS:
%  Note:  If you want to pass in already probability inegral transformed data by the suspect distribtion
%         use the uniform distribution with parameters 0 1
%
%
% Author: Kevin Sheppard
% kksheppard@ucsd.edu
% Revision: 2    Date: 12/31/2001


x=sort(x);
cdfvals=feval(dist,x,varargin{:});
n=length(x);
S=(1:n)'/n;
size=size/2;

d=max(abs(cdfvals-S));
statistic=d;
crit=kscritical(n,size);
H=statistic>crit;

k = (n^(0.5) + 0.12 + 0.11/n^(0.5))*statistic ;
tol=1;
pvalue=2*exp(-2*k*k);
s=-1;
i=2;
while tol >1e-10
    old=pvalue;
    pvalue=pvalue+2*s/exp(2*k*k*i*i);
    i=i+1;
    s=s*(-1);
    tol=abs(pvalue-old);
end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function crit=kscritical(n,pvalue);
% This is a helper function for kolmorgorov that returns the appropriate critical value.
% Uses a table from (1956) and asymptotic values Miller(1956) JASA


if n<=100
    alpha=[.1 .05 .025 .01 .005];
    lookuptable= ...
        [0.9000    0.9500    0.9750    0.9900    0.9950
        0.6838    0.7764    0.8419    0.9000    0.9293
        0.5648    0.6360    0.7076    0.7846    0.8290
        0.4926    0.5652    0.6239    0.6889    0.7342
        0.4470    0.5094    0.5633    0.6272    0.6685
        0.4104    0.4680    0.5193    0.5774    0.6166
        0.3815    0.4361    0.4834    0.5384    0.5758
        0.3583    0.4096    0.4543    0.5065    0.5418
        0.3391    0.3875    0.4300    0.4796    0.5133
        0.3226    0.3687    0.4093    0.4566    0.4889
        0.3083    0.3524    0.3912    0.4367    0.4677
        0.2958    0.3382    0.3754    0.4192    0.4491
        0.2847    0.3255    0.3614    0.4036    0.4325
        0.2748    0.3142    0.3489    0.3897    0.4176
        0.2659    0.3040    0.3376    0.3771    0.4042
        0.2578    0.2947    0.3273    0.3657    0.3920
        0.2504    0.2863    0.3180    0.3553    0.3809
        0.2436    0.2785    0.3094    0.3457    0.3706
        0.2374    0.2714    0.3014    0.3368    0.3612
        0.2316    0.2647    0.2941    0.3287    0.3524
        0.2262    0.2586    0.2872    0.3210    0.3443
        0.2212    0.2528    0.2809    0.3139    0.3367
        0.2165    0.2475    0.2749    0.3073    0.3295
```

```
        0.2120    0.2424    0.2693    0.3010    0.3229
        0.2079    0.2377    0.2640    0.2952    0.3166
        0.2040    0.2332    0.2591    0.2896    0.3106
        0.2003    0.2290    0.2544    0.2844    0.3050
        0.1968    0.2250    0.2499    0.2794    0.2997
        0.1935    0.2212    0.2457    0.2747    0.2947
        0.1903    0.2176    0.2417    0.2702    0.2899
        0.1873    0.2141    0.2379    0.2660    0.2853
        0.1845    0.2109    0.2342    0.2619    0.2809
        0.1817    0.2077    0.2308    0.2580    0.2768
        0.1791    0.2047    0.2274    0.2543    0.2728
        0.1766    0.2019    0.2243    0.2507    0.2690
        0.1742    0.1991    0.2212    0.2473    0.2653
        0.1719    0.1965    0.2183    0.2440    0.2618
        0.1697    0.1939    0.2154    0.2409    0.2584
        0.1675    0.1915    0.2127    0.2379    0.2552
        0.1655    0.1891    0.2101    0.2349    0.2521
        0.1635    0.1869    0.2076    0.2321    0.2490
        0.1616    0.1847    0.2052    0.2294    0.2461
        0.1597    0.1826    0.2028    0.2268    0.2433
        0.1580    0.1805    0.2006    0.2243    0.2406
        0.1562    0.1786    0.1984    0.2218    0.2380
        0.1546    0.1767    0.1963    0.2194    0.2354
        0.1530    0.1748    0.1942    0.2172    0.2330
        0.1514    0.1730    0.1922    0.2149    0.2306
        0.1499    0.1713    0.1903    0.2128    0.2283
        0.1484    0.1696    0.1884    0.2107    0.2260
        0.1470    0.1680    0.1866    0.2086    0.2239
        0.1456    0.1664    0.1848    0.2067    0.2217
        0.1442    0.1648    0.1831    0.2047    0.2197
        0.1429    0.1633    0.1814    0.2029    0.2177
        0.1416    0.1619    0.1798    0.2011    0.2157
        0.1404    0.1604    0.1782    0.1993    0.2138
        0.1392    0.1591    0.1767    0.1976    0.2120
        0.1380    0.1577    0.1752    0.1959    0.2102
        0.1369    0.1564    0.1737    0.1943    0.2084
        0.1357    0.1551    0.1723    0.1927    0.2067
        0.1346    0.1538    0.1709    0.1911    0.2051
        0.1336    0.1526    0.1696    0.1896    0.2034
        0.1325    0.1514    0.1682    0.1881    0.2018
        0.1315    0.1503    0.1669    0.1867    0.2003
        0.1305    0.1491    0.1657    0.1853    0.1988
        0.1295    0.1480    0.1644    0.1839    0.1973
        0.1286    0.1469    0.1632    0.1825    0.1958
        0.1277    0.1459    0.1620    0.1812    0.1944
        0.1268    0.1448    0.1609    0.1799    0.1930
        0.1259    0.1438    0.1598    0.1786    0.1917
        0.1250    0.1428    0.1586    0.1774    0.1903
        0.1241    0.1418    0.1576    0.1762    0.1890
        0.1233    0.1409    0.1565    0.1750    0.1878
        0.1225    0.1399    0.1554    0.1738    0.1865
        0.1217    0.1390    0.1544    0.1727    0.1853
        0.1209    0.1381    0.1534    0.1716    0.1841
        0.1201    0.1372    0.1524    0.1704    0.1829
        0.1194    0.1364    0.1515    0.1694    0.1817
        0.1186    0.1355    0.1505    0.1683    0.1806
        0.1179    0.1347    0.1496    0.1673    0.1795
        0.1172    0.1339    0.1487    0.1663    0.1784
        0.1165    0.1331    0.1478    0.1653    0.1773
        0.1158    0.1323    0.1469    0.1643    0.1763
        0.1151    0.1315    0.1461    0.1633    0.1752
        0.1144    0.1307    0.1452    0.1624    0.1742
        0.1138    0.1300    0.1444    0.1614    0.1732
        0.1131    0.1292    0.1436    0.1605    0.1722
        0.1125    0.1285    0.1427    0.1596    0.1713
        0.1119    0.1278    0.1419    0.1587    0.1703
        0.1113    0.1271    0.1412    0.1579    0.1694
        0.1106    0.1264    0.1404    0.1570    0.1685
        0.1101    0.1257    0.1397    0.1562    0.1676
        0.1095    0.1251    0.1389    0.1553    0.1667
        0.1089    0.1244    0.1382    0.1545    0.1658
        0.1083    0.1238    0.1375    0.1537    0.1649
        0.1078    0.1231    0.1368    0.1529    0.1641
        0.1072    0.1225    0.1361    0.1521    0.1632
        0.1067    0.1219    0.1354    0.1514    0.1624
        0.1061    0.1213    0.1347    0.1506    0.1616
        0.1056    0.1207    0.1340    0.1499    0.1608];

    crit=interp1(alpha,lookuptable(n,:),pvalue);
else
    A=0.09037*((-1*log10(pvalue)))^(3/2) + 0.01515*(log10(pvalue))^(2) - .08467*pvalue - .11143;
    crit= sqrt(log(1/pvalue)/(2*n))- .16693/n - A*n^(-3/2);
end
```

A.2.8 normcdf.m

```
function cdf = norm_cdf (x, m, v)
% PURPOSE: computes the cumulative normal distribution
%          for each component of x with mean m, variance v
%---------------------------------------------------------
% USAGE: cdf = norm_cdf(x,m,v)
% where: x = variable vector (nx1)
%        m = mean vector (default=0)
%        v = variance vector (default=1)
%---------------------------------------------------------
% RETURNS: cdf (nx1) vector
%---------------------------------------------------------

% Written by TT (Teresa.Twaroch@ci.tuwien.ac.at) on Jun 3, 1993
% Updated by KH (Kurt.Hornik@ci.tuwien.ac.at) on Oct 26, 1994
% Copyright Dept of Probability Theory and Statistics TU Wien
% Updated by James P. Lesage, jpl@jpl.econ.utoledo.edu 1/7/97

  [r, c] = size(x);

  if (r*c == 0)
  error('norm_cdf: x must not be empty');
  end;

  if (nargin == 1)
    m = zeros(r,1);
    v = ones(r,1);
  end;

  cdf = zeros(r, 1);
  cdf(1:r,1) = stdn_cdf((x(1:r,1) - m(1:r,1)) ./ sqrt (v(1:r,1)));
```

A.2.9 stdncdf.m

```
function cdf = stdn_cdf(x)
% PURPOSE: computes the standard normal cumulative
%          distribution for each component of x
%---------------------------------------------------
% USAGE: cdf = stdn_cdf(x)
% where: x = variable vector (nx1)
%---------------------------------------------------
% RETURNS: cdf (nx1) vector
%---------------------------------------------------

% written by:
% James P. LeSage, Dept of Economics
% University of Toledo
% 2801 W. Bancroft St,
% Toledo, OH 43606
% jpl@jpl.econ.utoledo.edu

  if (nargin ~= 1)
    error('Wrong # of arguments to stdn_cdf');
  end;

  cdf = .5*(1+erf(x./sqrt(2)));
```

A.2.10 regressr.m

```
function [pvalor,rquadrado]= regressr (x,y)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                              REGRESSR                                      %
%   by Rafael Marce <rafamarce@ub.edu>                                       %
%   Written in May 2003 at the USACE Environmental Laboratory,               %
%              Waterways Experiment Station, Vicksburg (MS).                 %
%   Help and software from Carlos E. Ruiz is greatly appreciated             %
%===========================================================================%
%       Permission is granted to modify and re-distribute this code         %
%       in any manner as long as this notice is preserved.                  %
%===========================================================================%
%-------------------------- DISCLAIMER: -----------------------------------%
%          This code is provided as is with no guarantees.                  %
%---------------------------------------------------------------------------%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   REGRESSR.     Least squares regression                                   %
%   The only output defined is the pvalue, but other outputs                 %
%   (slope, intercept, recta, F, t statistics) can be                        %
%   easily incorpored.                                                       %
%   From Sokal & Rohlf 1995.Biometry. WH Freeman and Co.                     %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

diffx=x-mean(x);
diffy=y-mean(y);
prodxy=diffx.*diffy;
sumaxy=sum(prodxy);
sumaxq=sum(diffx.*diffx);
sumayq=sum(diffy.*diffy);
rq=sumaxy*sumaxy/sumaxq;
rquadrado=rq/sumayq;

slope=sumaxy/sumaxq;
intercept=mean(y)-slope*mean(x);

valors_predits = intercept + slope*x;

sq= (sum((y-valors_predits).*(y-valors_predits)))/(length(x)-2);
sb=sqrt(sq/sumaxq);

t=slope/sb; %Slope zero test....

F=t^2;

Ftrans = (length(x)-2) ./ ((length(x)-2) + 1 .* F);
p=1 - betainc(Ftrans, (length(x)-2)/2, 0.5 );

pvalor=1-p;
```

A.2.11 runsrf.m

```
function [tstatistic,expectedruns,nombreruns,intervalo]= runsrf(x)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                              RUNSRF                                        %
%   by Rafael Marce <rafamarce@ub.edu>                                       %
%   Written in May 2003 at the USACE Environmental Laboratory,               %
%              Waterways Experiment Station, Vicksburg (MS).                 %
%   Help and software from Carlos E. Ruiz is greatly appreciated             %
%=========================================================================%
%       Permission is granted to modify and re-distribute this code        %
%       in any manner as long as this notice is preserved.                 %
%=========================================================================%
%------------------------- DISCLAIMER: ------------------------------------%
%          This code is provided as is with no guarantees.                 %
%-------------------------------------------------------------------------%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   RUNSRF. Runs test for vector x                                           %
%   The output is:                                                           %
%   't-statistic' if t-statistic < 1.960 runs observed=runs expected         %
%   'expectedruns'  expected runs in a random distribution                   %
%   'nombreruns'  observed runs                                              %
%   'intervalo'  if observed runs>expected runs+intervalo=ciclyc trend%
%              if observed runs<expected runs+intervalo=monotonic trend%
%   For details see Sokal & Rohlf 1995.Biometry. WH Freeman and Co.          %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for i=1:(length(x)-1)
   if x(i+1)>x(i)
   runserie(i)=1;
elseif x(i+1)<x(i)
   runserie(i)=-1;
else
   runserie(i)=0;
end
end

noceros=find(runserie);
runlimpia=runserie(noceros);
nombreruns=1;
for i=2:length(runlimpia)
   if runlimpia(i)==runlimpia(i-1)
   else
      nombreruns=nombreruns+1;
   end
end
expectedruns=(2*length(runlimpia)-1)/3;
expectedstandesv=sqrt((16*length(runlimpia)-29)/90);
tstatistic=abs((nombreruns-expectedruns)/expectedstandesv);
intervalo=1.960*expectedstandesv;
```

A.2.12 Data.dat

An extended version of this file is available in the digital support that is attached to this book.

```
9       36.12    0.117
23      25.44    0.101
37      19.52    0.107
51      32.24    0.128
65      28.68    0.137
79      40       0.08
100     44.4     0.117
114     22.2     0.189
128     78.15    0.084
144     34.18    0.11
170     64.5     0.091
184     34.18    0.176
200     34.18       0.108
213     34.18    0.106
233     16.84    0.127
247     20.86    0.097
261     38.06    0.134
277     18.18    0.158
291     20.19    0.183
303     14.4     0.247
326     15.5     0.273
340     11.1     0.363
352      8       0.198
368     16.84    0.338
382     11.1     0.458
396     10.55    0.44
416      6.5     0.633
444      5       0.763
487      5       0.496
506      5.5     0.502
541     10       0.333
598      5       0.174
626      5       0.667
647      5       0.545
689      3.12    0.813
786      5       0.482
802      5       0.406
815     46.6     0.127
843     19.52    0.174
871     48.8     0.189
878     41.1     0.171
898     78.15    0.187
948      9       0.446
969     14.4     0.318
997     16.84    0.208
1024     7       0.459
1053     5       0.602
1080     4.29    0.751
1115     9       0.538
1143    11.1     0.289
1171     7       0.676
1206    15.5     0.279
```

A.2.13 Coninput.dat

An extended version of this file is available in the digital support that is attached to this book.

```
1       59.1
2       56.4
3       46.6
4       40
5       36.12
6       32.24
7       36.12
8       33.21
9       30.3
10      36.12
11      42.2
12      48.8
13      40
14      40
15      46.6
16      46.6
17      53.7
18      57.75
19      46.6
20      40
21      38.06
22      36.12
23      30.3
24      25.44
25      23.82
26      23.82
27      23.82
28      22.2
29      22.2
30      20.86
31      20.86
32      20.86
33      18.18
34      16.84
35      15.5
36      19.52
37      19.52
38      19.52
39      48.8
40      46.6
41      42.2
42      36.12
43      46.6
44      44.4
45      40
46      42.2
47      42.2
48      40
49      40
50      40
51      34.18
52      32.24
```

Appendix B

Cohn's equation with a cubic fit to time

Equation 1.1 was transformed into:

$$\begin{aligned}\ln C =& \beta_0 + \beta_1 \ln\frac{Q}{Q'} + \beta_2\left(\ln\frac{Q}{Q'}\right)^2 + \beta_3\, T1 \\ &+ \beta_4\, T2 + \beta_5\, T3 + \beta_6 \sin(2\pi T) \\ &+ \beta_7 \cos(2\pi T) + \varepsilon\end{aligned} \tag{B.1}$$

in order to have a cubic fit to time. $T1$, $T2$, and $T3$ are the cubic polynomial for time, transformed so that these predictor variables are orthogonal. Other terms are as in Eq. 1.1. Cohn et al. (1992) used an empirical orthogonalization that simplifies the numerical work to identify the linear time trend from the fitted coefficient on T (Eq. 1.1). The polynomials were divided by a centering variable defined so that polynomials were orthogonal:

$$T' = M(T) + \frac{\sum_{i=1}^{N}\left(T_i - M(T)\right)^3}{2\times\sum_{i=1}^{N}\left(T_i - M(T)\right)^2} \tag{B.2}$$

were $M(T)$ is the mean of T and N the number of cases. An analogous formula is valid for the centering variable Q' in Eq. 1.1. This result is a particular case of empirical orthogonal polynomials. Supposing a vector X of n observations, we can define a family of vectors that are functions of X (Cohn [USGS], *pers. comm. unref.*):

$$V[0] = \{1,\ldots,1\} \tag{B.3}$$

$$V[1] = X - M(X) \tag{B.4}$$

$$\begin{aligned}V[k] = X * V[k-1] - \frac{M(X * V[k-1] * V[k-1])}{M(V[k-1] * V[k-1])} \\ * V[k-1] - \frac{M(X * V[k-1] * V[k-2])}{M(V[k-2] * V[k-2])} \\ * V[k-2]\end{aligned} \tag{B.5}$$

being $M(X)$ the mean of X, $k < n$, and the symbol $*$ signifying element-by-element vector multiplica-

tion. Vectors $V[k]$ are orthogonal. $V[2]$ could be expressed by simply using a centering variable, but not $V[3]$ (the cubic result we wanted). So, the orthogonal terms $T1$, $T2$, and $T3$ in Eq. B.1 correspond with vectors $V[1]$, $V[2]$, and $V[3]$, respectively. We were not concerned with $V[0]$ because we use a constant in the model.

Appendix C

Fuzzy Regression as an exploratory data analysis

We briefly detail in this *Appendix* some ecological applications of the neuro-fuzzy tool developed in *Chapter 1*. In this context, we named this exploratory free-model regression analysis *Fuzzy Regression*.

EXAMPLE 1. SETAR MODEL

One of the best models proposed to explain the Hudson's Bay Co. data on the evolution of lynx populations is the Self ExciTing AutoRegressive model (SETAR):

$$\Delta X = 0.62 + 0.25X_{t-1} - 0.43X_{t-2} \text{ if } X_{t-2} \leq 3.25$$
$$\Delta X = 0.25 + 0.52X_{t-1} - 1.24X_{t-2} \text{ if } X_{t-2} \geq 3.25$$

The fit to observed data is very good.

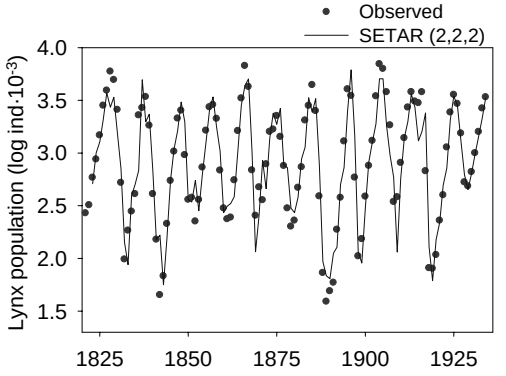

Figure C.1 – SETAR results compared to Hudson's Bay data

The same problem can be examined with fuzzy regression, simply taking X_{t-1} and X_{t-2} as independent variables. Then we proceed as in *Chapter 1*, that is, we let the Fuzzy Regression fit a collection

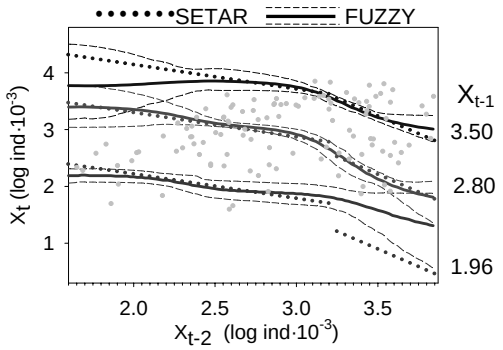

Figure C.2 – SETAR and Fuzzy Regression results compared to Hudson's Bay data

of functions without any prior model. The comparison between the SETAR and the Fuzzy Regression results shows that the dynamics of both models are almost identical. Thus, we can be confident that the SETAR model is virtually the best possible model considering the data available.

EXAMPLE 2. CARBON GAIN AND LIGHT AMBIENT IN *Posidonia oceanica* (L.) Delile

In this case we offered to Pere Renom and Dr. Javier Romero (University of Barcelona) the possibility to analyze with Fuzzy Regression their data on carbon gain in *P. oceanica* from four different stations in the Catalan coast. Note that the author was only involved in this step of the research, which is part of the PhD project by P. Renom. Experimental design, data collection, and ecological interpretation of results should be entirely attributed to Pere Renom and Dr. Javier Romero.

In this study the authors were interested in analyzing the photosynthetic response of different meadows of *P. oceanica*, in order to elucidate its physiological adaptations in restricted light environments. In the Fuzzy Regression the dependent variable was the carbon gain, and the independent variables the amount of light arriving at the water surface (expressed as the remaining light after the effect of cloudiness, RCLOU), and the amount of light arriving at the meadow (expressed as the remaining light after the effect of turbidity, RTURB).

The results show that the four meadows have different adaptations, expressed as different fitted curves of carbon gain respect the light ambient.

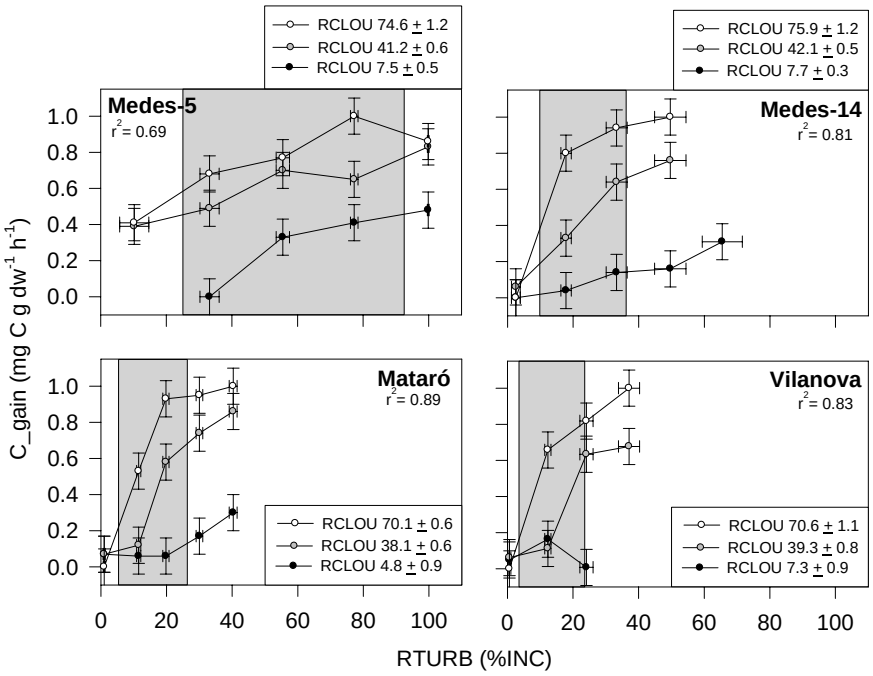

Figure C.3 – Non-parametric regressions relating RTURB, RCLOUD, and leaf Carbon gain for the four experimental sites. Solid lines correspond to the calculated function for a particular value of RCLOUD. Some parts of the functions were not drawn because its uncertainty was too high due to the scarcity of observed data. Both, the number of functions plotted and their corresponding RCLOUD value are optimized by the fuzzy regression procedure (*see* Marcé et al. 2004). Grey boxes depict from 10^{th} to 90^{th} percentile of RTURB and vertical doted lines represent the centre of the associated distribution. r^2: determination coefficient for the fuzzy regression.

References

Agència Catalana de l'Aigua (ACA). 2001. *Delimitació de zones inundables per a la redacció de l'INUNCAT*. Departament de Medi Ambient, Generalitat de Catalunya, Barcelona.

Akaike, H. 1983. Information measures and model selection. *International Statistical Institute* 22: 277–291.

Alavian, V., G.H. Jirka, R.A. Denton, M.C. Johnson, abd H.G. Stefan. 1992. Density currents entering lakes and reservoirs. *ASCE Journal of Hydraulic Engineering* 118: 1464–1489.

Alcalá, F.J. 2005. *Recarga a los acuferos espaoles mediante balance hidrogeoqumico.* Barcelona: PhD dissertation, Universitat Politècnica de Catalunya. 751p.

Alexander, R.B., R.A. Smith, and G.E. Schwarz. 2000. Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico. *Nature* 403: 758–761.

Alexander, R.B., P.J. Johnes, E. Boyer, and R.A. Smith. 2002. A comparison of models for estimating the riverine export of nitrogen from large watersheds. *Biogeochemistry* 57/58: 295–339.

Alexander, R.B., A.H. Elliott, U. Shankar, and G.B. McBride. 2002b. Estimating the sources and transport of nutrients in the Waikato River basin, New Zealand. *Water Resour. Res.* 38, 1268, doi:10.1029/2001WR000878.

Anderson, M.J., and P. Legendre. 1999. An empirical comparison of permutation methods for tests of partial regression coefficients in a linear model. *Journal of Statistical Computation and Simulation* 62: 271–303.

Armengol, J., M. Crespo, J.A. Morguí, and A. Vidal. 1986. Phosphorous budgets and forms of phosphorous in the Sau reservoir sediment: an interpretation of the limnological record. *Hydrobiologia* 143: 331–336.

Armengol, J., and A.Vidal. 1988. The use of different phosphorus fractions for the stimation of the trophic evolution of the Sau reservoir. *Arch. Hydrobiol. Beih.* 30: 61–70.

Armengol, J., F. Sabater, A. Vidal, and S. Sabater. 1991. Using the rescaled range analysis for the study of hydrological records: The river Ter as an example. *Oecol. Aquat.* 10: 21–33.

Armengol, J., J.C. García, M. Comerma, M. Romero, J. Dolz, M. Roura, B. Han, A. Vidal, and K. Šimek. 1999. Longitudinal processes in canyon type reservoirs: the case of Sau (N.E. Spain), p. 313–345. *In* G. Tundisi and M. Štraskraba [eds.], Theoretical reservoir ecology and its applications. Leiden: International Institute of Ecology. Brazilian Academy of Sciences and Backhuys Publishers.

Arnold, J.G., and P.M. Allen. 1999. Automated methods for estimating baseflow and ground water recharge from streamflow records. *J. Am. Water Resour. As.* 35(2), 411–424.

Àvila, A., and M. Alarcon. 1999. Relationship between precipitation chemistry and meteorological situations at a rural site in NE Spain. *Atmospheric Environment* 33: 1663–1677.

Beaulac, M.N., and K.H. Reckhow KH . 1982. An examination of land use-nutrient export relationships. *Wat. Res. Bull.* 18: 1013–1024.

Behrendt, H. 1993. Separation of point and diffuse loads of pollutants using monitoring data of rivers. *Water Science and Technology* 23(3-5): 165–167.

Beisner, B.E., C.L. Dent, and S.R. Carpenter. 2003. Variability of lakes on the landscape: roles of phosphorus, food webs, and dissolved organic carbon. *Ecology* 84: 1563–1575.

Bellot, J., and A. Escarré. 1998. Stemflow and throughfall determination in a resprouted Mediterranean holm-oak forest. *Ann. Forest Sci.* 55(7), 847–865.

Benner, R. 2003. Molecular indicators of the bioavailability of dissolved organic matter, p121–137. *In* S.E.G. Findlay and R.L. Sinsabaugh [eds], Aquatic Ecosystems. Interactivity of dissolved organic matter. San Diego (CA): Academic Press.

Bernal, S., A. Butturini, and F. Sabater 2002. Variability of DOC and nitrate responses to storms in a small Mediterranean forested catchment. *Hydrol. Earth Syst. Sci.* 6: 1031–1041.

Bernal, S., A. Butturini, J.L. Riera, E. Vázquez, and F. Sabater. 2004. Calibration of the INCA model in a Mediterranean forested catchment: the effect of hydrological inter-annual variability in an intermittent stream. *Hydrol. Earth Syst. Sci.* 8(4), 729–741.

Bernal, S. 2006. *Nitrogen storm responses in an intermittent Mediterranean stream.* Barcelona: PhD dissertation, Universitat de Barcelona. 235p.

Berris, S.N. 1995. *Conceptualization and simulation of runoff generation from rainfall for three basins in Thurston County, Washington, U.S.* Geological Survey, Water Resources Investigation Report 94-4038, Prepared in Cooperation with Thurston County Department of Public Works, USGS, Tacoma, WA.

Beven, K. 1989. Changing ideas in hydrology: the case of physically-based models. *Journal of Hydrology* 105: 157–172.

Beven, K. 1996. The limits of splitting: hydrology. *Sci. Total Environ.* 183, 89–97.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, T.H. Jobes, and A.S. Donigian. 2001. *Hydrological Simulation Program-Fortran (HSPF) user's manual for release 12*. U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, GA.

Biddanda, B.A., and J.B. Cotner. 2002. Love handles in aquatic ecosystems: the role of dissolved organic carbon drawdown, resuspended sediments, and terrigenous inputs in the carbon balance of Lake Michigan. *Ecosystems* 5: 431–445.

Björk, S. 1972. Ecosystem studies in connection with the restoration of lakes. *Ver. Int. Verein. Limnol.* 18: 379–387.

Björk, S. 1974. *European lake rehabilitation activities.* Inst. Limnol. Rep. University of Lund. Sweden.

Bogan, T., O. Mohseni, and H.G. Stefan. 2003. The stream temperature-equilibrium temperature relationship. *Water Resources Research* 39: 1245. DOI:10.1029/2003WR002034.

Bogan, T., H.G. Stefan, and O. Mohseni. 2004. Imprints of secondary heat sources on the stream temperature/equilibrium temperature relationship. *Water Resources Research* 40: W12510. DOI:10.1029/2003WR002733.

Bond, J.G. 1978. *Geologic map of Idaho, 1:500000*. Moscow (ID): Idaho Geological Survey. Map.

Borri, D., G. Concilio, and E. Conte. 1998. A fuzzy approach for modelling knowledge in environmental systems evaluation. *Comput., Environ. and Urban Systems* 22: 299–313.

Boström, B., J.M. Andersen, S. Fleischer, and M. Jansson. 1988. Exchange of phosphorous across the sediment-water interface. *Hydrobiol.* 170: 229–244.

Boyle, D.P., H.V. Gupta, S. Sorooshian, V. Koren, Z. Zhang, and M. Smith. 2001. Toward improved streamflow forescasts: value of semidistributed modeling. *Water Resour. Res*, 37(11), 2749–2759.

Butturini, A. 1998. *Contribution of the boundary zones on nutrient dynamics in a stream with Mediterranean regime*. Barcelona: PhD dissertation, Universitat de Barcelona. 350p.

Butturini, A., and F. Sabater. 1998. Ammonium and phosphate retention in a Mediterranean stream: hydrological versus temperature control. *Can. J. Fish. Aquat. Sci.* 55: 1938–1945.

Butturini, A., and F. Sabater. 2000. Seasonal variability of dissolved organic carbon in a Mediterranean stream. *Biogeochemistry* 51(3), 303–321, doi:10.1023/A:1006420229411.

Butturini, A., and F. Sabater. 2002. Nitrogen concentrations in a small Mediterranean stream: 1. Nitrate 2. Ammonium. *Hydrology and Earth System Sciences* 6: 539–550.

Buzás, K. 2001. Use of fuzzy method to estimate river nutrient loads from scarce observation. *Water Science and Technology* 43: 257–264.

Caissie, D., M.G. Satish, and N. El-Jabi. 2005. Predicting river water temperatures using the equilibrium temperature concept with application on Miramichi River catchments (New Brunswick, Canada). *Hydrological Processes* 19: 2137–2159.

Carol, J., L. Benejam, C. Alcaraz, A. Vila-Gispert, L. Zamora, E. Navarro, J. Armengol, and E. García-Berthou. 2006. The effects of limnological features on fish assemblages of 14 Spanish reservoirs. *Ecology of Freshwater Fish* 15: 66–77.

Carpenter, S.R., D. Ludwig, and W.A. Brock. 1999. Management of eutrophication for lakes subject to potentially irreversible change. *Ecological Applications* 9: 751–771.

Casamitjana, X., E. Roget, and G. Schladow. 1993. The seasonal cycle of a grownd water dominated lake. *J. Hydraul. Res.* 31: 293–306.

Centre de Recerca Ecològica i Aplicacions Forestals (CREAF). 2001. *Inventari Ecològic i Forestal de Catalunya*. Centre de Recerca Ecològica i Aplicacions Forestals, Universitat Autònoma de Barcelona, Bellaterra, Spain.

Céspedes, R., S. Lacorte, A. Ginebreda, and D. Barceló. 2006. Chemical monitoring and occurrence of alkylphenols, alkylphenol ethoxylates, alcohol ethoxylates, phthalates and benzothiazoles in sewage treatment plants and receiving waters along the Ter River basin (Catalonia, N.E. Spain). *Analytical and Bioanalytical Chemistry* 385: 992–1000.

Chapra, S.C., and R.P. Canale. 1991. Long-Term Phenomenological Model of Phosphorus and Oxygen in Stratified Lakes. *Wat. Res.* 25(6): 707–715.

Chapra, S.C. 1997. *Surface water-quality modeling*. McGraw-Hill.

Charlton, M.N. 1980. Hypolimnion oxygen consumption in lakes: discussion of productivity and morphometry effects. *Can. J. Fish. Aquat. Sci.* 37: 1531–1539.

Claassen, H.C., D.R. Halm. 1995. A possible deficiency in estimates of wet deposition obtained from data generated by the NADP/NTN network. *Atmospheric Environment* 29: 437–448.

Clarke, R.T. 1990. Statistical characteristics of some estimators of sediment and nutrient loadings. *Water Resour. Res.* 26: 2229–2233.

Clement, A. 2001. Improving uncertain nutrient load estimates for Lake Balaton. *Water Science and Technology* 43: 279–286.

Cochran, W.G. 1977. *Sampling techniques*. 3rd ed. Wiley, NY.

Cohn, T.A., L.L. DeLong, E.J. Gilroy, R.M. Hirsch, and D.K. Wells. 1989. Estimating constituent loads. *Water Resour. Res.* 25:937–942.

Cohn, T.A., D.L. Caulder, E.J. Gilroy, L.D. Zynjuk, and R.M. Summers. 1992. The validity of a simple statistical model for estimating fluvial constituent loads: An empirical study involving loads entering Chesapeake Bay. *Water Resour. Res.* 28: 2353–2363.

Cohn, T.A. 1995. Recent advances in statistical methods for the estimation of sediment and nutrient transport in rivers. *Reviews of Geophysics, Supplement* July 1995: 1117–1123.

Cole, T., and E. Buchak. 1995. *CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 2.0. Tech. Rpt. EL-95-May 1995*. Vicksburg: Waterways Experiments Station.

Comerma, M., J.C. García, J. Armengol, M. Romero, and K. Šimek. 2001. Planktonic Food-Web structure along the Sau Reservoir (Spain) in Summer 1997. *Internat. Rev. Hydrobiol.* 86 (2): 195–209.

Comerma, M. 2003. *Processos heterotròfics microbians a l'embassament de Sau*. PhD dissertation. Barcelona: Universitat de Barcelona.

Comerma, M., J.C. Garcia, M. Romero, J. Armengol, and K. Šimek. 2003. Carbon flow dynamics in the pelagic community of the Sau Reservoir (Catalonia, NE Spain). *Hydrobiologia* 504: 87–98.

Comerma, M., J.C. Garcia, M. Romero, J. Armengol, and K. Šimek. 2004. Carbon flow dynamics in the pelagic community of the Sau Reservoir (Catalonia, NE Spain). *Hydrobiologia* 511: 259–259.

Committee on Environment and Natural Resources (CERN). 2000. *Integrated assesment of hypoxia in the northern Gulf of Mexico*. National Science and Technology Council Committee on Environmental and Natural Resources.

Cooke, G.D., R.T. Heath, R.H. Kennedy, and M.R. McComas. 1978. *The effect of sewage diversion and aluminium sulphate application on two eutrophic lakes.* EPA-600/3-78-033.

Cooke, G.D., E.B. Welch, S.A. Peterson, and P.R. Newroth. 1993. *Restoration and management of lakes and reservoirs.* Lewis Publishers. Boca Raton. 548 pp.

Cornett, R.J., and F.H. Rigler. 1979. Hypolimnion oxygen deficits: their prediction and interpretation. *Science* 205: 580–581.

Cornett, R.J., and F.H. Rigler. 1980. The areal hypolimnetic oxygen deficit: An empirical test of the model. *Limnol. Oceanogr.* 25: 672–679.

Cornett, R.J. 1989. Predicting changes in hypolimnetic oxygen concentrations with phosphorus retention, temperature, and morphometry. *Limnology and Oceanography* 34: 1359–1366.

Costa-Branco, P.J., and J.A. Dente. 2001. Fuzzy systems modeling in practice. *Fuzzy sets and Systems* 121: 73–93.

Crowfoot, R.M., W.F. Payne, and G.B. O'Neill. 2003. *Water Resources Data Colorado Water Year 2003. Volume 1: Missouri River Basin, Arkansas River Basin, and Rio Grande Basin*. Denver (CO): US Geological Survey. 587p.

D'Angelo, D.J., and J.R. Webster. 1991. Phosphate retention in streams draining pine and hardwood catchments in the southern Appalachian mountains. *Freshwater Biology* 26: 335–345.

Daniel, M.H.B., A. A. Montebelo, M. C. Bernardes, J. P. H. B. Ometto, P. B. de Camargo, A. V. Krusche, M. V. Ballester, R. L. Victoria, and L. A. Martinelli. 2002. Effects of urban sewage on dissolved oxygen, dissolved inorganic and organic carbon, and electrical conductivity of small streams along a gradient of urbanization in the Piracicaba river basin. *Wat. Air. Soil. Pollut.* 136: 189–206.

Davis J.C., and G.W. Minshall. 1999. Nitrogen and phosphorus uptake in two Idaho (USA) headwater wilderness streams. *Oecologia* 119: 247–255.

del Giorgio P.A., J.J. Cole, N.F. Caraco, and R.H. Peters. 1999. Linking planktonic biomass and metabolism to net gas fluxes in northern temperate lakes. *Ecology* 80: 1422–1431.

del Giorgio, P.A., J. Davis. 2003. Patterns in dissolved organic matter lability and consumption across aquatic ecosystems, p399–424. *In* S.E.G. Findlay and R.L. Sinsabaugh [eds], Aquatic Ecosystems. Interactivity of dissolved organic matter. San Diego (CA): Academic Press.

Dillon, P.J. 1975. The phosphorus budget of Cameron lake, Ontario: the importance of flushing rate on the degree of eutrophy in lakes. *Limnol. Oceanogr.* 19: 28–39.

Doherty, J. 2003. *PEST Surface Water Utilities*. Watermark Numerical Computing and University of Idaho, Brisbane, Australia.

Doherty, J., and J.M. Johnston. 2003. Methodologies for calibration and predictive analysis of a watershed model. *J. Am. Water Resour. As.* 39(2), 251–265.

Doherty, J. 2004. *PEST Model-independent Parameter Estimation, User Manual: 5th edition*. Watermark Numerical Computing, Brisbane, Australia.

Dolan, D.M., A.K. Yui, and D.R. Geist. 1981. Evaluation of river load estimation methods for total phosphorus. *Journal of Great Lakes Research* 7: 207–214.

Doyle, M.W., E.H. Stanley, and J.M. Harbor. 2003. Hydrogeomorphic controls on phosphorus retention in streams, *Water Resour. Res.* 39: 1147. doi:10.1029/2003WR002038.

Duan, Q., S. Sorooshian, and V. Gupta. 1992. Effective and efficient global optimization for conceptual rainfall-runoff models. *Water Resour. Res.* 28(4): 1015–1031.

Edinger, J.E., D.W. Duttweiler, and J.C. Geyer. 1968. The response of water temperatures to meteorological conditions. *Water Resources Research* 4: 1137–1143.

Erlandsen, H., P. Breetum, J.E. Lovik, S. Markager, and T. Källqvist. 1988. *Kolbotnvatnet. Sammenstilling av resultater fra perioden 1984-1989.* Report from Norsk Institut for Vannforskning. NIVA, Oslo. 118 pp.

Espadaler, I., J. Caixach, J. Om, F. Ventura, M. Cortina, F. Pauné, and J. Rivera. 1997. Identification of organic pollutants in Ter river and its system of reservoirs supplying water to Barcelona (Catalonia, Spain): A study by GC/MS and FAB/MS. *Wat. Res.* 31: 1996–2004.

Fearnside, P.M. 1995. Hydroelectric dams in the Brazilian Amazon as sources of 'greenhouse gases'. *Environ. Conserv.* 22: 7–19.

Fearnside, P.M.. 2006. Greenhouse gas emissions from hydroelectric dams: reply to Rosa et al. *Climatic Change* 75: 103–109.

Ferguson, R.I. 1986. River loads underestimated by rating curves. *Water Resour. Res.* 22: 74–76.

Ferguson, R.I. 1987. Accuracy and precision of methods for estimating river loads. *Earth Surface Processes and Landforms* 12: 95–104.

Fernandez-Turiel, J.L., D. Gimeno, J.J. Rodriguez, M. Carnicero, and F. Valero. 2003. Factors influencing the quality of a surface water supply system: The Ter River, Northeastern Spain. *Fresenius Environmental Bulletin* 12: 67–75.

Findlay, S.E.G. 2003. Bacterial response to variation in dissolved organic matter, p363–379. *In* S.E.G. Findlay and R.L. Sinsabaugh [eds], Aquatic Ecosystems. Interactivity of dissolved organic matter. San Diego (CA): Academic Press.

Findlay, S.E.G., and R.L. Sinsabaugh, [eds]. 2003. *Aquatic Ecosystems. Interactivity of dissolved organic matter*. San Diego (CA): Academic Press. 512p.

Folke, C., S.R. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson, and C.S. Holling. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics* 35: 557–581.

Ford, D.E. 1990. Reservoir transport processes, p. 15–42. *In* K.W. Thorton, B.L. Kimmel, and F.E. Payne [eds], Reservoir Limnology: Ecological Perspectives. Wiley Interscience.

Forman, R.T.T., and L.E. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29: 207–231.

Foy, R.H. 1986. Suppression of phosphorus release from lake sediments by the addition of nitrate. *Wat. Res.* 20(11): 1345–1351.

Freshwater Research, and Brown & Caldwell. 2001. *Assessment of Brownlee Reservoir water quality*. Technical report for the city of Boise, ID. 90p.

Gallart, F., P. Llorens, J. Latron, and D. Regues. 2002. Hydrological processes and their seasonal controls in a small Mediterranean mountain catchment in the Pyrenees. *Hydrol. Earth Syst. Sci.* 6(3): 527–537.

Gasol, J.M., M. Comerma, J.C. García, J. Armengol, E.O. Casamayor, P. Kojecká, and K. Šimek. 2002. A transplant experiment to identify the factors controlling bacterial abundance, activity, production, and community composition in a eutrophic canyon-shaped reservoir. *Limnol. Oceanogr.* 47: 62–77.

Gelman, A., and D.B. Rubin. 1992. Inference from iterative simulation using multiple sequences. *Statistical Science* 7: 457–472.

Geraldes, A.M., and M.J.L. Boavida. 2004. Limnological variations of a reservoir during two successive years: one wet, another dry. *Lakes. Reserv. Res. Manage.* 9: 143–152.

Gibbs, M.M. 1992. Influence of hypolimnetic stirring and underflow on the limnology of Lake Rotoiti, New Zealand. *New. Zeal. J. Mar. Freshwat. Res.* 26: 453–463.

Gilroy, E.J., R.M. Hirsch, and T.A. Cohn. 1990. Mean square error of regression-based constituent transport estimates. *Water Resour. Res.* 26: 2069–2077.

Giles, J. 2006. Methane quashes green credentials of hydropower. *Nature* 444: 524–525.

Gleick, P.H. 2003. Global Freshwater Resources: Soft-Path Solutions for the 21st Century. *Science* 302: 1524–1528.

Goolsby, D.A., W.A. Wattaglin, G.B. Lawrence, R.S. Artz, B.T. Aulenbach, R.P. Hooper, D.R. Keeney, and G.J. Stensland. 1999. *Flux and sources of nutrients in the Mississippi-Atchafalaya river basin. Topic 3. Report for the Integrated Assessment on hypoxia in the Gulf of Mexico*. NOAA Coastal Ocean Program. Decision Analysis Series No. 17. NOAA Coastal Ocean Program, Silver Spring, M.D.

Goolsby, D.A., and W.A. Battaglin. 2001. Long-term changes in concentrations and flux of nitrogen in the Mississippi River Basin, USA. *Hydrological Processes* 15: 1209–1226.

Grasshoff, K., M. Erhardt, and K. Kremling. 1983. *Methods of sea water analyses*. Verlag Chemie, Weinheim.

Guasch, H., and S. Sabater. 1998. Estimation of the annual primary production of stream epilithic biofilms based on photosynthesis-irradiance relations. *Archiv fur Hydrobiologie* 141: 469–481.

Gücker, B., and M.T. Pusch. 2006. Regulation of nutrient uptake in eutrophic lowland streams. *Limnol. Oceanogr.* 51: 1443–1453.

Gupta, H.V., S. Sorooshian, and P.O. Yapo. 1998. Toward improved calibration of hydrologic models: multiple and noncommensurable measures of information. *Water Resour. Res.* 34(4): 751–763.

Haggard, B.E., E.H. Stanley, and D.E. Storm. 2005. Nutrient retention in a point-source-enriched stream. *J. N. Am. Benthol. Soc.* 24: 29–47.

Hall, R.J., E.S. Bernhardt, and G.E. Likens. 2002. Relating nutrient uptake with transient storage in forested mountain streams. *Limnol. Oceanogr.* 47: 255–265.

Halweil, B. 2002. Farming in the public interest. *In* Worldwatch Institute [ed.], State of the World 2002. W.W. Norton & Company.

Han, B., J. Armengol, J.C. García, M. Comerma, M. Roura, J. Dolz, and M. Straškraba. 2000. The thermal structure of Sau reservoir (NE: Spain): a simulation approach. *Ecological Modelling* 125: 109–122.

Hansen, J., K. Reitzel, H.S. Jensen, and F. Andersen. 2003. Effects of aluminium, iron, oxygen and nitrate additions on phosphorous release from the sediment of a Danish softwater lake. *Hydrobiol.* 492: 139–149.

Harrison, J.R. 2005. *Partitioning Snake River organic matter and modeling aerobic oxidation in Brownlee Reservoir, Idaho*. Moscow (ID): PhD dissertation, University of Idaho. 244p.

Heaney, S.I., J.E. Corry, and J.P. Lishman. 1992. Changes of water quality and sediment phosphorus of a small productive lake following decreased phosphorus loading. *In* D.W. Sutcliffe and J.G. Jones [eds.], Eutrophication: research and application to water supply. Freshwater Biological Association.

Hempel, C.G., and P. Oppenheim. 1948. Studies in the Logic of Explanation. *Philosophy of Science* 15: 135–175.

Hipel, K.W. 1985. Time series analysis in perspective. *Water Resources Bulletin* 21: 609–624.

Houser, J.N., D.L. Bade, J.J. Cole, and M.L. Pace. 2003. The dual influences of dissolved organic carbon on hypolimnetic metabolism: organic substrate and photosynthetic reduction. *Biogeochemistry* 64 (2): 247-269.

Howarth, R.W., G. Billen, D. Swaney, A. Townsend, N. Jaworski, K. Lajtha, J.A. Downing, R. Elmgren, N. Caraco, T. Jordan, F. Berendse, J. Freney, V. Kudeyarov, P. Murdoch, and Z. Zhu. 1996. Regional nitrogen budgets and riverine N and P fluxes for the drainages to the North Atlantic Ocean: natural and human influences. *Biogeochemistry* 35: 75–139.

Hunt, R.J., D.T. Feinstein, C.D. Pint, and M.P. Anderson. 2006. The importance of diverse data types to calibrate a watershed model of the Trout Lake Basin, Northern Wisconsin, USA. *J. Hydrol.* 321, 286–296.

Hutchinson, G.E. 1957. *Treatise on Limnology. Vol. 1: Geography, Physics and Chemistry*. John Wiley and Sons.

Icold. 1998. *World Registry of Dams. Computer Database*. Paris: International Commission on Large Dams.

Idaho Department of Environmental Quality (IDEQ), and Oregon Department of Environmental Quality (ODEQ). 2004. *Snake River-Hells Canyon Total Maximum Daily Load (TMDL)*. Boise (ID): IDEQ and ODEQ. 638p.

Imberger, J. 1979. Mixing in reservoirs, p148–228. *In* H.G. Fisher, E.J. List, R.C.Y. Koh, J. Imberger, and N.H. Brooks [eds], Mixing in inland and coastal waters. New York: Academic Press.

Imberger, J., and J.C. Patterson. 1981. A dynamic reservoir simulation model: DYRESM 5, p 310–361. *In* H.B. Fisher [ed], Transport Models of Inland and Coastal Waters. Academic Press.

Institut Cartogràfic de Catalunya (ICC). 2002. *Mapa geolgic de Catalunya 1:50000*. Barcelona: Generalitat de Catalunya. Map.

International Rivers Network. 2006. *Fizzy science. Loosening the Hydro Industry's Grip on Reservoir Greenhouse Gas Emissions Research*. Berkeley: International Rivers Network, p27.

Istvánovics, V., and L. Somlyódy. 1999. Limnological differences between a shallow pre-reservoir and a shallow lake. A case study of the Upper Kis-Balaton Reservoir and Lake Balaton, p347–384. *In* J.G. Tundisi and M. Straškraba [eds], Theoretical reservoir ecology and its applications. Leiden: International Institute of Ecology. Brazilian Academy of Sciences and Backhuys Publishers.

Jakeman, A.J., and G.M. Hornberger. 1993. How much complexity is warranted in a rainfall-runoff model?. *Water Resour. Res.* 29(8): 2637–2649.

Jang, J.R. 1993. ANFIS: Adaptive-Network-Based Fuzzy Inference System. *IEEE Transactions on Systems, Man, and Cybernetics* 23: 665–685.

Jang, J.R., and C. Sun. 1995. Neuro-Fuzzy modeling and control. *Proceedings of the IEEE* 83: 378–406.

Jansson, M., J. Karlsson, and P. Blomqvist. 2003. Allochthonous organic carbon decreases pelagic energy mobilization in lakes. *Limnol. Oceanogr.* 48: 1711–1716.

Jaworski, N.A., P.M. Groffman, A.A. Keller, and J.C. Prager. 1992. A watershed nitrogen and phosphorus balance: the Upper Potomac River basin. *Estuaries* 15: 83–95.

Jeffrey, S.W., and G.F. Humphrey. 1975. New spectrophotometric equations for determining chlorophylls a, b, c1 and c2 in higher plants, algae and natural phytoplankton. *Biochem. Physiol. Pflanzen.* 167: 191–194.

Jensen, H.S., and F.Ø. Andersen. 1992. Importance of temperature, nitrate, and pH for P-release from aerobic sediments of four shallow, eutrophic lakes. *Limnol. Oceanogr.* 37: 577–589.

Johnes, P.J. 1996. Evaluation and management of the impact of land use change on the nitrogen and phosphorus load delivered to surface waters: the export coefficient modeling approach. *Journal of Hydrology* 183: 323–349.

Johnes, P.J., B. Moss, and G.L. Phillips. 1996. The determination of water quality by land use, livestock numbers and population data - testing of a model for use in conservation and water quality management. *Freshwater Biology* 36: 951–473.

Johnes, P.J., and A.L. Heathwaite. 1997. Modelling the impact of land use change on water quality in agricultural catchments. *Hydrological Processes* 11: 269–286.

Johnson, J.B., and K.S. Omland. 2004. Model selection in ecology and evolution. *Trends in Ecology and Evolution* 19: 101–108.

Johnson, M.S., W.F. Coon, V.K. Mehta, T.S. Steenhius, E.S. Brooks, and J. Boll. 2003. Application of two hydrologic models with different runoff mechanisms to a hillslope dominated watershed in the northeastern US: a comparison of HSPF and SMR. *J. Hydrol.* 284: 57–76.

Johnson, S.L. 2003. Stream temperature: scaling of observations and issues for modelling. *Hydrological Processes* 17: 497–499.

Kaushal, S.S., P.M. Groffman, G.E. Likens, K.T. Belt, W.P. Stack, V.R. Kelly, L.E. Band,and G.T. Fisher. 2005. Increased salinization of fresh water in the northeastern United States. *Proceedings of the National Academy of Science of the United States of America* 102: 13517–13520.

Kelly, V.J. 2001. Influence of reservoirs on solute transport: a regional-scale approach. *Hydrological Processes* 15: 1227–1249.

Kendall, C., S.R: Silva, and V.J. Kelly. 2001. Carbon and nitrogen isotopic compositions of particulate organic matter in four large river systems across the United States. *Hydrological Processes* 15: 1301–1346.

Kennedy, R.H. 1999. Basin-wide considerations for water quality management: Importance of phosphorus retention by reservoirs. *International Review of Hydrobiology* 84: 557–566.

Kennedy, R.H. 1999b. Reservoir design and operation: limnological implications and management opportunities, p1–28. *In* J.G. Tundisi and M. Straškraba [eds], Theoretical reservoir ecology and its applications. Leiden: International Institute of Ecology. Brazilian Academy of Sciences and Backhuys Publishers.

Kennedy, R.H., J.G. Tundisi, V. Straškrábová, O.T. Lind, and J. Hejzlar. 2003. Reservoirs and the limnologist's growing role in sustainable water resource management. *Hydrobiologia* 504: xi–xii.

Kennedy, R.H. 2005. Toward integration in reservoir management. *Lake and Reservoir Management* 21: 128–138.

Khu, S.T., and H. Madsen. 2005. Multiobjective calibration with Pareto preference ordering: an application to rainfall-runoff model calibration. *Water Resour. Res.* 41, W03004, doi:10.1029/2004WR003041.

Kimmel, B.L., O.T. Lind, and L.J. Paulson. 1990. Reservoir primary production. p. 133–194. *In* K.W. Thorton, B.L. Kimmel, and F.E. Payne [eds], Reservoir Limnology: Ecological Perspectives. Wiley Interscience.

Kirchner, J. 2006. Getting the right answers for the right reasons: linking measurements, analyses, and models to advance the science of hydrology. *Water Resour. Res.* 42, W03S04, doi:10.1029/2005WR004362.

Kleeberg, A., and H.P. Kozerski. 1997. Phosphorous release in Lake Grober Mggelsee and its implications for lake restoration. *Hydrobiol.* 342/343: 9–26.

Knowlton, M.F., and J.R. Jones. 1989. Summer distribution of nutrients, phytoplankton and dissolved oxygen in relation to hydrology in Table Rock Lake, a large Midwestern reservoir. *Arch. Hydrobiol. Suppl.* 83(2): 197–225.

Krambeck, H., A. Milstein, and M. Zoran. 1992. Physical aspects of the ecosystem structure of dual purpose reservoirs in the Israeli coastal area; Preliminary results of a solar driven data acquisition system. *Limnologica* 22 (2): 129–135.

Kritzberg, E.S., J.J. Cole, and M.L. Pace. 2004. Autochthonous versus allochthonous carbon sources of bacteria: Results from whole-lake ^{13}C addition experiments. *Limnol. Oceanogr.* 49: 588–596.

Kuczera, G. 1982. On the relationship between the reliability of parameter estimates and hydrologic time series data used in calibration. *Water Resour. Res.* 18(1): 146–154.

Legates, D.R., and G.J. McCabe Jr. 1999. Evaluating the use of "goodness-of-fit" measures in hydrologic and hydroclimatic model validation. *Water Resour. Res.* 35(1): 233–241.

Legendre, P., and L. Legendre. 1998. *Numerical Ecology*. 2nd Ed. Developments in ecological modeling, Vol 20. Elsevier, Amsterdam.

Legendre, P. 2002. *Program for multiple linear regression (ordinary or through the origin) with permutation test-User's notes*. Montréal: Département de sciences biologiques, Université de Montréal. 11p.

Lek, S., M. Delacoste, P. Baran, I. Dimopoulos, J. Lauga, and S. Aulanier. 1996. Application of neural networks to modelling nonlinear relationships in ecology. *Ecological Modelling* 90: 39–52.

Lek, S., and J.F. Guégan. 1999. Artificial neural networks as a tool in ecological modelling, an introduction. *Ecological Modelling* 120: 65–73.

Lennox, S.D., R.H. Foy, R.V. Smith, and C. Jordan. 1997. Estimating the contribution from agriculture to the phosphorus load in surface water. *In* H. Tunney, O.T. Carton, P.C. Brookes, and A.E. Johnston [eds.], Phosphorus loss from soil to water. CAB International.

Likeš, J. 1980. Variance of the MVUE for lognormal variance. *Technometrics* 22: 253–258.

Livingstone, D.M., and D.M. Imboden. 1996. The prediction of hypolimnetic oxygen profiles: a plea for a deductive approach. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 924–932.

Llorens, P. 1997. Rainfall interception by Pinus sylvestris forest patch overgrown in a Mediterranean mountainous abandoned area II. Assessment of the applicability of Gash's analytical model. *J. Hydrol.* 199: 346–359.

Llorens, P., R. Poch, J. Latron, and F. Gallart. 1997. Rainfall interception by Pinus sylvestris forest patch overgrown in a Mediterranean mountainous abandoned area I. Monitoring design and results down to the event scale. *J. Hydrol.* 199: 331–345.

Lovett, G.M., G.E. Likens, D.C. Buso, C.T. Driscoll, and S.W. Bailey. 2005. The biogeochemistry of chlorine at Hubbard Brook, New Hampshire, USA. *Biogeochemistry* 72: 191–232.

Lucassen, E.C.H.E.T., A.J.P. Smolders, A.L. Van der Salm, and J.G.M. Roelofs. 2004. High groundwater nitrate concentrations inhibit eutrophication of sulphate-rich freshwater wetlands. *Biogeochem.* 69: 249–267.

Luglié, A., Y. Aktan, P. Casiddu, and N. Sechi. 2001. The trophic status of Bidighinzu Reservoir (Sardinia) before and after the diversion of waste waters. *J. Limnol.* 60(2): 135-142.

Madsen, H. 2000. Automatic calibration of a conceptual rainfall-runoff model using multiple objectives. *J. Hydrol.* 235: 276–288.

Madsen, H. 2003. Parameter estimation in distributed hydrological catchment modeling using automatic calibration with multiple objectives. *Adv. Water Resour.* 26: 205–216.

Maier, H.R., and G.C. Dandy. 2000. Neural networks for the prediction and forecasting of water resources variables: a review of modelling issues and applications. *Environmental Modelling & Software* 15: 101–124.

Maltchik, L., S. Molla, C. Casado, and C. Montes. 1994. Measurement of nutrient spiralling in a Mediterranean stream: comparison of two extreme hydrological periods. *Arch. Hydrobiol.* 130: 215–227.

Marcé, R., M. Comerma, J.C. García, J. Gomà, and J. Armengol. 2000. Limnology of Foix Reservoir (Barcelona, Spain). *Limnetica* 19: 175–191.

Marcé, R., M. Comerma, J.C. García, and J. Armengol. 2004. A neuro-fuzzy modelling tool to estimate fluvial nutrient loads in watersheds under time-varying human impact. *Limnol. Oceanogr.: Methods* 2: 342–355.

Marcé, R., E. Moreno-Ostos, J. Ordóez, C. Feijoo, E. Navarro, L. Caputo, and J. Armengol. 2006. Nutrient fluxes through boundaries in the hypolimnion of Sau Reservoir: expected patterns and unanticipated processes. *Limnetica* 25(1-2): 527–540.

Marcé, R., C. Feijoó, E. Navarro, J. Ordonez, J. Gomà, and J. Armengol. 2007. Interaction between wind-induced seiches and convective cooling governs algal distribution in a canyon-shaped reservoir. *Freshwater Biology* (in press).

Margalef, R., D. Planas, J. Armengol, A. Vidal, N. Prat, A. Guiset, J. Toja, and M. Estrada. 1976. *Limnología de los embalses españoles*. Ministerio de Obras Públicas.

Margalef, R. 1983. *Limnología*. Ediciones Omega.

Martí, E., and F. Sabater. 1996. High variability in temporal and spatial nutrient retention in Mediterranean streams. *Ecology* 77: 854–869.

Martí, E., J. Aumatell, L. Godé, M. Poch, and F. Sabater. 2004. Nutrient retention efficiency in streams receiving inputs from wastewater treatment plants. *Journal of Environmental Quality* 33: 285–293.

Matias, N.G., and M.J. Boavida. 2005. Effects of catchment development on the trophic status of a deep and a shallow reservoir in Portugal. *Lake and Reservoir Management* 21: 350–360.

Mattheus, D.A., and S.W. Effler. Assessment of long-term trends in the oxygen resources of a recovering urban lake, Onondaga Lake, New York. *Lakes. Reserv. Res. Manage.* 22: 19–32.

Mašín, M., J. Jezbera, J. Nedoma, V. Straškrábová, J. Hejzlar, and K. Šimek. 2003. Changes in bacterial community composition and microbial activities along the longitudinal axis of two canyon-shaped reservoirs with different inflow loading. *Hydrobiologia* 504: 99–113.

McAuliffe, T.F., R.J. Lukatelich, A.J. McComb, and S. Qiu. 1998. Nitrate applications to control P release from sediments of a shallow eutrophic estuary: an experimental evaluation. *Mar. Freshwat. Res.* 49: 463–473.

McCallister, S.L., J.E. Bauer, J.E. Cherrier, and H.W. Ducklow. 2004. Assessing sources and ages of organic matter supporting river and estuarine bacterial production: a multiple-isotope ($\Delta^{14}C$, $\delta^{13}C$, and $\delta^{15}N$) approach. *Limnology and Oceanography* 49: 1687–1702.

McIsaac, G.F., M.B. David, G.Z. Gertner, and D.A. Goolsby. 2001. Nitrate flux in the Mississippi River. *Nature* 414: 166–167.

McKnight, D.M., E. Hood, and L. Klapper. 2003. Trace organic moieties of dissolved organic material in natural waters, p71–96. *In* S.E.G. Findlay and R.L. Sinsabaugh [eds.], Aquatic Ecosystems. Interactivity of dissolved organic matter. San Diego (CA): Academic Press.

McManus J, E.A. Heinen , and M.M. Baehr. 2003. Hypolimnetic oxidation rates in Lake Superior: Role of dissolved organic material on the lake's carbon budget. *Limnol. Oceanogr.* 48: 1624–1632.

Merseburger, G.C., E. Martí, and F. Sabater. 2005. Net changes in nutrient concentrations below a point source input in two streams draining catchments with contrasting land uses. *Science of the Total Environment* 347: 217–229.

Michel, R.L. 1992. Residence times in river basins as determined by analysis of long-term tritium records. *Journal of Hydrology* 130: 367–378.

Mohseni, O., and H.G. Stefan. 1999. Stream temperature air temperature relationship: a physical interpretation. *Journal of Hydrology* 218: 128–141.

Molot, L.A., P.J. Dillon, B.J. Clark, and B.P. Neary. 1992. Predicting end-of-summer oxygen profiles in stratified lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 49: 2363–2372.

Moore, C., and J. Doherty. 2005. Role of the calibration process in reducing model predictive error. *Water Resour. Res.* 41, W05020, doi:10.1029/2004WR003501.

Moran, M.D. 2003. Arguments for rejecting the sequential Bonferroni in ecological studies. *Oikos* 100: 403–405.

Morin, G., and D. Couillard. 1990. Predicting river temperatures with a hydrological model, p171–209. *In* Encyclopedia of Fluid Mechanic, Surface and Groundwater Flow Phenomena, Vol. 10. Gulf Publishing Company: Houston.

Muckhopadhyay, B., and E.H. Smith. 2000. Comparison of statistical methods for estimation of nutrient load to surface reservoirs for sparse data set: Application with a modified model for phosphorus availability. *Water Research* 34: 3258–3268.

Mulholland, P.J., J.D. Newbold, J.W. Elwood, L.A. Ferren, and J.R. Webster. 1985. Phosphate spiralling in a woodland stream: seasonal variations. *Ecology* 6: 1012–1023.

Mulholland, P.J., A.D. Steiman, and J.W. Elwood. 1990. Measurements of phosphate uptake length in streams: comparison of radiotracer and stable PO4 releases. *Can. J. Fish. Aquat. Sci.* 47: 2351–2357.

Munn, N.L., and J.L. Meyer. 1990. Habitat-specific solute retention in two small streams: an intersite comparison. *Ecology* 71: 2069–2082.

Murphy, J., and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Act.* 27: 31–36.

Navarro, E., H. Guasch, and S. Sabater. 2002. Use of microbenthic algal communities in ecotoxicological tests for the assessment of water quality: the Ter river case study. *Journal of Applied Phycology*14: 41–48.

Nedoma, J., J.C. Garcia, M. Comerma, K. Šimek, and J. Armengol. 2006. Extracellular phosphatases in a Mediterranean reservoir: seasonal, spatial and kinetic heterogeneity. *Freshwater Biology* 51: 1264–1276.

Newbold, J.D., J.W. Elwood, R.V. O'Neill, and W. Van Winkle. 1981. Measuring nutrient spiralling in streams. *Can. J. Fish. Aquat. Sci.* 38: 860–863.

Newbold, J.D., J.W. Elwood, R.V O'Neill, and A.L. Sheldon. 1983. Phosphate dynamics in a woodland stream ecosystem; a study of nutrient spiralling. *Ecology* 64: 1249–1265.

Newbold, J.D. 1987. Phosphate spiralling in rivers and river-reservoir systems: implications of a model, pp 303–327. *In* F. Craig and J.B. Kemper [eds.], Regulated streams. Plenum Publishing Corp., New York.

Niyogi, D.L., K.S. Simon,and C.R. Townsend. 2004. Land use and stream ecosystem functioning:nutrient uptake in streams that contrast in agricultural development. *Arch. Hydrobiol.* 160: 471–486.

Nürnberg, G.K. 1984. The prediction of internal phosphorus load in lakes with anoxic hypolimnia. *Limnology and Oceanography* 29: 111–124.

Nürnberg, G.K. 1995. Quantifying anoxia in lakes. *Limnol. Oceanogr.* 40: 1100–1111.

Nürnberg, G.K. 1996. Trophic state of clear and colored, soft-and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. *Lake and Res. Manage.* 12: 432–447.

Nürnberg, G.K. 2002. Quantification of oxygen depletion in lakes and reservoirs with the hypoxic factor. *Lake and Res. Manage.* 18: 299–306.

Nürnberg, G.K., and B.D. LaZerte. 2004. Modeling the effect of development on internal phosphorus load in nutrient-poor lakes. *Water Resources Research* 40: W01105.

O'Neill, R.V., and B. Rust. 1979. Aggregation error in ecological models. *Ecological Modelling* 7: 91–105.

Oreskes, N., K. Shrader-Frechette, and K. Belitz. 1994. Verification, validation, and confirmation of numerical models in the Earth Sciences. *Science* 263: 641–646.

Pace, M.L., and Y.T. Prairie. 2005. Respiration in lakes, p. 103–121. *In* P.A. del Giorgio and P.J. le. B. Williams [eds.], Respiration in Aquatic Ecosystems. Oxford University Press.

Payn, R.A., J.R. Webster, P.J. Mulholland, H.M. Valett, and W.K. Dodds. 2005. Estimation of stream nutrient uptake from nutrient addition experiments. *Limnol. Oceanogr.: Methods* 3: 174–182.

Peters, N.E., O.P. Bricker, and M.M. Kennedy (Eds). 1997. *Water quality trends and geochemical mass balance*. Advances in hydrological processes. Wiley. Chichester, UK.

Peterson, B.J., L. Deegan, J. Helfrich, J.E. Hobbie, M. Hullar,B. Moller, T.E. Ford, A. Hersey, A. Hiltner, G. Kipphut, M.A. Lock, D.M. Fiebig, V. McKinley, M.C. Miller, J.R. Vestal, R. Ventullo, and G. Volk. 1993. Biological responses of tundra river to fertilization. *Ecology* 74: 653–672.

Peterson, B.J., W.M. Wollheim, P.J. Mulholland, J.R. Webster, J.L. Meyer, J.L. Tank, E. Martí, W.B. Bowden, H.M. Valett, A.E. Hershey, W.H. McDowell, W.K. Dodds, S.K. Hamilton, S. Gregory, and D.D. Morrall. 2001. Control of Nitrogen Export from Watersheds by Headwater Streams. *Science* 292: 86–90.

Phillips, J.M., B.W. Webb, D.E. Walling, and G.J.L. Leeks. 1999. Estimating the suspended sediment loads of rivers in the LOIS study area using infrequent samples. *Hydrological Processes* 13: 1035–1050.

Prat, N., M. Vilà-Escalé, C. Solà, J. Jubany, M. Miralles, M. Ordeix, B. Ríos, R. Andreu, N. Bonada, R. Casanovas-Berenguer, C. Múrria, T. Puntí,and M. Rieradevall. 2004. *La qualitat ecològica del Llobregat, el Besòs, el Foix, la Tordera i el Ter. Informe 2002*. Estudis de la Qualitat Ecològica, 12. Àrea de Medi Ambient de la Diputació de Barcelona. CD-ROM.

Preston, S.D., V.J. Bierman, and S.E. Silliman. 1989. An evaluation of methods for the estimation of tributary mass loads. *Water Resour. Res.* 25: 1379–1389.

Puig, M.A., J. Armengol, G. González, J. Penuelas, S. Sabater, and F. Sabater. 1987. Chemical and biological changes in the Ter river induced by a series of reservoirs, p373–382. *In* F.J. Craig and J.B. Kemper [eds], Regulated streams: Advances in ecology. Plenum Press.

Quinlan, R., J. P. Smol, and R. I. Hall. 1998. Quantitative inferences of past hypolimnetic anoxia in south-central Ontario lakes using fossil midges (Diptera: Chironomidae). *Can. J. Fish. Aquat. Sci.* 55: 587–596.

Raat, K.J., J.A. Vrugt, W. Bouten, and A. Tietema. 2004. Towards reduced uncertainty in catchment nitrogen modelling: quantifying the effect of field observation uncertainty on model calibration. *Hydrol. Earth Syst. Sci.* 8(4): 751–763.

Rainwater, F. H., and L.L. Thatcher. 1960. *Methods for collection and analysis of water samples*. US Geological Survey Water Supply Paper 1454. Washington, DC.

Raphael, J.M. 1962. Prediction of temperature in rivers and reservoirs. *ASCE Journal of the Power Division* 88: 157–181.

Rastetter, E.B., A.W. King, B.J. Cosby, G.M. Hornberger, R.V. O'Neill, and J.E. Hobbie. 1992. Aggregating fine-scale ecological knowledge to model coarser-scale attributes of ecosystems. *Ecological Applications* 2: 55–70.

Raymond, P., and J. Bauer. 2001. Use of ^{14}C and ^{13}C natural abundances for evaluating riverine, estuarine, and coastal DOC and POC sources and cycling: a review and synthesis. *Organic Geochemistry* 23: 469–485.

Reavie, E.D., K.E. Neill, J.L. Little, and J.P. Smol. 2006. Cultural eutrophication in three southeastern Ontario lakes: A paleolimnological perspective. *Lake and Res. Manage.* 22: 44–58.

Reckhow, K.H. 1979. Empirical lake models for phosphorus: development, applications, limitations and uncertainty, p193–221. *In* D. Scavia and A. Robertson [eds.], Perspectives on lake ecosystem modeling. Ann Arbor (MI): Ann Arbor Science Publishers.

Reckhow, K.H., and S.C. Chapra. 1983. *Engineering approaches for lake management. Volume 1: Data analysis and empirical modeling*. Butterworth Publishers.

Reckhow, K. H., and S. C. Chapra 1999. Modeling excessive nutrient loading in the environment. *Environmental Pollution* 100: 197–207.

Reynolds, C.S. 1992. Eutrophication and management of planktonic algae: what Vollenweider couldn't tell us?. *In* D.W. Sutcliffe and J.G. Jones [eds.], Eutrophication: research and application to water supply. Freshwater Biological Association.

Richards, R.P., and J. Holloway. 1987. Monte Carlo studies of sampling strategies for estimating tributary loads. *Water Resour. Res.* 23: 1939–1948.

Riera, J.L. 1993. *Regional limnology of Spanish reservoirs. Relationships between nutrients, seston, and phytoplankton*. PhD dissertation. Barcelona: Universitat de Barcelona.

Rigler, F.H. 1982. Recognition of the possible: an advantage of empiricism in ecology. *Can. J. Fish. Aquat. Sci.* 39: 1323–1331.

Rigler, F.H., and R.H. Peters. 1995. *Science and limnology*. Ecology Institute, Oldendorf/Luhe.

Ripl, W. 1976. Biochemical oxidation of polluted lake sediment with nitrate. A new restoration method. *Ambio* 5: 132–135.

Ripl, W. 1978. *Oxidation of lake sediment with nitrate: A restoration method for former recipients.* Inst. Limn. Lund. 151 pp.

Robertson, D.M., and E.D. Roerish. 1999. Influence of various water quality sampling strategies on load estimates for small streams. *Water Resour. Res.* 35: 3747–3759.

Rodà, F., J. Retana, C.A. Gracia, and J. Bellot (Eds.). 1999. *Ecology of Mediterranean evergreen oak forests*. Ecological Studies 137, Springer-Verlag, Berlin.

Romaní, A.M., and S. Sabater. 1999. Epilithic ectoenzyme activity in a nutrient-rich Mediterranean river. *Aquatic Sciences* 61: 122–132.

Romaní, A.M., and S. Sabater. 2000. Variability of heterotrophic activity in Mediterranean stream biofilms: A multivariate analysis of physical-chemical and biological factors. *Aquatic Sciences* 62: 205–215.

Romaní, A.M., and S. Sabater. 2001. Structure and activity of rock and sand biofilms in a Mediterranean stream. *Ecology* 82: 3232–3245.

Romero, J.R., M.R. Hipsey, J.P. Antenucci, and D.P. Hamilton. 2004. *Computational Aquatic Ecosystem Dynamics Model CAEDYM v2.1. (Science manual)*. Centre for Water Research, The University of Western Australia.

Rueda, F.J. 2006. Basin scale transport in stratified lakes and reservoirs: towards the knowledge of freshwater ecosystems. *Limnetica* 25(1-2): 33–56.

Rueda, F.J., E. Moreno-Ostos, and J. Armengol. 2006. The residence time of river water in the reservoirs. *Ecol. Model.* 191: 260–274.

Ruggiero, A., A.G. Solimini, and G. Carchini. 2006. Effects of a waste water treatment plant on organic matter dynamics and ecosystem functioning in a Mediterranean stream. *Ann. Limnol. - Int. J. Lim.* 42: 97–107.

Sabater, F., and J. Armengol. 1986. Chemical characterization of the Ter river. *Limnetica* 2: 75–84.

Sabater, F. 1988. The geochemical features of the Ter river watershed (NE Spain). *Oecologia aquatica* 9: 77–87.

Sabater, F., J. Armengol, and S. Sabater. 1989. Measuring discontinuities in the Ter river. *Regulated Rivers:Research and Management* 3: 133–142.

Sabater, F., S. Sabater, and J. Armengol. 1990. Chemical characteristics of a Mediterranean river as influenced by land use in the watershed. *Water Research* 24: 143–155.

Sabater, F., J. Armengol, and S. Sabater. 1991. Physico-chemical disturbances associated with spatial and temporal variation in a Mediterranean river. *J. N. Am. Benthol. Soc.* 10: 2–13.

Sabater, F., H. Guasch, E. Martí, J. Armengol, and S. Sabater 1995. The Ter: A Mediterranean river case-study in Spain. *In* C.E. Cushing, K.W. Cummins, and G.W. Minshall [eds.], River and stream ecosystems. Elsevier, Amsterdam.

Sabater, F., A. Butturini, E. Martí, I. Munoz, A.M. Romaní, J. Wray, and S. Sabater. 2000. Effects of riparian vegetation removal on nutrient retention in a Mediterranean stream. *Journal of the North American Benthological Society* 19: 609–620.

Sabater, S., and F. Sabater. 1992. Longitudinal changes of benthic algal biomass in a mediterranean river during two high production periods. *Arch. Hydrobiol.* 124: 475–487.

Sabater, S., H. Guasch, E. Martí, J. Armengol, M. Vila, and F. Sabater. 1992. The Ter, a Mediterranean river system in Spain. *Limnetica* 8: 141–149.

Scharf, W. 1999. Restoration of the highly eutrophic Lingese Reservoir. *Hydrobiol.* 416: 85–96.

Schindler, D.W. 1977. Evolution of phosphorus limitation in lakes. *Science* 195: 260–262.

Schlesinger, W.H. 1997. *Biogeochemistry an analysis of Global Change.* 2nd ed. Academic Press.

Schulz, K., R. Seppelt, E. Zehe, H.J. Vogel, and S. Attinger. 2006. Importance of spatial structures in advancing hydrological sciences. *Water Resour. Res.* 42, W03S03, doi:10.1029/2005WR004301.

Shamir, E., B. Iman, H.V. Gupta, and S. Sorooshian. 2005. Application of temporal descriptors in hydrologic model parameter estimation. *Water Resour. Res* 41, W06021, doi:10.1029/2004WR003409.

Shohomish County Surface Water Management (SWM). 2002. *Swamp Creek drainage needs report*. Department of Public Works, Surface Water Management Division, Everett, WA.

Šimek, K., J. Armengol, M. Comerma, J.C. Garcia, T.H. Chrzanowski, M. Macek, J. Nedoma, and V. Straškrábová. 1998. Characteristics of protistan control of bacterial production in three reservoirs of different trophy. *International Review of Hydrobiology* 83: 485–494.

Šimek, K., K. Juergens, J. Nedoma, M. Comerma, and J. Armengol. 2000. Ecological role and bacterial grazing of Halteria spp.: small freshwater oligotrichs as dominant pelagic ciliate bacterivores. *Aquatic Microbial Ecology* 22: 43–56.

Šimek, K., J. Armengol, M. Comerma, J.C. García, P. Kojecka, J. Redoma, and J. Hejzlar. 2001. Changes in the epilimnetic bacterial community composition, production, and protist-induced mortality along the longitudinal axis of a highly eutrophic reservoir. *Microb. Ecol.* 42: 359–371.

Simon, K.S., C.R. Townsend, B.J.F. Biggs, and W.B. Bowden. 2005. Temporal variation of N and P uptake in 2 New Zealand streams. *J. N. Am. Benthol. Soc.* 24: 1–18.

Singh, V.P., and D.A. Woolhiser. 2002. Mathematical modeling of watershed hydrology. *J. Hydrol. Eng.* 7(4): 270–292.

Sinokrot, B.A., and H.G. Stefan. 1993. Stream temperature dynamics: measurements and modeling. *Water Resources Research* 29: 2299–2312.

Skahill, B., and J. Doherty. 2006. Efficient accommodation of local minima in watershed model calibration. *Journal of Hydrology* 329: 122–139.

Smith, R.A., G.E. Schwarz, and R.B. Alexander. 1997. Regional interpretation of water-quality monitoring data. *Wat. Resour. Res.* 33: 2781–2798.

Sokal, R.R., and F.J. Rolf. 1995. *Biometry*. W.H. Freeman and Company, NY.

Solorzano, L. 1969. Determination of ammonia in natural waters by the phenol-hypochlorite method. *Limnol. Oceanogr.* 14: 799–801.

Sommaruga, R., M. Krossbacher, W. Salvenmoser, J. Catalan, and R. Psenner. 1995. Presence of large virus-like particles in a eutrophic reservoir. *Aquatic Microbial Ecology* 9: 305–308.

Søndergaard, M., and M. Middelboe. 1995. A cross-system analysis of labile dissolved organic carbon. *Marine Ecology Progress Series* 118: 283–294.

Soumis, N., É. Duchemin, R. Canuel, and M. Lucotte. 2004. Greenhouse gas emissions from reservoirs of the western United States *Global Biogeochem. Cycles* 18: GB3022. doi:10.1029/2003GB002197.

Srinivasan, R., J.G. Arnold, R.S. Muttiah, D. Walker, and P.T. Dyke. 1993. Hydrologic unit modeling of the United States (HUMUS), p451–456. *In* S. Yang [ed], Advances in Hydro-Science and Engineering, Vol. I. Washington.

Stålnacke, P., A. Grimvall, K. Sundblad, and A. Tonderski. 1999. Estimation of riverine loads of nitrogen and phosphorus to the Baltic Sea, 1970-1993. *Environmental Monitoring and Assessment* 58: 173–200.

Stålnacke, P., and A. Grimvall. 2001. Semiparametric approaches to flow normalization and source apportionment of substance transport in rivers. *Environmetrics* 12: 233–250.

Stefan, H.G., and E.B. Preud'homme.1993. Stream temperature estimation from air temperature. *Water Resources Research* 29: 27–45.

Straškraba, M. 1998. Limnological differences between deep valley reservoirs and deep lakes. *Int. Rev. Hydrobiol.* 83: 1–12.

Straškraba M., J.G. Tundisi, and A. Duncan. 1993. State-of-the-art of reservoir limnology and water quality management. *Hydrobiologia* 504: 213–288.

Straškraba, M. 1999a. Retention time as a key variable of Reservoir limnology. p385–410. *In* J.G. Tundisi and M. Straškraba [eds], Theoretical reservoir ecology and its applications. Leiden: International Institute of Ecology. Brazilian Academy of Sciences and Backhuys Publishers.

Straškraba, M. 1999b. Self-Organization, direct and indirect effects. p29–52. *In* J.G. Tundisi and M. Straškraba [eds], Theoretical reservoir ecology and its applications. Leiden: International Institute of Ecology. Brazilian Academy of Sciences and Backhuys Publishers.

Straškraba, M., and J.G. Tundisi. 1999. Reservoir ecosystem functioning: theory and application, p565–583. *In* J.G. Tundisi and M. Straškraba [eds], Theoretical reservoir ecology and its applications. Leiden: International Institute of Ecology. Brazilian Academy of Sciences and Backhuys Publishers.

Stream Solute Workshop. 1990. Concepts and methods for assessing solute dynamics in stream ecosystems. *Journal of the North American Benthological Society* 9: 95–119.

Swift Jr., L.W., W.T. Swank, J.B. Mankin, R.J. Luxmoore, and R.A. Goldstein. 1975. Simulation of evapotranspiration and drainage from mature and clear-cut deciduous forest and young pine plantation. *Water Resour. Res.* 11(5): 667–673.

Tchobanoglous, G., F.L. Burton, and H.D. Stensel. 2003. *Wastewater Engineering: Treatment and reuse*. 4th ed. Metcalff and Eddy Inc. and Mc Graw-Hill Inc.

Thomann, R., and J. Mueller. 1987. *Principles of Surface Water Quality and Modeling*. Harper-Collins: New York.

Tomaszek, J.A., and P. Koszelnik. 2003. A simple model of nitrogen retention in reservoirs. *Hydrobiologia* 504: 51–58.

Tonkin, M.J., and J. Doherty. 2005. A hybrid regularized inversion methodology for highly parameterized environmental models. *Water Resour. Res.* 41, W10412, doi:10.1029/2005WR003995.

Townsend, S.A. 1999. The seasonal pattern of dissolved oxygen, and hypolimnetic deoxygenation, in two tropical Australian reservoirs. *Lakes. Reserv. Res. Manage.* 4: 41–53.

Tsutakawa, R.K., and J.E. Hewett 1978. Comparison of two regression lines over a finite interval. *Biometrics* 34: 391–398.

Tundisi G.J., T. Matsumura-Tundisi, and O. Rocha. 1999. Theoretical basis for reservoir management, p505–528. *In* J.G. Tundisi and M. Straškraba [eds], Theoretical reservoir ecology and its applications. Leiden: International Institute of Ecology. Brazilian Academy of Sciences and Backhuys Publishers.

Uhlmann, D. 1998. Reservoirs as ecosystems. *International Review of Hydrobiology* 83: 13–20.

U.S. Environmental Protection Agency (USEPA). 1978. *User's manual for the Agricultural Runoff Management (ARM) model*. EPA-823/3-78-080, U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.

U.S. Environmental Protection Agency (USEPA). 1999. *HSPFParm: an interactive database of HSPF model parameters, Version 1.0*. EPA-823-R-99-004, U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 2000. *BASINS Technical Note 6: estimating hydrology and hydraulic parameters for HSPF*. EPA-823-R-00-012, U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 2001. *Better Assessment Science Integrating point and Non-point Sources, BASINS Version 3.0*. EPA-823-H-01-001, U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Valett, H.M., C.L. Crenshaw, and P.F. Wagner. 2002. Stream nutrient uptake, forest succession, and biogeochemical theory. *Ecology* 83: 2888–2901.

van der Leeden, F., F.L. Troise, and D.K. Todd. 1991. *The Water Encyclopedia*. Second Edition, Lewis Publishers, Chelsea, MI.

Van Dijk, G.M., P. Stålnacke, A. Grimvall, A. Tonderski, K. Sundblad, and A. Schafer. 1996. Long-term trends in the nitrogen and phosphorus concentrations in the Lower River Rhine. *Archiv fur Hydrobiologia* 113: 99–109.

Vandelannoote, A., H. Deelstra, and F. Ollevier. 1999. The inflow of the Rusizi river to Lake Tanganyika. *Hydrobiologia* 407: 65–73.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and. E. Gushing. 1980. The river continuum concept. *Can. J. Fish. Aquat. Sci.* 37: 130–137.

Vecchia, A.V. 1985. Periodic autoregressive-moving average (PARMA) modeling with applications to water resources. *Water Resources Bulletin* 21: 721–730.

Vecchia, A.V., and R.L. Cooley. 1987. Simultaneous confidence and prediction intervals for nonlinear regression models with application to a groundwater flow model. *Water Resour. Res.* 23(7): 1237–1250.

Vidal, A. 1969. Evolution d'un lac de barrage dans le NE de l'Espagne pendant les quatre premières annés de service. *Verh. Internat. Verein. Limnol.* 17: 191–200.

Vidal, A., and J. Om. 1993. The eutrophication process in Sau reservoir (NE Spain): A long-term study. *Ver. Internat. Verein. Limnol.* 25: 1247–1256.

Vidal J., X. Casamitjana, J. Colomer, and T. Serra. 2005. The internal wave field in Sau reservoir: Observation and modeling of a third vertical mode. *Limnology and Oceanography* 50: 1326–1333.

Viessman, W., M.J. Hammer. 1993. *Water supply and pollution control, 5th ed*. New York: Harper Collins College Publishers. 860p.

Vollenweider, R.A. 1968. *Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication.* Pub. No. DAS/SAI/68.27. Organization for Economic Cooperation and Development, Directorate for Scientific Affairs. 250p.

Vrugt, J.A., H.V. Gupta, L.A. Bastidas, W. Bouten, and S. Sorooshian. 2003. Effective and efficient algorithm for multiobjective optimization of hydrologic models. *Water Resour. Res.* 39(8), 1214, doi:10.1029/2002WR001746.

Vrugt, J.A., H.V. Gupta, W. Bouten, and S. Sorooshian. 2003b. A Shuffled Complex Evolution Metropolis algorithm for optimization and uncertainty assessment of hydrologic model parameters. *Water Resources Research* 39: 1214. DOI:10.1029/2002WR001746.

Vrugt, J.A., C.G.H. Diks, H.V. Gupta, W. Bouten, and J.M. Verstraten. 2005. Improved treatment of uncertainty in hydrologic modeling: combining the strengths of global optimization and data assimilation. *Water Resour. Res.* 41, W01017, doi:10.1029/2004WR003059.

Walker, W.W. 1996. *Simplified procedures for eutrophication assessment and prediction: User Manual*. Instruction Report W-96-2. US Army Corps of Engineers. Vicksburg, MS.

Wallace, J.B., J.R. Webster, and J.L. Meyer. 1995. Influence of log additions on physical and biotic characteristics of a mountain stream. *Can. J. Fish. Aquat. Sci.* 52: 2120–2137.

Walsh, J.J. 1991. Importance of continental margins in the marine biogeochemical cycling of carbon and nitrogen. *Nature* 350: 53–55.

Wang, l., and J.M. Mendel. 1992. Generating fuzzy rules by learning from examples. *IEEE Transactions on Systems, Man, and Cybernetics* 22: 1414–1427.

Wauer, G., T. Gonsiorczyk, K. Kretschmer, P. Casper, and R. Koschel. 2005. Sediment treatment with nitrate-storing compound to reduce phosphorous release. *Water Res.* 39: 494–500.

Webb, B.W., J.M. Phillips, D.E. Walling, I.G. Littlewood, C.D. Watts, and G.J.L. Leeks. 1997. Load estimation methodologies for British rivers and their relevance to the LOIS RACS(R) programme. *The Science of the Total Environment* 194-195: 379–389.

Webb, B.W., J.M. Phillips, and D.E. Walling. 2000. A new approach to deriving 'best-estimate' chemical fluxes for rivers draining the LOIS study area. *The Science of the Total Environment* 251-252: 45–54.

Webster, J.R., D.J. D'Angelo, and G.T. Peter. 1991. Nitrate and phosphate uptake in streams at Cweeta Hydrologic Laboratory. *Verh. Int. Ver. Limnol.* 24: 1681–1686.

Werner, U., U. Stöhr, and N. Hees. 1989. *Biogas plants in animal husbandry*. Lengerich: Deutsches Zentrum fr Entwicklungstechnologien (GTZ). 153p.

Westerhoff, P., and D. Anning. 2000. Concentrations and characteristics of organic carbon in surface water in Arizona: influence of urbanization. *Journal of Hydrology* 236: 202–222.

Wetzel, R.G. 1990. Reservoir ecosystems: Conclusions and speculations, p. 195–208. *In* K.W. Thorton, B.L. Kimmel, and F.E. Payne [eds], Reservoir Limnology: Ecological Perspectives. Wiley Interscience.

Wetzel, R.G. 2001. *Limnology. Lake and river ecosystem*. 3rd ed. Academic Press. 1006p.

Whitehead P.G., E.J. Wilson, and D. Butterfield. 1998. A semi-distributed Integrated Nitrogen model for multiple source assessment in Catchments (INCA): Part I - model structure and process equations. *Sci. of the Total Environ.* 210/211: 547–558.

Whitfield, P. H. 1982. Selecting a method for estimating substance loadings. *Water Resources Bulletin* 18(2): 203–210.

Whittemore, D.O. 2000. *Water quality of the Arkansas River in Southwest Kansas*. Kansas Geological Survey Open-File Report 2000-44. 74p.

Williams, P.J. le B., and P.A. del Giorgio. 2005. Respiration in aquatic ecosystems: history and background, p1–17. *In* P.A. del Giorgio and P.J. le B. Williams [eds.], Respiration in aquatic ecosystems. New York: Oxford University Press.

Wool, T.A, R.B. Ambrose, J.L. Martin, and E.A. Comer. 2003. *Water Quality Analysis Simulation Program (WASP) Version 6.0: User's Manual*. USEPA.

World Commission on Dams. 2000. *Dams and Development: a New Framework for Decision-Making*. London: Earthscan Publication, p404.

Young, R.A., C.A. Onstad, and D.D. Bosch. 1995. AGNPS: An agricultural nonpoint source model. *In* V.P. Singh [ed], Computer Models of Watershed Hydrology. Highlands Ranch, Colorado: Water Resource Publications.

Zadeh, L.A. 1965. Fuzzy sets. *Inform. and Contr.* 8: 338–353.

Zetterqvist, L. 1991. Statistical estimation and interpretation of trends in water quality time series. *Water Resour. Res.* 27(7): 1637–1648.

Zheng , Y., and A.A. Keller. 2006. Understanding parameter sensitivity and its management implications in watershed-scale water quality modeling. *Water Resour. Res.* 42, W05402, doi:10.1029/2005WR004539.