DEVELOPMENT OF AN EUROPEAN QUANTITATIVE
EUTROPHICATION RISK ASSESSMENT OF
POLYPHOSPHATES IN DETERGENTS

MODEL IMPLEMENTATION AND QUANTIFICATION OF THE EUTROPHICATION RISK ASSOCIATED TO THE USE OF PHOSPHATES IN DETERGENTS

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FINAL STUDY REPORT

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This final report compiles the information generated during the three phases of this research project and has been produced under the scientific supervision of Dr. Jose V. Tarazona, by the Laboratory for Ecotoxicology, Department of the Environment, of the Spanish National Institute for Agriculture and Food Research and Technology (INIA) in cooperation with Green Planet Environmental Consulting S.L. and Green Planet Research S.L. within the scope of a CEEP (Comité Européen d'Etudes des Polyphosphates) Cefic Sector Group research agreement.

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EXECUTIVE SUMMARY

This report presents the results obtained for the study entitled: "DEVELOPMENT OF AN EUROPEAN QUANTITATIVE EUTROPHICATION RISK ASSESSMENT OF PHOSPHATES IN DETERGENTS". The report includes the final estimations and substitutes those presented previously.

The report is presented in two sections. Section 1 describes the development of the conceptual model, exposure scenarios, effect evaluation and risk assessment protocol. Section 2 presents the implementation and a set of examples based on generic European scenarios as well as a pan European probabilistic estimation covering the diversity observed for the European conditions.

The proposed risk assessment protocol is a higher tier method with probabilistic estimations for the effect assessments and additional possibilities for expanding the exposure estimation in a probabilistic way; therefore, it deviates significantly from the methodology developed by the European Chemicals Bureau (ECB) for assessing the risk of industrial chemicals. However, the philosophy and basic risk assessment concepts are, as much as possible, in line with those risk assessment principles.

Problem formulation: The risk to be assessed has been defined according to the European chemicals policy rules and regulations: the identification of the risk associated to a specific chemical substance under the conditions expected for the uses defined by the industrial producer. The risk to be quantified is the eutrophication risk associated to the emissions of phosphorus resulting from the use of phosphates in domestic detergents. The assessed substance, phosphorus (P), is widely distributed in the environment and there are many sources of environmental release other than the one addressed in this study (presence of phosphates in detergents). The risk assessment methodology should be able to identify the risk associated to the specifically addressed source (e.g. using the added risk approach or comparative risk assessment methods; the latter has been the option adopted for this study). Similarly, the risk is addressed in a way that could be directly used as supporting tool for risk management measures at the European level. Therefore, the methodology is based on generic risk estimations for sensitive ecosystems potentially exposed; and does not pretend to identify where these conditions exist. Historical pollution, synergistic or antagonistic effects with other substances, adaptation mechanisms, etc., are also excluded from the problem formulation; however, it must be considered that as the effect assessment is based on real field data, part of the observed variability should be attributed to these phenomena.

Exposure assessment: As already indicated, the exposure assessment is based on a generic estimation of the Predicted Environmental Concentration, and should be able to distinguish among the assessed contribution (in this particular case detergents), background levels and the contribution from other sources. The addressed source represents a consumer use of an industrial substance, and therefore is widely spread. The contribution of diffuse sources to the overall P load is a critical element, and, therefore, the selected scenario has been an expanded regional assessment focusing at the river basin level. The local, regional and continental assessment models presented in the European Technical Guidance Document (ECB, 2003) cannot be applied for this scenario; thus, a new approach has been developed. The proposed river basin scenario estimates the annual average total phosphorus (TP) concentration by using export coefficients based on population density, removal at the treatment plant and land uses distribution. A simplified model has been developed and validated using Danube river basin data. This simplified model is considered good enough for a generic evaluation and allows comparative assessments for estimating the expected influence of different risk management alternatives. The mathematical implementation of the model allows probabilistic assessments covering variability and uncertainty using Monte Carlo analysis.

Effect assessment: The assessment of the effects associated to phosphorus releases has been the crucial part of this work, requiring a high level of innovation, as the European environmental risk assessment protocols focus on the toxicity of the substance, not on nutrient enrichment. The adopted solution is based on the combination of information obtained under real situations, collected through the analysis of published field studies validated one by one, and the methods for assessing adverse effects linked to nutrient enrichment currently being developed for the implementation of the European Water Framework Directive (WFD). The analysis of the data allowed the estimation of the probabilistic distributions associated to the TP concentration measured in sensitive water bodies (lakes, reservoirs, stagnant waters) fulfilling the "Good status" criteria developed for the WFD, and those with "Less-than-good status" conditions. Over 300 field case studies distributed all around Europe have been analysed one by one to determine if the eutrophication status could be attributed to good conditions or not. The cases are therefore divided between those fulfilling the good status conditions, or "G+"; and those with less than good status, or "G-". Probability distributions of the TP concentrations in each of the two groups "G+" and "G-" were then estimated.

The obtained probability distributions represent the best estimation for the conditional probabilities p(TP | G+) and p(TP | G-). The conditional probability is the probability of some event A occurring, given that some other event B is known to have occurred. In this case, p(TP | G+) represents the probability of a water body having a certain total phosphorus concentration, TP, given that the water body is in good status conditions, G+. Similarly, p(TP | G-) represents the probability of a water body having a certain total phosphorus concentration, TP, given that the water body is not in good status conditions, G-. These conditional probabilities will be used in the risk characterization for quantifying the eutrophication risk associated to a given TP concentration.

The suitability of the developed approach has been estimated using two alternative methodologies, a semi-quantitative assessment for confirming the coherence of the field observations and the assumed effect classification; and the Morphoedaphic Index for addressing the role of anthropogenic contributions. Both methods confirmed the coherence of the effect assessment process and were used in the individual re-evaluation of each case included in the database.

The analysis of the effect database identified differences in the distribution associated to ecoregions and water bodies' ecotypes. The results were perfectly coherent with the assumptions from the experts workshop suggesting the need for considering three combinations of ecoregions&type-classes:

- Atlantic, Northern and Central European shallow lakes
- Atlantic, Northern and Central European deep lakes
- Mediterranean water bodies.

After the review process, a total of 303 field cases, were selected. The distribution of cases among the three classes was as follows: 138 cases representing Atlantic, Northern and Central European shallow lakes; 47 cases representing Atlantic, Northern and Central European deep lakes, and 118 cases representing Mediterranean water bodies. The number and distributions of cases obtained for the Atlantic, Northern and Central European deep lakes was not sufficient for a proper evaluation, and this eco-region&type-class has not been further considered in the risk characterization.

Then, the specific probability distributions for each eco-region&type-class were estimated. The statistical analysis demonstrated that the fitting of the raw data to a lognormal distribution was not good enough in most cases. Thus un-fitted distributions of the raw data were employed.

Risk characterization: The combination of the exposure estimations and the effect assessment offers a quantitative estimation of the expected risk. It should be noted that the exposure assessment estimates concentrations in the in-flow water, and does not consider in-lake phosphorous processes. Depending on lake characteristics (such as depth, residence time, etc.) lake concentrations can be even orders of magnitude lower than the concentrations in inflowing rivers. The same river concentration will not produce the same concentration in shallow ponds (mean depth of a few meters) and in a deep alpine lake (mean depth higher than 100 meters). Following the discussions at the expert workshop, it was decided to use the worst-case exposure conditions related to the concentration in the river and equivalent to the inflow phosphorous concentration for sensitive areas. It should be considered that for lakes, the estimations represent the eutrophication potential of the inflow water, which constitutes an unrealistic worst case estimation particularly for deep lakes.

It was very clear from the literature review that the collected data cannot be considered a random sample of water bodies. As a consequence the conditional probability of a water body to be in less than good status given a certain TP concentration, p(G- | TP) cannot be directly estimated from the data base.

The risk characterization has been quantified through the estimation of a probability range and the most likely value, between the maximum and minimum values of the range.

For each exposure assessment estimation, TP, the eutrophication risk associated to that concentration is defined as the likelihood of a sensitive site, susceptible to eutrophication, to be in less-than-good eutrophication status. This value is represented by the joint probability for having a certain TP concentration and being in less-than-good status corrected by the percentage of sites in the area with potential for suffering eutrophication problems if enough amounts of nutrients are provided. The correction by the maximum value of p(G-) provides a risk value ranging from 0 to 1 (or 0% to 100% when expressed as percentage). The risk does not cover non-sensitive water bodies; thus, for example, if in a given area, 40% of the water bodies have potential for eutrophication, the risk refers exclusively to this 40%, not to all water bodies; thus a risk of 50% means that half of this 40% sensitive water bodies are expected to be in less-than-good status conditions.

The conditional probabilities p(TP | G-) and 1- p(TP | G+) define the range for the eutrophication risk.

The “Most Likely Probability” value, mlp, was estimated from the combination of the probability distributions obtained for the conditional probabilities p(TP | G-) and p(TP | G+), and the most likely probability value for the number of sites with less than good status, expressed as mlp(G-).

$$\mathrm{mlp}(G- \mid TP) = p(TP \mid G-)\,\mathrm{mlp}(G-) / p(TP)$$

A proper value for mlp(G-) is essential for the estimation of the mlp values.

Risk communication: Due to the complexity of the proposed methodology a specific expert consultation was conducted to obtain information on the understanding, comprehension, perception and preferences of different alternatives for presenting the results. The preferences from the experts were for receiving as much information as possible on the risk characterization output and its associated uncertainty. For the proposed methodology this requirement can be accomplished by including in the presented results both the estimations for the probability range and the “mlp” value.

Comparative risk assessment: Following this approach, the comparative risk estimations have been done through parallel estimations of the eutrophication risk associated to: all sources of P; all sources except detergents; all diffuse sources; and all point sources. The results are presented in table and graph forms. The implemented model also allows the assessment of additional risk management options, such as removal of phosphates from domestic detergents, improvement of P removal technologies in sewage treatment works and risk mitigation measures reducing diffuse sources.

Section 2 of the report offers several risk estimations for generic scenarios, covering different combinations of:

European average consumption of P-based detergents *versus* European highest national consumption of P-based detergents
Mediterranean *versus* Atlantic shallow lakes effect assessment
Average European values for Population density *versus* low density (one third) areas
Average European River flow value *versus* high flow (twice the average) rivers.
Average European values for land use distribution *versus* areas with low agricultural intensity.
Generic *versus* specific estimation for P removal at the sewage treatment plant.

The results show that there is not a linear relationship between the contribution of a P source (detergents or any other) to the total emission and its contribution to the total risk. The selected scenarios covered contributions of P-based detergents from 8 to 26 % of the TP load (considering the removal of P at the sewage treatment plant for the estimation of loads from point sources), and TP annual averages ranging from 154 to 546 µg/l. The contribution of detergents can be estimate as the difference between the total risk and the risk without detergents. As the risk is presented as a range and a most likely value three comparisons are required:

- The differences in the upper bound of the risk range, 1-p(TP|G+), varied between 0.2 to 3.4 %.
- The differences in the lower bound of the risk range, p(TP|G-), varied between 1.2 to 10.3 %.
- The differences in the most likely value, mlp(G-|TP), varied between 0.5 to 9.3.

Results are summarised in the following tables:

Table ES.1 Summary of the results obtained for the different generic scenarios. The table shows the detergent contribution, in percentage, to the total P load in the catchment (considering the removal of P at the sewage treatment plant for the estimation of loads from point sources); the estimated annual average total P concentration; the employed effect assessment class; and the difference between the total risk and the risk without P-based detergents.

(This difference is presented for the upper bound, the lower bound and the most likely probability (mlp) estimated for the assumption that 33% of water bodies in the area are in less than good status)

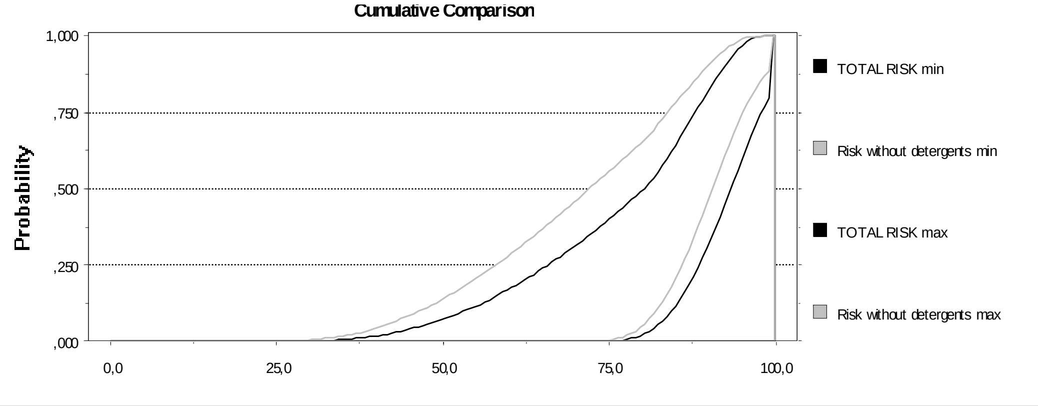
Scenario	Detergent contribution	TP conc.	Ecoregion&type Class	Difference between total risk and risk without detergents		
	%	µg/l		Upper bound 1-p(TP|G+)	Lower bound P(TP|G-)	mlp(G-|TP)
1a	13.1	465	Mediterranean	1.6	4.5	3.7
1b	13.1	465	At-N&C shallow	0.2	1.2	0.5
1c	26	546	Mediterranean	3.4	8.1	7.6
1d	26	546	At-N&C shallow	0.4	2.3	1
2a	13.1	232	Mediterranean	1.6	4.7	4.4
2b	13.1	232	At-N&C shallow	0.4	2.8	1.1
2c	26	273	Mediterranean	3.4	10.3	9.3
2d	26	273	At-N&C shallow	0.8	5.4	2
3a	8	255	Mediterranean	0.9	2.8	2.5
3b	8	255	At-N&C shallow	0.2	1.4	0.6
3c	16.8	282	Mediterranean	2	6.3	5.5
3d	16.8	282	At-N&C shallow	0.5	2.9	1.1
4a	9.6	212	Mediterranean	1.1	3.3	3.2
4b	9.6	212	At-N&C shallow	0.4	2.1	0.8
4c	19.8	239	Mediterranean	2.5	7.4	6.9
4d	19.8	239	At-N&C shallow	0.7	4.4	1.6
5a	9.9	154	Mediterranean	1.1	3	3.2
5b	9.9	154	At-N&C shallow	0.4	3.3	1.4
5c	20.4	174	Mediterranean	2.5	6.8	7.2
5d	20.4	174	At-N&C shallow	0.8	6.7	2.7

Table ES.2.. Median and arithmetic mean values obtained for the different generic scenarios.

Parameter	Detergent contribution	TP conc.	Difference between total risk and risk without detergents		
	%	µg/l	Upper bound 1-p(TP|G+)	Lower bound P(TP|G-)	mlp(G-|TP)
All scenarios					
Median	15	247	0.85	3.85	2.6
Arith mean	16	283	1.24	4.48	3.31
Mediterranean scenarios					
Median	15	247	1.80	5.50	4.95
Arith mean	16	283	2.01	5.72	5.35
Atlantic-N&Central shallow scenarios					
Median	15	247	0.40	2.85	1.10
Arith mean	16	283	0.48	3.25	1.28

In addition, a pan European probabilistic estimation covering the diversity observed for the European conditions is presented. The contribution of P-based detergents to the total risk is presented in the figures below through the comparison of the estimated risk ranges for the Mediterranean and for the Atlantic, Northern and Central (Atlantic-N&Central) shallow eco-region&type classes.

MEDITERRANEAN ECO-REGION&TYPE CLASS



ATLANTIC-N&CENTRAL SHALLOW ECO-REGION&TYPE CLASS

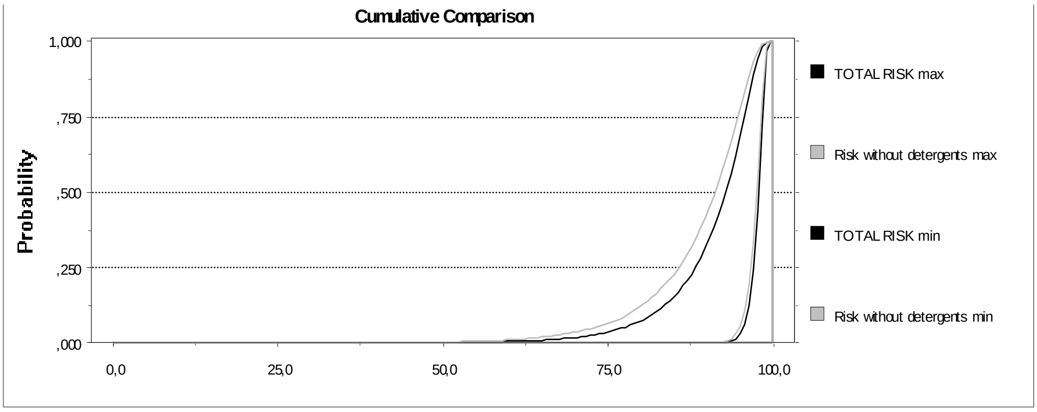


Figure ES.1. Comparison between "Total Eutrophication Risk" (black lines) and "Eutrophication Risk without P-Detergent contribution" (grey lines) ranges. Max and min represents the upper and lower bounds respectively.

The report also presents estimations for the most likely value based on a tentative mlp(G-) of 0.33 corresponding to the assumption that 33% of water bodies in the area are in less than good status.

The results obtained for the generic scenarios and for the pan-European probabilistic estimation are quite consistent. The estimated difference between the total risk and the risk without P-based detergents is typically around the range 2-8% based on the Mediterranean effect assessment and around the range 0.4-2% based on the Atlantic-N&Central shallow effect assessment.

As expected, a large variability among regions has been obtained. The model is ready for conducting additional calculations for other scenarios and assumptions if required.

INTRODUCTION

Polyphosphates are widely used as builder in household cleaning products. In conjunction with surfactants, they allow detergents to perform efficiently in all washing conditions. They are widely used in laundry detergents, dishwasher detergents, industrial and institutional detergents. Phosphates are widely used in the form of sodium tripolyphosphate Na5P3O10 (STPP) with CAS-No 7758-29-4 (pentasodium triphosphate, or Triphosphoric acid, pentasodium salt; EINECS No. 231-838-7). Through the voluntarily programme HERA, industry has conducted an environmental and human risk assessment of STPP (HERA, 2003). Household cleaning applications are estimated by industry to account for 90-95% of STPP use in Europe.

As an ingredient of household cleaning products, STPP included in domestic waste waters is mainly discharged to the aquatic compartment, directly, via sewage treatment plants (STP), via septic tanks, infiltration or other autonomous wastewater elimination systems. As STPP is an inorganic substance, biodegradation studies are not applicable. However, STPP can be hydrolysed, finally to orthophosphate, which can be assimilated by algae and/or by microorganisms. STPP thus ends up being assimilated into the natural phosphorus cycle. Reliable published studies confirm biochemical understanding, showing that STPP is progressively hydrolysed by biochemical activity in contact with wastewaters (in sewerage pipes and within sewage works) and also in the natural aquatic environment (HERA, 2003).

However, the HERA (2003) report does not address the eutrophication risk associated to the emission of phosphorus into the aquatic environment due to the hydrolysis of STPP. The report states that "*The eutrophication of surface waters due to nutrient enrichment is not addressed in this document because a PNEC cannot be defined for such effects, which depend on many factors varying spatially and temporally (temperature, light, concentrations of phosphates and of other nutrients, activity of grazer population …*)". As a consequence, the Environmental risk of STPP in the HERA report covers exclusively the toxicity of STPP but not its potential contribution to eutrophication.

The Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) of the European Union considered that the argument was not acceptable. The committee recognised that a PNEC for eutrophication cannot be defined as a single number applicable to all ecosystems; but considered that the basic rules for environmental risk assessment are applicable, although a higher tier assessment should be required, e.g. a landscape evaluation with probabilistic outcomes for each landscape scenario (CSTEE, 2003)

Obviously, the CSTEE recognised the complexity of the eutrophication phenomena, and the limited role of anthropogenic phosphorus loads:

"The risk of eutrophication related to anthropogenic phosphate loads plays a role when the following key factors appear simultaneously in the spatial and temporal scales:

- *The ecosystem can respond to the additional nutrient load with an increase in algal productivity resulting in structural and functional changes*
- *Phosphorus is the limiting nutrient*

Increase in phosphorus loads will result in eutrophication problems only in those locations and points in time which these conditions are fulfilled." (CSTEE, 2003) .

In addition, the committee suggested that a quantitative assessment of the extent of eutrophication in EU water bodies in relation to phosphorus load from different sources, and in particular in relation to STPP contribution, could be performed on the basis of a literature review on existing experimental and modelling information, produced on the evolution of the eutrophication problem and on the recovery of eutrophic water bodies.

The first step for a scientifically sound risk assessment of complex problems is the development of a proper conceptual model (USEPA, 1998). The European Technical Guidance Document (EU, 2003) offers very simplistic conceptual models for assessing the environmental risk of individual chemicals, focusing on exposure predictions and the derivation of a Predicted No Effect Concentration (PNEC) on the basis of the observed toxicity. Higher tier studies can be included in the PNEC derivation, but scarce guidance is presented on the methodology for this incorporation. The use of higher tier studies and indirect effects is much more common in other risk assessments, e.g. those conducted for the registration of pesticides. A revision of the conceptual models employed in the different European risk assessment protocols was published by the European Scientific Steering Committee (SSC, 2003). Nevertheless, the complexity of the eutrophication process requires the development of a specific conceptual model.

This report presents an innovative conceptual model for quantifying the risk associated to the additional input of phosphorus associated to the use of STPP in detergents.

The work has been structured in three work packages:

Work package 1: Search for information and developing of the initial conceptual model.

Work package Phase 2: Presentation and discussion of the conceptual model to an international expert panel.

Work package 3: Implementation of the agreed model and estimation of the eutrophication risk.

Work package 1 included the development of an innovative conceptual model for covering the eutrophication risk associated to phosphorus emissions, and new proposals for the exposure and effect assessment as well as for a quantitative risk characterization and risk communication. During Phase 2, these results were presented to and discussed with an international expert panel, including a Experts Workshop held in Madrid in November 2005. The recommendations from the experts have been used for updating the proposal and the conceptual model, developing a mathematical implementation and producing a set of risk estimations for the suggested scenarios.

The specific results obtained in Phase I and II were distributed as the following reports:

Green Planet Report EC-CEEP-05-2-Final
Green Planet Research Report GPR-CEEP-06-1-Final Draft

This final study report covers the final phase and also the previous work conducted for the development of the model, and therefore, has been produced as the main and final deliverable of the whole study. For facilitating the comprehension of the study results, the key elements of the model development in the final employed form have been included and fully described in this report. Thus this final study report constitutes a self-standing report replacing those produced in the previous phases.

The report is scheduled in two main sections. The first section describes the model development work conducted in this study and the scientific basis supporting the innovative proposal employed for characterizing the eutrophication risk in a quantitative form.

The second section offers the risk characterization results obtained for a set of generic European scenarios, based on the proposals discussed during the expert workshop, as well as a pan European probabilistic estimation covering the diversity observed for the European conditions.

SECTION 1.

DEVELOPMENT OF THE CONCEPTUAL MODEL, EXPOSURE SCENARIOS, EFFECT EVALUATION AND RISK ASSESSMENT PROTOCOL

INTRODUCTION

There are different definitions for the term Eutrophication, but most agree with the basic concept: eutrophication is the enrichment of nutrients to water resulting in an increase of the primary production (growth of e.g. algae). The EC Urban Waste Water Treatment Directive defines Eutrophication as:

"the enrichment of water by nutrients especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water concerned”.

Therefore, the risk for eutrophication cannot be defined as the likelihood for nutrient enrichment, but as the likelihood for this enrichment to provoke undesirable disturbances. The definition of which level of disturbance is considered as undesirable becomes a critical part of the assessment. Following the initial proposal as well as suggestions from consultations with experts from different organizations and from the SCHER (the new scientific committee substituting the CSTEE), it has been decided to follow the recommendations adopted for the implementation of criteria for defining eutrophication related effects in the Common Implementation Strategy of Water Framework Directive (CIS-WFD). Ecosystem responses resulting in deviations from the “Good Status definition” are assumed to be unacceptable, and modifications in the algae and plant growth not resulting in deviations from the “Good Status definition” are considered acceptable in terms of negative ecosystems consequences.
In the CIS-WFD, the eutrophication phenomenon definition begins with the explanation of those situations and processes considered as eutrophication related disturbances, which lead to the undesirable ecosystem impairment.

Following the principles of the CIS-WFD, two definitions for "Significant Undesirable Disturbances" have been used to define negative ecosystem consequences. The first definition covers the significant increases in algal growth and biomass production; the second covers changes in taxonomic diversity not necessarily associated to significant increase in overall primary production.

Both definitions follow the first proposal from the ECOSTAT Eutrophication Activity group. The work started with the ECOSTAT draft definitions from 2004 and 2005; and was revised after the new adopted definitions, presented in the final report of the CIS of the WFD Eutrophication Activity, "Towards a Guidance Document on Eutrophication Assessment in the context of European Water Policies", March 2006.

In addition, there were many other documents developed around the CIS process that were considered in order to clarify the criteria to use in the effect assessment. The idea was the collect as much validated information as possible on the biological elements that are expected to be affected in the eutrophication process. In this sense, a number of draft and final reports have been considered:

- CIS-WFD. Guidance document No. 6. "Towards a guidance on establishment of the intercalibration network and the process on the intercalibration exercise". 2000.
- CIS-WFD. Guidance document No. 7. "Monitoring under the Water Framework Directive". 2000.
- CIS-WFD. Guidance document No. 10. "River and lakes – Typology, reference conditions and classification systems". 2000.
- Finnish Environment Institute. "Monitoring and Assessment of the Ecological Status of Lakes A pilot procedure developed and tested in the Life Vuoksi Project". 2004.
- CEH, UK Environment Agency and Scottish Environment Protection Agency. "Risk Assessment Methodology for Determining Nutrient Impacts in Surface Freshwater Bodies". Science Report SC020029/SR. NUPHAR Project.

The definitions and criteria employed in these reports have been used as endpoints for the development of a new risk assessment scheme.

During the first phase of this project three types of studies where initially considered: field, mesocosms and laboratory studies. However, the relationship between P inputs and algal growth rate showed a much higher variability than expected even under controlled experimental conditions; and a similar situation was observed for related parameters. The variability and number of variables involved in these relationships was so large that the capacity of mesocosms and laboratory studies for predicting effects under real situations was, in our opinion, seriously impaired. Therefore, the project focused on field studies to integer the natural variability using the most realistic situations. The analysis and interpretation of the reviewed information and the application of risk assessment concepts has allowed the development of a specific proposal for assessing the eutrophication risk associated to nutrients and in particular to P emissions.

Considering the overall aims of this project, the protocol should be considered in the line of a higher tier generic and targeted risk assessment protocol. It is generic in the sense that it represents a broad assessment for a particular chemical covering relevant conditions for

Europe, and it is targeted as it covers exclusively the emissions associated to a particular use and environmental compartment.

The work is presented following the typical chapters of environmental risk assessment protocols: emission scenario and exposure assessment; effect assessment, risk characterization and risk communication.

The exposure part includes the development of the emission scenario and the proposed model for quantitative exposure estimations; including the model validation and the results obtained for a selected group of generic scenarios.

The effect assessment covers a new conceptual alternative for assessing the effects of nutrients based on field studies.

The risk characterization chapter includes alternatives for presenting the assessment results and for estimating and presenting the results of comparative assessments. As phosphates in detergents are just one of the multiple sources of P, the risk communication chapter includes options for a comparative risk assessment.

The mathematical implementation and application of this model to several generic and specific European scenarios are presented in Section 2.

EXPOSURE ASSESSMENT

The development of models for assessing the input of nutrients at the river basin level has a long history and, therefore, the first step within this project was to review the available information. The level of scientific development in this area is very high and excellent proposals and reviews have been published. Thus, the main objective for the exposure assessment was to identify and implement the type of model required for a generic a Pan European assessment model. In recent years, the implementation of Geographic Information Systems (GISs) has allowed a clear sift in nutrient load models to GIS-based approach. The advantages of a GIS model for a site-specific assessment are obvious, while the levels of detail and information requirements are excessive for the type of generic assessment model required for this study.

The model should be able for producing estimations on the TP level resulting from the combination of all P sources, but also, to identify the specific contributions from the use of phosphates in detergents. In addition, the model should be able to produce a realistic estimation of current conditions, incorporating the outcome of the risk management options already implemented, and to give opportunities for assessing the expected consequences from further improvement in P emission control.

Considering the available information and the needs described above, an emission assessment scenario was developed and implemented for allowing the estimation of TP concentrations.

EMISSION SCENARIO

A river basin scenario is considered the best approach for a quantitative risk assessment. P loads from diffuse and point sources should be considered. The final objective of this model is the identification of the additional contribution of STPP at a Pan European level. STPP is considered an additional source of P; other sources, covering both point and diffuse loads, must be considered; therefore, a simplified approach based on generic river basin information, must be developed for quantifying the overall P contribution and the specific input from the hydrolysis of STPP.

The emission scenario has been developed as a generic river basin scenario; where TP concentrations at a river point are estimated based on a balance between river hydrology and upstream P loads including:

- Diffuse sources: P loads estimated from the land use distribution, mostly covering natural loads and agricultural contributions.
- Point sources: P loads from discharges of WWTP (Waste Water Treatment Plants) effluents.

The generic scenario was developed through a tiered approach, starting with a simplistic approach offering deterministic estimations, which can be refined for presenting probabilistic outputs. The approach also allows to conduct a sensitivity analysis for assessing the role and relevance of the different parameters included in the model.

The model estimates the TP concentration at any point of the river based on the river flow at that point and the contribution from point sources and diffuse emissions. Several values for the same river basin can be estimated provided that the information is available (Figure 1).

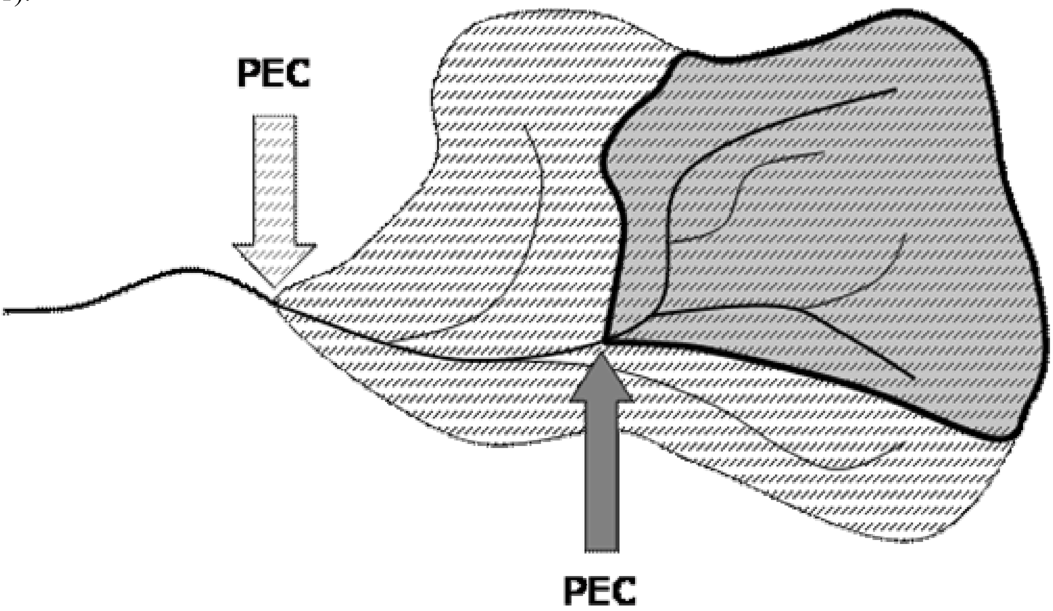


Figure 1: The exposure assessment scenario. The annual average Predicted Environmental Concentration (PEC) for selected points in the river basin is estimated on the basis of direct and indirect nutrient loads in the upstream catchment and the river flow.

DIFFUSE SOURCES CONTRIBUTIONS

The contribution of P and other nutrients from diffuses sources is usually estimated through the export coefficients approach. Site-specific models may include over twenty coefficients considering very specific land use patters, livestock production conditions, fertilizers and manure management, etc. and may require the modulation of some coefficients as a function of land topography. As already mentioned, this level of detail is excessive for the objective of this project; thus, a simplistic emission assessment from diffuse sources was done by using several P-export coefficients related to main land uses emissions.

Generic export coefficients for four general land use categories: arable land, forest, pastures and "other" land uses were obtained from a literature review. Table 1 presents the export coefficients selected after the update of the literature review conducted by Lasevils and Berrux (2000).

Table 1. Export coefficients selected for the simplified model and reported range in the literature.

Land use	Units	Coefficient	Range	References
Arable Land	$kg\ ha^{-1}\ year^{-1}$	0.66	0.02 - 123	Lasevils and Berrux, 2000. Hilton et al., 2002 Hanrahan et al., 2001 De Wit and Bendoricchio, 2001
Pasture	$kg\ ha^{-1}\ year^{-1}$	0.4	0.002 – 5.8	
Forest	$kg\ ha^{-1}\ year^{-1}$	0.02	0.01 – 0.51	
Other	$kg\ ha^{-1}\ year^{-1}$	0.2	0.02 - 3	

The reported ranges for the export coefficients are highly variable, mostly due to the inclusion of very extreme values far away from the average. Due to the differences in the reporting format, it was not possible to produce a fully-harmonized set of coefficients. Thus, expert judgment in addition to statistical analyses where employed for the selection of the most likely value. The values selected for arable land, pasture and forests were those mostly used by other authors and basically correspond to the median value of the reported range. The hardest difficulty appeared for the “Other” category, as it covers very different situations; an averaged value was selected.

These values were presented at the expert workshop and the overall approach was considered as acceptable. It must be considered that these generic export coefficients represent averaged values for relatively large river basins, where the site-specific topographic and climatic conditions of the different subsectors within each use pattern area in the river basin are compensated. As a consequence, the use of these generic (average) export coefficients is only appropriate for relatively large river basins. The use of generic factors for relatively small river basins requires the inclusion of a “slope factor” to differentiate export coefficients accounting for differences due to erosive processes (see Vighi et al., 1991); or alternatively, the use of GIS based models with coefficients adapted to the land characteristics, the approach used in several recent models such as MONERIS (UBA, 2003). These approaches have not been required for the calculations conducted within this generic and pan-European study which focus on large river basins, but should be implemented if the approach is extended to regional assessments.

The literature review did not provide a sufficient database for performing a probabilistic implementation of the export coefficients based on a statistical evaluation of reported data. Certainly, the number of reported data was large in some cases and covered a large variability. Nevertheless, it was obvious from the review that the individual data do not corresponded to areas of equal relevance. Therefore, an statistical assessment would require a weighting procedure for each data, assigning to each number an specific weight related to the relevance of that particular conditions within Europe. This information was not available and, consequently, the probabilistic implementation of the export coefficients can only be done by expert judgement.

POINT SOURCES CONTRIBUTIONS

The main point sources contributions of P emissions are human metabolism and the use of phosphates in detergents. Emissions from human metabolism are obviously associated to the population. Using the literature review done by Lasevils and Berrux (2000) it was selected an average value of 1.5 gP per inhabitant and day. A slightly higher value of 1.62 gP per inhabitant and day has been use for the Danube River basin (Schreiber et al., 2003). The difference is less than 10%, and it should be considered that a value of 1.5 has been recently suggested for the same river basin when domestic and industrial emissions are combined and presented as population equivalents (Zessner and Lindtner, 2005).

Emissions from Detergents

P contributions from the use of phosphates in detergents are largely dependent on use patterns, marketing conditions and the adoption on specific conditions on the use of phosphates in detergents either through regulatory or voluntary agreements.

As indicated in the contract agreement CEEP (the European Detergent and Industrial Phosphates industry sector of CEFIC) was responsible for providing specific data on P emissions from the use of phosphates in detergents.

For reference and to avoid confusion with figures published elsewhere, it should be noted that by molecular weight, 1 kg of STPP contains 0.253 kg of phosphorus (P) and 1 kg equivalent phosphate (P_2O_5) contains 0.437 kg of P

Data was collected from two sources:

a) the EU detergent phosphate (STPP) manufacturing industry

CEEP has provided data for 2005 sales of STPP for use in household detergents within the European Union (25 states), collected from the 9 European Union producers of STPP*. For commercial and competition confidentiality reasons, the data was collected by the statistics department of CEFIC (European Chemical Industry Council, Brussels) and individual company figures and breakdowns by type of detergent application cannot be disclosed. These data can be summarised as follows:

Total year 2005 sales in EU-25 of STPP for domestic detergents, figures from the 9 EU producers of STPP*:	207 084 tonnes as P2O5
Estimation for imports:	10 000 tonnes as P2O5
Total =	217 084 tonnes as P2O5

Equivalent in P: 95,000 tP/year for EU-25

* Thermphos International BV, BK Giulini GmbH, Chemische Fabrik Budenheim KG, FMC Foret SA, Prayon SA, Rhodia HPCII, Alwernia, Fosfa Joint Stock Company Breclav-Postorna, Wizow

The European average consumption can be estimated from this figure, 95,000 tonnesP/year for EU-25, and a population of 462,300 inhabitants, obtained an average value of 0.56 gP/person/day.

However, these figures may include detergent phosphates sold to detergent manufacturers in the European Union, but which are then exported in finished detergent products, and so are not in fact used by consumers in Europe.

b) the European detergent industry

The International Association for Soaps, Detergents and Maintenance Products (AISE www.aise-net.org) provided data for the quantities of phosphates used in detergents sold in the European Union (25 states, tonnes phosphorus tP/year) for the year 2004, broken down by country-by-country detergent sales, as follows:

AISE data for 2004	tonnes P/year for country	per capita gP/person/day
Austria	800	0.27
Belgium	650	0.17
Czech Republic	2 650	0.71
Cyprus	0	0.00
Denmark	800	0.40
Estonia	300	0.62
Finland	700	0.36
France	8 000	0.36
Germany	5 000	0.17
Greece	1 750	0.42
Hungary	3 080	0.84
Ireland	650	0.44
Italy	1 500	0.07
Latvia	600	0.72
Lithuania	850	0.68
Luxembourg	0	0.00
Malta	0	0.00
Netherlands	1 200	0.20
Poland	9 150	0.66
Portugal	1 350	0.35
Slovak Republic	2 010	2.80
Slovenia	450	0.23
Spain	9 200	0.57
Sweden	1 300	0.39
United Kingdom	9 500	0.43
Total	61 490	0.36

The detergent industry, officially represented by AISE, is the only stakeholder with access to accurate information regarding the actual quantities of phosphate used in detergents (because of movements of finished products, as indicated above). Therefore, the AISE figures were used as the basis for the average European (EU-25) consumption, that is 0.36 gP/person/year.

Considering that about one half of the EU population is located in countries with legal or voluntary restrictions for the use of phosphate in detergents, the meaning of the European average is limited, and therefore, a worst case estimation, covering countries with no restrictions to the use of phosphate in detergents has been also used. For this, the highest national per capita consumption from the AISE figures was used. The outlier figure of 2.8 gP/person/year for the Slovak Republic was considered to be not representative; thus, the value reported for Hungary of 0.84 gP/person/year was used.

This worst case figure is 2.3x higher than the European average from the AISE figures, and significantly higher than AISE figures for countries such as Poland (0.66 gP/person/year) , Portugal (0.35 gP/person/year) or Spain (0.57 gP/person/year) where phosphates are still widely used in laundry detergents. It is also 1.5x higher than the European average derived from the STPP industry figures. Therefore it can be considered to be a realistic worst case.

Reductions in Emissions through Waste Water Management

A second step in these estimations is to consider the reductions associated to current management practices. First, not all of the population is connected to sewage collecting systems, and second, collected municipal sewages is expected to be treated in Sewage Treatment Plants (STPs) before being discharged into receiving water bodies, and this treatment will reduce P emissions. The reduction in P emissions obviously depends on the type of treatment. Jiang et al. (2004) published a summary of expected P removal for several types of sewage treatment plants. The removal of P at a conventional secondary treatment plant is of about 20-25%. The implementation of tertiary treatment with specific P removal may achieve reductions close to 90% and even over 99% for very specific treatments.

In the EU, Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment, amended by Commission Directive 98/15/EC of 27 February 1998, established requirements for treating urban waste waters. These requirements are associated to the characteristics of the receiving water bodies, which are classified as *sensitive* or *not sensitive* areas. The identification of a water body as a *sensitive area* is an essential prerequisite for the practical implementation of the Directive. The rules applied to areas identified as *sensitive* must be also applied to the catchments which contribute to the pollution of the *sensitive areas* (e.g. a river running into an estuary or coastal area which is designated as *sensitive*).

In accordance with Article 5 of the Directive, the Member States were required to identify *sensitive areas* at the latest by 31 December 1993 with reference to the identification criteria given in Annex II.. These criteria refer to three groups of *sensitive areas*:

- freshwater bodies, estuaries and coastal waters which are eutrophic or which may become eutrophic if protective action is not taken;
- surface freshwaters intended for the abstraction of drinking water which contain or are likely to contain more than 50 mg/l of nitrates;
- areas where further treatment is necessary to comply with other Council Directives, such as the Directives on fish waters, on bathing waters, on shellfish waters, on the conservation of wild birds and natural habitats, etc.

If a water body falls into one of these three groups, this is sufficient for it to be designated as *sensitive*.

The Directive establishes a time-table, which Member States must adhere to, for the provision of collecting and treatment systems for urban waste water in agglomerations which meet the criteria laid down in the Directive. The main deadlines are as follows:

- 31 December 1998: all agglomerations of more than 10 000 "population equivalent" (p.e.) which discharge water into *sensitive areas* must have a proper collection and treatment system;
- 31 December 2000: all agglomerations of more than 15 000 p.e. must have a collection and treatment system which enables them to satisfy the requirements in Table 1 of Annex I;
- 31 December 2005: all agglomerations of between 2 000 and 10 000 p.e. which discharge water into sensitive areas, and all agglomerations of between 2 000 and 15 000 p.e. which do not discharge into such areas must have a collection and treatment system.

As shown by the EU Commission implementation report dated 2004 (EC, 2004), which is based mainly on December 2001 figures, many of the EU-15 Member States are well behind the Directive implementation deadlines and are still a long way from putting into place the required sewage collection, treatment and nutrient removal. The 10 new Member States each have specific deadlines for catching up implementation of the different requirements of this Directive, generally by around 2010 – 2015.

Based on the data in the EU 2004 report on levels of sewage treatment in place (completed with expert estimates for France, Spain, and the 10 new EU states for which this report does not provide data), and on literature information concerning phosphate removal in sewage works indicated above, CEEP has conducted an expert estimation of the overall figures for P removal (as TP) from sewage for each European country. These can be considered "pessimistic" estimates because levels of sewage treatment are known to have significantly improved since the 2001 figures used in this report. This compilation is presented in Table 4.

Emissions from Point Sources

The TP emissions from point sources can be calculated as follow:

Point emissions = (Human metabolism + Detergents)x(1- % Removal at STP)/100

Table 4. Level of compliance of Directive 91/271/EEC (EC, 2004) and CEEP expert estimates* of P removal in sewage treatment.

Country	Population 2006	Sewage concerned by "normal" areas (population equivalents)	Sewage concerned by "sensitive" areas (population equivalents)	*Calculated: sewage NOT from treated agglomerations* (population equivalents)	Conformity in "normal" areas	Conformity in "sensitive" areas *	*Calculated P removal - 2001 (EU figures)*	*Calculated P-removal after Directive implementation*
Austria	8,188,806	15,189,287	1,851,885	*0*	100%	79%	**37%**	**38%**
Belgium	10,481,831		8,952,516	*5,110,321*		22%	**26%**	**41%**
Denmark	5,425,373		6,698,384	*1,406,343*		99%	**64%**	**57%**
Finland	5,260,970		6,377,300	*1,434,590*		10%	**31%**	**56%**
France	61,004,840	42,548,060	16,728,379	*25,438,977*	68%	**40%**	**18%**	**25%**
Germany	82,515,988	8,264,830	124,876,488	*2,631,197*	100%	90%	**65%**	**70%**
Greece	11,275,420	8,317,800	609,400	*5,919,100*	49%	10%	**10%**	**17%**
Ireland	4,065,631	3,901,479	3,362,856	*0*	18%	42%	**29%**	**52%**
Italy	59,115,261	55,142,105	3,024,094	*24,215,542*	52%	43%	**11%**	**19%**
Luxembourg	459,393		804,500	*0*		74%	**76%**	**79%**
Netherlands	16,386,216		15,906,991	*6,842,021*		79%	**46%**	**46%**
Portugal	10,501,051	8,455,900	1,372,700	*4,603,891*	37%	4%	**10%**	**21%**
Spain	44,351,186	53,862,365	5,740,260	*8,589,611*	62%	**40%**	**16%**	**25%**
Sweden	9,076,757		7,672,670	*4,473,155*		64%	**37%**	**41%**
UK	60,139,274	65,980,345	6,221,177	*16,818,361*	89%	27%	**19%**	**23%**

*CEEP estimated figures and calculations are presented in bold.

RIVER BASIN HYDROLOGY

For this simplistic generic scenario, the required information on river hydrology is the Annual Average River Flow (RF) at the final part of the catchment area. This RF depends on the characteristics of the catchment area, particularly size, climatic conditions, topography and water management.

The European Rivers Network (ERN) website (ERN, 2006) offered some data to construct a database of rivers, which was completed and confirmed with information from published reports of some European river basin authorities.

A positive correlation between catchment area and river flow is generally expected, as presented in Figure 2. This figure also shows significant variations that can be observed for some rivers. These differences can be related to topography and climatic conditions. For example, the Po and the Rhône rivers have three-times higher RF than estimated from the equation (see below) due to the Alps contributions; while Guadiana and Guadalquivir Rivers have about half or even less RF than expected due to the higher evapotranspiration observed in the Mediterranean ecological region.

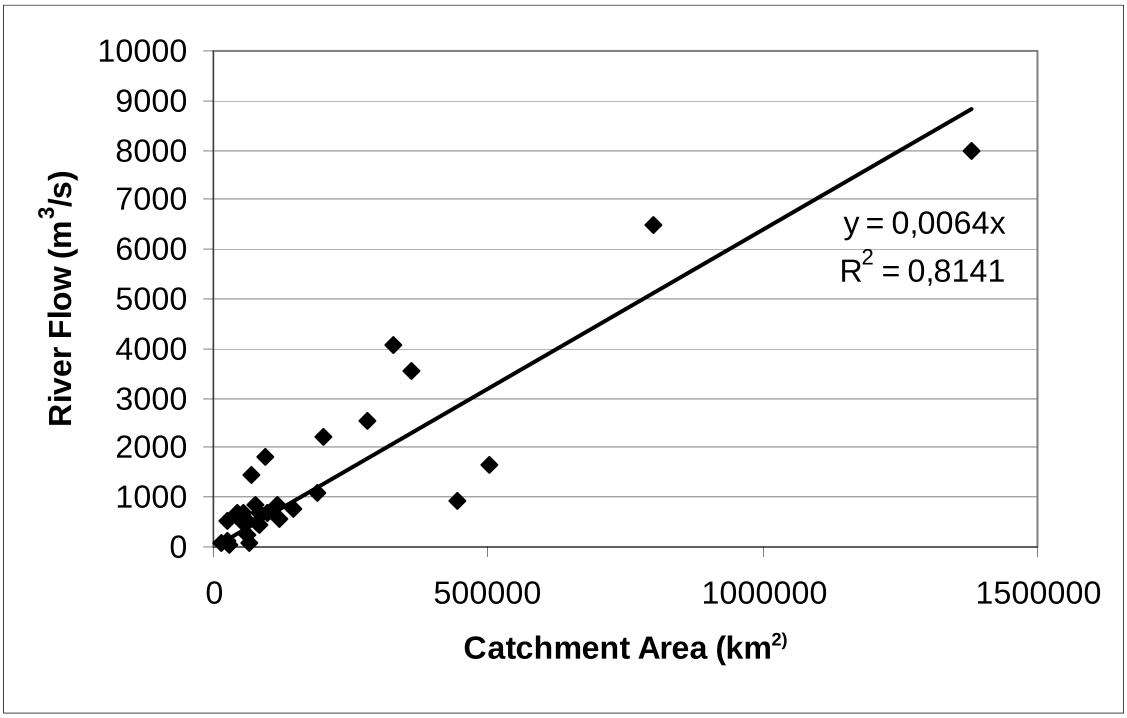


Figure 2. Relationship between Catchment Area and Annual Average River Flow at the mouth of several European rivers.

The Experts attending the Workshop suggested the development of a set of generic scenarios covering a range of conditions expected for European ecosystems. The equation presented in Figure 2 was used for setting the relationship between catchment area and river flow:

$$\text{River Flow } (m^3/s) = 0.0064 \text{ Catchment Area } (km^2)$$

The data included in Figure 2 cover 32 European rivers with catchment areas larger than 12000 km^2. The whole data set will be used in the probabilistic refinement. The statistical analysis of these data indicated that the data distribution does not offer a proper fitting to any of the most common probability distributions. Thus a customized distribution was created using Crystal Ball.

This customized distribution is shown in Figure 3, and it will be employed in the probabilistic implementation. Data are presented as deviations per unit of the actual RF from that predicted by the regression slope. The range covers from 0.16 to 3.24 indicating that the actual RF can be between about one sixth and three times (16% and 324%) the predicted RF. The 10th and 90th percentiles of this distribution are 0.52 and 2.55 respectively. Therefore, the data indicate that, roughly, most cases would be within a factor of 2 of the predicted value. As the TP concentration has an inverse linear correlation with the RF, the variability observed for these estimations can be considered as the expected variability in the prediction of TP concentrations.

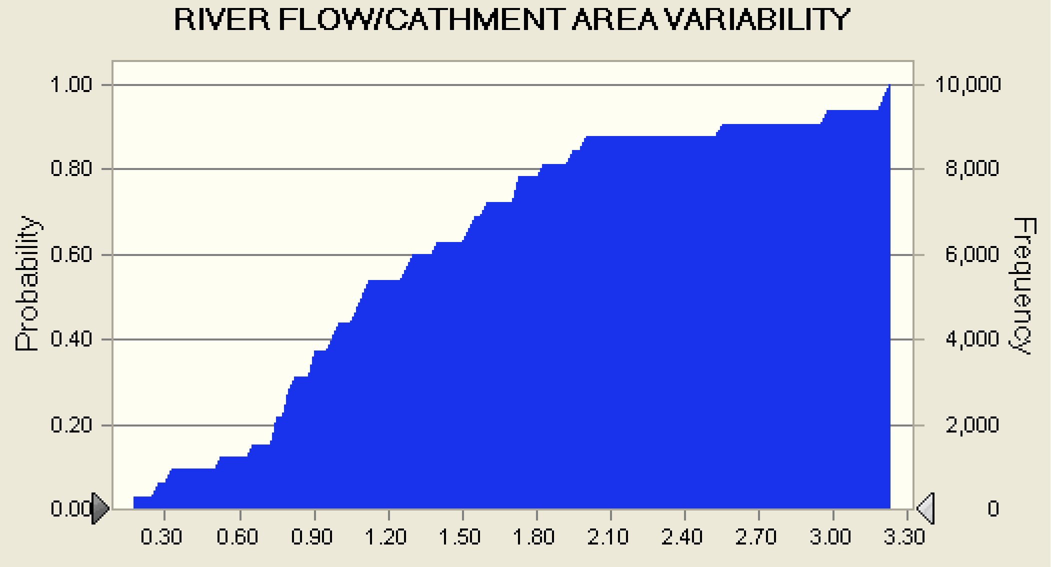


Figure 3: Distribution of the variability in the River Flow/Catchment Area relationship observed for 32 large European rivers. Data are presented as deviations (per unit) from the regression slope shown in Figure 2.

MODEL IMPLEMENTATION

The mathematical implementation of the model was conducted with Excel data sheets. The probabilistic implementation for covering the variability and uncertainty was conducted by using Monte Carlo analysis based on Crystal Ball software.

The relevant model parameters related to the Exposure estimations where included in an input interface. These parameters are summarised in Table 5.

Table 5. Parameters employed for the Exposure estimation.

MODEL PARAMETER	UNITS
Population Density	person/ha
Catchment Area	ha
River Flow	m^3/s
Land use: Arable Land area	%
Land use: Pasture area	%
Land use: Forest area	%
Land use: Other uses area	%
Arable Land coefficient	kg/ha/year
Pasture coefficient	kg/ha/year
Forest coefficient	kg/ha/year
Other land uses coefficient	kg/ha/year
P emission from Population	g/person/day
P emission from Domestic Detergents	g/person/day
Current P reduction at STP	% (relative to P inflow entering STP)

The final estimation of the exposure level was determined using simplistic mass balance equations. The exposure is determined through the TP concentration determined as:

$$\boxed{TP = (DLa+PLa-STPRa)/WRa}$$

Where:
TP = TP concentration at the point of estimation;
DLa = upstream TP loads from diffuse sources;
PLa = upstream TP loads from population including P-based detergent consumption;
STPRa = TP percentage retained/recovered at the STP, which if relevant should also incorporate any additional reductions in P emissions from population, such as e.g. people not connected to sewage collection systems;
WRa = annual cumulative amount of water at the point of estimation.

For allowing the identification of independent contributions, PLa is determined as the sum of the individual major P contributions: from human metabolism and domestic detergents. It should be noted that minor contributions are not included and, therefore, if relevant for some scenarios, must be transformed into population equivalents and included as a component of the population emissions.

Water management should also be considered in certain cases. If the amount of water employed for irrigation and/or transferred to other river basins is significant, an expert judgement is required for considering whether the WRa should be calculated from the measured RF or from the annual amount of available surface water resources obtained through a water mass balance of precipitation, evapotranspiration and groundwater recharge in the catchment area.

The model estimates the TP concentration at the selected point of estimation. However, TP annual variability may be very large, as point emissions are not related to rainfall events. Therefore, any comparison between monitored and predicted values requires the use of monitoring designs able to estimate an accurate annual average concentration. The use of generic coefficients assumes the homogeneous distribution of pollution sources along the catchment area. P sedimentation and uptake by algae/plants within the river basin is not considered in the model. These processes are particularly significant in lentic waters, e.g. lakes and reservoirs. Therefore, the model predicts the concentration in the lotic waters, i.e. waters (streams and watercourses) entering a lake or reservoir; while the in-lake concentration is expected to be lower than the estimation due to the buffer capacity of these lentic systems (dilution, P sedimentation, algae/plants P consumption, etc.). All these issues should be considered when using the model output.

Data from the Pilot River Basin Network (PRBN) were used in the report of the Phase I for an initial screening assessment of the model capability. However, the large variability reported for the TP concentration in several catchments and the lack of information on the model parameters does not allow a further use of these data for conducting a validation process.

Thus additional validation possibilities were explored. The information produced by the ICPDR (International Commission for the Protection of the Danube River) was considered suitable for a screening analysis. The UBA report produced (Schreiber et al. 2002) for the Danube River Basin (DRB), presents estimations of the point and diffuse P sources for the different sub-catchments. The data were generated using the MONERIS model, a GIS-based model developed by UBA (Behrendt, et al., 2000) to estimate nutrient emissions into river basins of Germany. The same report includes basic characteristics on population, surface and land use, and basic hydrological characteristics of the sub-catchments of DRB. In addition, the TNMN Yearbook for 2001 and 2002 (ICPDR, 2001; 2002) offer monitoring data on TP concentration in several monitoring stations of the DRB and its main tributaries.

The capability of the model for estimating the contribution from diffuse sources was checked out through the comparison of model estimations -based on land use distribution- (relative proportion of diffuse sources, which also gives the proportion of point sources) and the point sources contributions, estimated from the MONERIS model. And point sources contribution was also checked out through the comparison of TP estimated by our model *versus* monitoring data (year 2001 and 2002) reported in the TNMN reports. This information is presented in Figure 4.

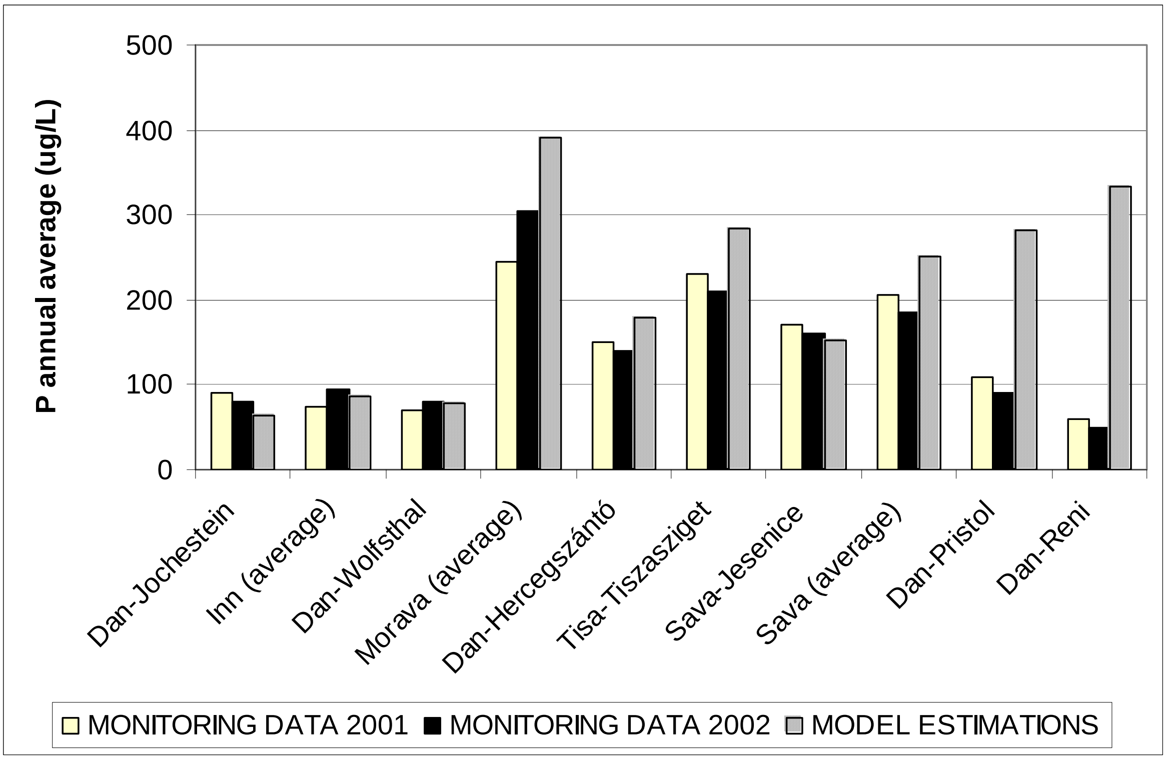


Figure 4. Comparison of monitoring 2001 and 2002 TP concentrations, for the Danube River and some tributaries, with model estimations.

The relationship between both datasets is shown in Figure 5.

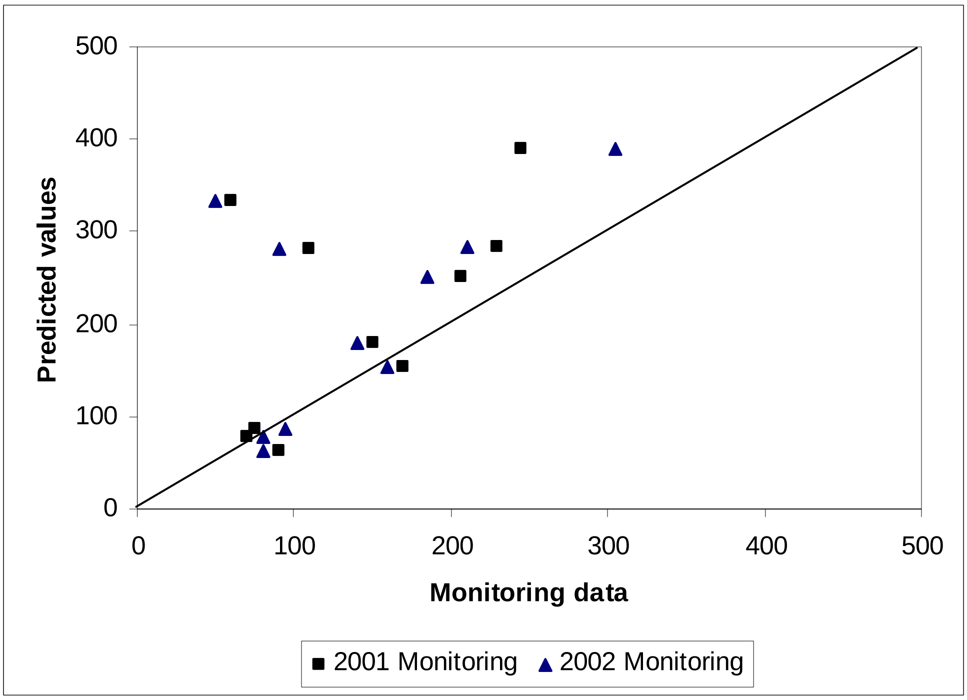


Figure 5. Relationship between monitoring 2001 and 2002 TP concentrations (µgP/l) for the Danube River and some tributaries with model predictions.

The comparison suggests that model estimations are generally in good agreement with monitoring data. The largest differences appear for the estimation conducted for the final part of the Danube River (i.e. Pristol and Reni monitoring stations). In these stations the decrease in the TP concentration observed in the monitoring outcomes is not predicted by the model. The TNMN reported data indicated that the tributaries in that final area of the Danube River have higher concentrations than the Danube itself. In addition, the data included in the UBA report allowed an estimation of the evolution of population density and included the percentage of arable land upstream the Danube River monitoring stations. This information is summarised in Figure 6 and does not explain the drastic reduction in the TP concentrations observed in the final part of the river. Therefore, a possible explanation is the reduction of P emissions due to sedimentation processes and the P uptake by biota. These processes are expected to be particularly relevant in the final part of the Danube River but they are not considered in the generic model developed in this study; this fact would explain the differences observed between model predictions and monitoring data for these two stations.

In general, the results obtained in this comparison indicate that the selected generic export coefficients for diffuse sources and the simplified hydrology assessment of the model offer acceptable predictions of the diffuse source contributions to the total load and its transformation in annual average concentrations.

Additional assessments have been done on the contribution of diffuse *versus* point sources. The model predicts, for the whole Danube River catchment area, that point sources represent a 45% of the overall P load. This value is very close to the 42%, estimated by Schreiber et al. (2002).

The results confirm the initial expectations indicating that the model offers “worst case” estimations, suitable for generic assessments of relatively large catchment areas (the estimations have been done for catchment areas above 25000 km^2). And, as a key element for the study target, the model addresses satisfactorily the relative contribution of different sources. Obviously, the capability of a generic model, like the one developed in this study, is not comparable with that of a GIS-based model. However, the information required for running a generic model is also much more limited, and thus easily achievable, for a pan-European assessment.

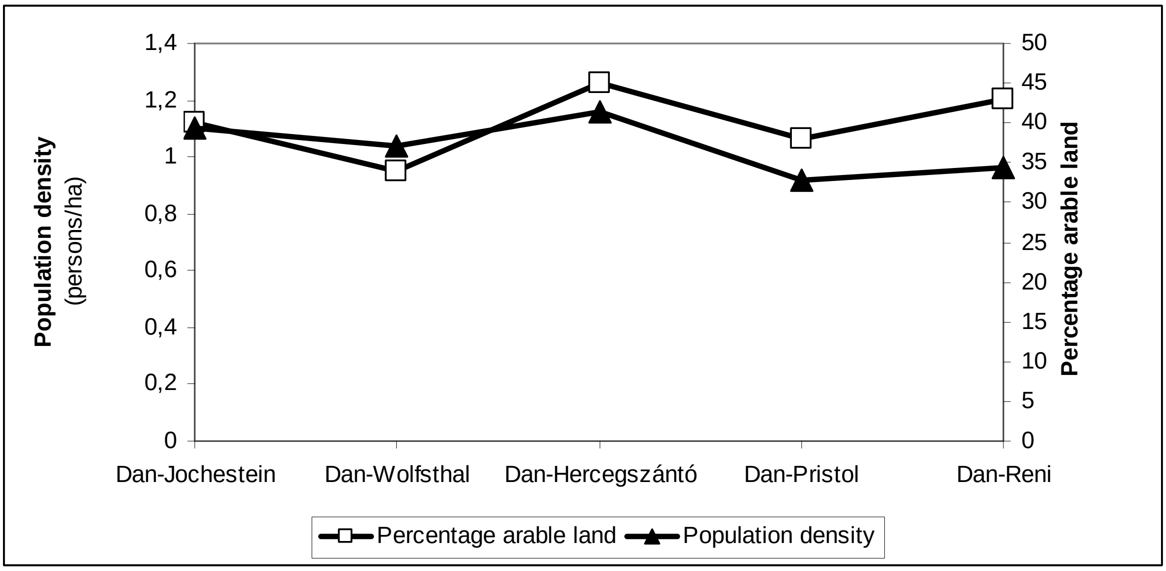


Figure 6. Estimated population density and percentage of arable land upstream the five Danube River sampling stations (data from UBA 2003).

SUMMARY

By using the available data, a generic simplistic model has been implemented for estimating the TP concentration in a selected river basin point and the relative contributions from diffuse sources, human metabolism, and detergents. The model is based on generic export coefficients based on four main land uses types to cover the P load from diffuse sources; and default emission values per habitant plus the expected reduction at the STP for covering the P loads from point sources. The data availability includes specific national values for detergent contributions and STP reduction for several European countries.

A screening assessment, based on Danube data was conducted using specific information on catchment area, water flow, land use patterns, and point sources loads for different sub catchments. The results indicate the capability of the model predictions for relatively large catchment areas, where the generic export coefficients can be applied as other factors, such as slope and site hydrology, are compensated within the area.

The options for refinement have been described elsewhere. Hilton et al. (2002) proposed the use of up to 25 land cover classes plus the additional contribution from livestock. Detailed river basin models have been developed and calibrated for major European rivers such as the Rhine, Elbe and Po (De Wit and Bendoricchio, 2001; De Wit et al., 2002).

Schreiber et al. (2003) have produced detailed estimations for the Danube river basin; and additional estimations using MONERIS model have been done by UBA.

Our results indicate that the simplified model offers acceptable estimations. More sophisticated models are obviously required for site specific assessment. In the sensitivity analysis conducted by Hanrahan et al (2001) for the Frome catchment human contribution and arable land emissions were the most important factors controlling P loading. Vighi et al. (1991) observed significant differences related to land slope.

The generic estimations produced by the model are based on a simplistic approach and does not cover local specific aspects, such as historic loads or the retention of P in the catchment area and the upstream river basin. However, the approach is considered suitable for a generic pan-European assessment. Thus, the developed model is considered sufficient for the generic estimations required for this study.

EFFECT ASSESSMENT

Phosphorus is an essential element which can be found in several biological macromolecules. The environmental hazards associated to the emission of P to the aquatic environment are related to its role as algae and plant nutrient. When P is the limiting factor and the environmental conditions favour the process, the algal growth rate increase associated to the P emissions may provoke an excessive development of algal populations (or some opportunist species within the algal community) leading to structural and functional changes in the ecosystem and, in some cases, extraordinary algal blooms resulting in fish kills, invertebrates impairment and macrophytes mortality due to anoxic conditions derived from that. The phenomenon is known as Eutrophication and P is just one of the factors involved in the process. Eutrophication compromises the beneficial uses of waters and can generally be perceived as an undesirable degradation of the environment; causing, in many cases, significant economic losses.

The effect to be quantified in this assessment is man-made accelerated eutrophication of inland freshwaters resulting in a deterioration of water quality, which interferes with the biological communities. Therefore, the hazard identification should not be based on the increase in algal growth rate, but on the potential of this increase to result in undesirable disturbances (Figure 7).

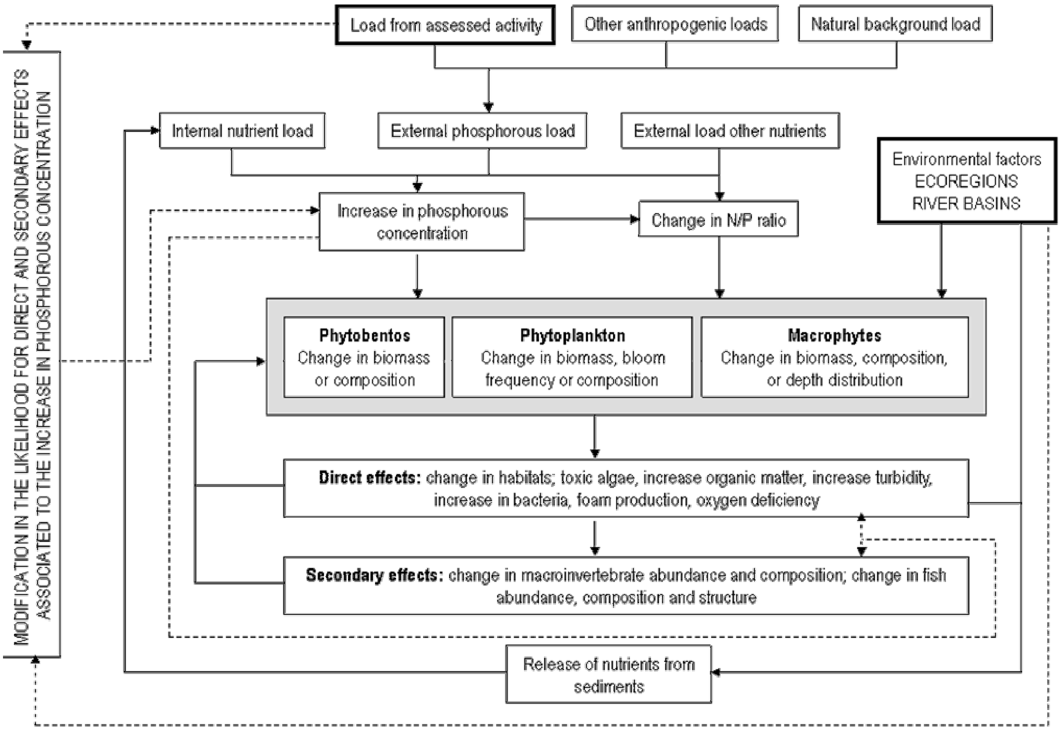


Figure 7: Conceptual framework for assessing the eutrophication risk associated to specific activities provoking nutrient emissions. Adapted and modified from the general ECOSTAT framework (ECOSTAT, 2004) developed under the Eutrophication Activity for the implementation of WFD.

EFFECTS CRITERIA

For the definition of undesirable effects, the recommendations adopted for the implementation of eutrophication effects in the Water Framework Directive have been used. Ecosystem responses resulting in deviations from the "Good Status definition" are assumed to be adverse effects, and modifications in the ecosystem balance not resulting in deviations from the "Good Status definition" are considered acceptable in terms of negative ecosystem consequences.

Two definitions for *Significant Undesirable Disturbances* have been used for defining negative ecosystem consequences. The first definition covers significant increases in algal growth and biomass production; the second covers changes in taxonomic diversity not necessarily associated to significant increase in overall primary production.

Both definitions follow the proposal from the ECOSTAT Eutrophication group. The draft proposals developed by the ECOSTAT group in 2004 where initially considered (ECOSTAT, 2004). Afterwards, in March 2005, the group revised the proposals and, therefore, we revised the evaluation in line with the new definitions. For transparency, both definitions will be presented here.

For adverse effects associated to the increase in primary production the following definition is proposed:

"*A significant undesirable disturbance is a direct or indirect anthropogenic impact on an aquatic ecosystem that appreciably degrades the health or threatens the sustainable human use of that ecosystem".*

Table 5 provides a general list of "significant undesirable disturbances" that may result from the accelerated growth of algae or higher forms of plant life".

Table 5-A: ECOSTAT 2004 proposal for significant undesirable disturbances that may result from accelerated growth of phytoplankton, macroalgae, phytobenthos, macrophytes or angiosperms

(a)	Causes the condition of other elements of aquatic flora in the ecosystem to be moderate or worse (e.g. as a result of decreased light availability due to increased turbidity & shading)
(b)	Causes the condition of benthic invertebrate fauna to be moderate or worse (e.g. as a result of increased sedimentation of organic matter)
(c)	Causes the condition of fish fauna to be moderate or worse (e.g. as a result of oxygen deficiency; release of hydrogen sulphide; changes in habitat availability)
(d)	Compromises the achievement of the objectives of a Protected Area for economically significant species (e.g. as a result of accumulation of toxins in shellfish)
(e)	Compromises the achievement of objectives for a Natura Protected Area
(f)	Compromises the achievement of objectives for a Drinking Water Protected Area (e.g. as a result of disturbances to the quality of water)
(g)	Compromises the achievement of objectives for other protected areas, e.g. bathing water, sensitive areas or polluted waters.
(h)	Causes a change that is harmful to human health (e.g. shellfish poisoning; wind borne toxins from algal blooms)
(i)	Causes a significant impairment of, or interference with, amenities and other legitimate uses of the environment (e.g. impairment of fisheries)

Table 5-B: ECOSTAT 2005 revision for significant undesirable disturbances that may result from accelerated growth of phytoplankton, macroalgae, phytobenthos, macrophytes or angiosperms

(a)	Causes the condition of other elements of aquatic flora in the ecosystem to be moderate or worse (e.g. as a result of decreased light availability due to increased turbidity & shading)
(b)	Causes the condition of benthic invertebrate fauna to be moderate or worse (e.g. as a result of increased sedimentation of organic matter)
(c)	Causes the condition of fish fauna to be moderate or worse (e.g. as a result of oxygen deficiency; release of hydrogen sulphide; changes in habitat availability)
(d)	Compromises the achievement of the objectives of a Protected Area for economically significant species (e.g. as a result of accumulation of toxins in shellfish)
(e)	Compromises the achievement of objectives for a Natura Protected Area
(f)	Compromises the achievement of objectives for a Drinking Water Protected Area (e.g. as a result of disturbances to the quality of water)
(g)	Compromises the achievement of objectives for other protected areas, e.g. bathing water, sensitive areas or polluted waters.
(h)	Causes a change that is harmful to human health (e.g. shellfish poisoning; wind borne toxins from algal blooms)
(i)	Causes a significant impairment of, or interference with, amenities and other legitimate uses of the environment (e.g. impairment of fisheries)
(j)	Causes significant damage to material property

For structural changes in the primary producers communities not necessarily resulting in overall increase of production rate, definition is proposed:

The condition of phytoplankton, phytobenthos, macrophytes, macroalgae or angiosperms would not be consistent with good ecological status where, as a result of anthropogenic nutrient enrichment, changes in the balance of taxa had occurred that are likely to adversely affect the functioning of the ecosystem"

Table 6-A describes the original proposal form 2004; while the new approach, developed in 2005, and, distinguishing between moderate and poor-bad status, is presented in Table 6-B.

Table 6-A: ECOSTAT 2004, draft guidance document, examples of ecologically significant undesirable changes to the balance of taxa

(a)	An entire functional group of taxa, or a keystone taxon, normally present at reference conditions is absent;
(b)	A nutrient-tolerant functional group of taxa not present under reference conditions is no longer rare
(c)	A substantial change in the balance of functional groups of taxa has occurred;
(d)	A group of taxa, or a taxon, of significant conservation importance normally present at reference conditions is missing.

Table 6-B: ECOSTAT 2005, draft guidance document, for other significant undesirable disturbances

Moderate conditions	**Poor or bad conditions**
The composition of taxa differs moderately from type-specific reference conditions such that:	
• nutrient-tolerant species or a functional group of taxa that are absent or rare at reference conditions is no longer rare	• communities are dominated by nutrient-tolerant functional groups normally absent or rare under reference conditions
• moderate number of species or taxa are absent or rare compared to reference conditions such that species or a functional group of taxa is in significant decline; or • The condition of species or functional group of taxa is exhibiting clear signs of stress such that there is a significant risk of localised extinctions at the limits of its normal distributional range	• one or more functional groups of taxa or keystone species normally present at reference conditions has become rare or absent • the distribution of species or a functional group of plant taxa is so restricted compared to reference conditions that a significant loss of function has occurred (e.g. invertebrates or fish are in significant decline because of the loss of habitats normally provided by functional groups of macrophyte; macroalgal or angiosperm taxa)
• a group of taxa or a species normally present at reference conditions is in significant decline	• a group of taxa or a species normally present at reference conditions has become rare or absent

EFFECTS CLASSIFICATION

The dose(concentration)/response assessment is even more complex as the response would depend on the conditions of the water body receiving the discharge. The review of available information confirmed the difficulty for establishing dose/response relationships even for controlled experimental conditions in mesocosms or semifield studies. Therefore, an innovative alternative is proposed, based on a probabilistic interpretation of field observations.

Using the definitions of negative ecosystem effects presented above (deviations from the "Good Status conditions" as described for the Water Framework Directive) the status of several European water bodies at different years have been analysed and described in two alternative ways:

- **Qualitative approach**: The information available for each water body is compared with the criteria established for good quality conditions. When the water body has remained in good ecological conditions through the whole year, the waterbody is classified as in "Good Status" (G+). When deviations from the good quality conditions have been observed (reported) during the whole or part of the assessed year, the water body is classified as in "Less than Good Status" (G-).

- **Semi-quantitative approach**: an integer value between -3 and +3 is given to each body and time period combination, according to the following classification criteria:
    - -3: high conditions
    - -2: very good conditions
    - -1: good conditions
    - 0: limit situation
    - +1: possibly negative effects
    - +2: clear negative effects
    - +3: dramatic consequences

  This semi-quantitative approach was used as and additional site assignment confirmation, and will be described below (see "Additional methods employed for the site allocation confirmation").

The classification is based on the observations and evidences of negative ecological consequences when reported, and also on the information on physical-chemical conditions (water transparency, hypolimnetic oxygenation conditions, excessive organic matter in sediments, P-release from sediments, etc.) and biological elements (Chlorophyll-a concentrations; phytoplankton, invertebrates and fish density and dominance, presence of algal blooms and species involved in the bloom, sifts in ecosystem structure and function, trophic status, presence of tolerant/pollution sensitive species, toxic species, etc.). Although the in-lake P concentration was noted in the database (TP annual average concentration), it was not considered for adopting the decision on classification levels. More information on exact parameters considered for the assessment will be presented in next section of Data analysis.

With all this information and the ongoing qualitative criteria defined by the WFD, it was possible to establish whether there were eutrophication related effects or not in a give waterbody, and to assign the level of severity of the effects.

The classification of a waterbody is based on a fix period time. As expected, annual variability was very high even for the same water body. Therefore, time series for the same system were analysed on a yearly basis. Figures or quality levels considered for the classification are annual averages of the different parameters or quality elements. At last, for a given waterbody, the level of eutrophication classified refers to one-year period time.

As mentioned before, each data point in the literature database was carefully reviewed, assigning a qualitative (G+ or G-) and a semi-quantitative (from -3 to +3) value to classify the eutrophication status.

In the quantitative approach, the classification of “G+” is assigned to situations fulfilling the criteria for Good status under the WFD as described by ECOSTAT (2004), this group covers Good and High status, as well as Reference conditions. Similarly the classification of “G-” is assigned to situations were the Good status is not achieved; this group covers the Moderate, Poor and Bad status.

For each data point in the database the level of TP associated to one situation (eutrophicated or not) is obtained from the reported value in the original paper. So, two datasets of TP concentrations for each group of water bodies (G+ and G-) were collected. Next step was to fit the two sets to probability distributions.

The natural trophic conditions of stagnant water bodies in Europe vary from Ultraoligotrophic to Hypereutrophic classes, and obviously this variability creates some difficulties when assessing anthropogenic deviations from the “good status” conditions. The Morphoedaphic index or MEI method (Vighi and Chiaudiani, 1985) was used for confirming the anthropogenic origin of the observed conditions. Whenever possible (about one half of the cases) the measured TP concentration was compared with the natural background TP estimated from the MEI. The comparison allowed the identification of potential divergences between the ecological assessment and the expected anthropogenic contribution. These potential divergences (less-than-good conditions with low anthropogenic contribution and good conditions with a high anthropogenic contribution) were revised case-by-case.

DATA ANALYSIS

Over 500 individual field cases were reviewed from literature. After a quality assessment, 303 individual cases were validated, assessed case by case, analysed with the MEI method, whenever possible (in-lake annual Conductivity figure is required), and included in the final effects assessment database.

Table 7 summarises the main characteristics of the field studies database. Nutrient concentrations were reported in all cases as annual averages as this is the parameter estimated by the model. Other characteristics, such as conductivity, temperature, dissolved oxygen or pH, were included as described in the original paper.

Table 7. Description of the selected field information used for the effect assessment. Validated set of 303 data items collected from European inland water bodies.

Characteristics	Descriptors	Units and endpoints
Geographical identification	European Ecological Region River Basin Waterbody Name	name name name
Morphological and physico-chemical description	Waterbody Type Area Mean Depth Depth Classification Conductivity Temperature Dissolved Oxygen Secchi disk pH TP & TN annual average conc.	name ha m Deep/Shallow µS/cm ºC mg/L m - µg/L
Ecological variables	Trophic Status Dominant Species Ecosystem structure	OECD (1982) Most relevant Number of species and structure (per taxa group)
Effect endpoints	Chlorophyll a Algal blooms Shifts in Species Composition, Abundance, Structure: Phytoplankton, Invertebrates, Other aquatic flora, Other fauna Sediment organic matter Change in water quality Oxygenation conditions at hypolimnion Other specific local effects	µg/L yes / no yes / no Relevant changes Relevant changes yes / no yes / no Oxygenated, hypoxia, anoxia yes / no
Eutrophication Assessment	Rationale Ecologically Relevant Effects (ERE) ERE - semi quantitative discrimination	Direct & indirect effects yes / no from -3 to +3
Data Validation	Trend in the semi-quantitative classification MorphoEdaphic Index (MEI based on conductivity) following Vighi, and Chiaudani, 1985.	

The effects database is presented in the Appendix (electronic form) to this final report, with all the details collected for the assessment. Annex I includes a table that aims to summarise the basic information (most relevant) required for the assessment. The table comprises the lake name and study year, the ecological region, TP concentration, a rationale, and the classification based on the semi-quantitative and qualitative scales.

ADDITIONAL METHODS EMPLOYED FOR THE SITE ALLOCATION CONFIRMATION

The semi-quantitative assessment was used as an additional method for confirming that each site had been properly allocated in the G+ or the G- category.
In the semi-quantitative classification, the groups G+ and G- were subdivided in three categories. Whenever possible, the classification has considered the proposals of the WFD. Therefore the intention was to maintain the following equivalences:

- -3 high conditions = REFERENCE CONDITIONS
- -2 very good conditions = HIGH STATUS
- -1 good conditions = GOOD STATUS
- 0 limit situation = LIMIT BETWEEN GOOD AND MODERATE STATUS
- +1 possibly negative effects = MODERATE STATUS
- +2 clear negative effects = POOR STATUS
- +3 dramatic consequences = BAD STATUS

The same guidance documents mentioned before included the next table entitled “Qualitative criteria for assessing ecological status in terms of eutrophication impacts” (Table 8). For the effects classification the qualitative criteria were adapted to the WFD recommendations for classification of Ecological status for eutrophication (Table 9).

Table 8. Qualitative criteria for assessing ecological status in terms of eutrophication impacts (ECOSTAT 2004).

Ecological Status	**WFD normative definition**	**Primary impacts (e.g. phytoplankton biomass)**	**Secondary impacts (e.g. O2 deficiency)**
High	Nearly undisturbed conditions	None	None
Good	Slight change in abundance, composition or biomass.	Slight	None
Moderate	Moderate change in composition or biomass.	Change in biomass, abundance & composition begins to be environmentally significant, i.e. pollution tolerant species more common.	Occasional impacts from increased biomass.
Poor	Major change in biological communities.	Pollution sensitive species no longer common. Persistent blooms of pollution tolerant species	Secondary impacts common & occasionally severe.
Bad	Severe change in biological comm.	Totally dominated by pollution tolerant species	Severe impacts common

Table 9. Adaptation of "Qualitative criteria for assessing ecological status in terms of eutrophication impacts" to the WFD recommendations for classification of Ecological status for eutrophication.

Ecological Status	**WFD normative definition**	**Primary impacts (e.g. phytoplankton biomass)**	**Secondary impacts (e.g. O2 deficiency)**	**Qualitative Classification**	**Quantitative Classification**
Reference	-	None	None	**G+**	**-3**
High	Nearly undisturbed conditions	None	None	**G+**	**-2**
Good	Slight change in abundance, composition or biomass.	Slight	None	**G+**	**-1**
Limit between Good and Less-than-good	Slight change in abundance, composition or biomass.	Slight	None	**G+/ G-**	**0**
Moderate	Moderate change in composition or biomass.	Change in biomass, abundance & composition begins to be environmentally significant, i.e. pollution tolerant species more common.	Occasional impacts from increased biomass.	**G-**	**+1**
Poor	Major change in biological communities.	Pollution sensitive species no longer common. Persistent blooms of pollution tolerant species	Secondary impacts common & occasionally severe.	**G-**	**+2**
Bad	Severe change in biological comm.	Totally dominated by pollution tolerant species	Severe impacts common	**G-**	**+3**

The figures of two relevant quantitative parameters, i.e. Chlorophyll-a and Secchi disk transparency, were plotted broken down by the semi-quantitative categories, as presented in Figures 8 and 9. The variability among parameters values within the same category covers several orders of magnitude; although a clear tendency, for a higher value for chlorophyll-a and TP, and a lower value for the Secchi disk is also observed. The points showing the larger deviation from the general tendency were reconfirmed one by one, and excluded from the definitive data set if the revision of available information did not allow a clear classification.

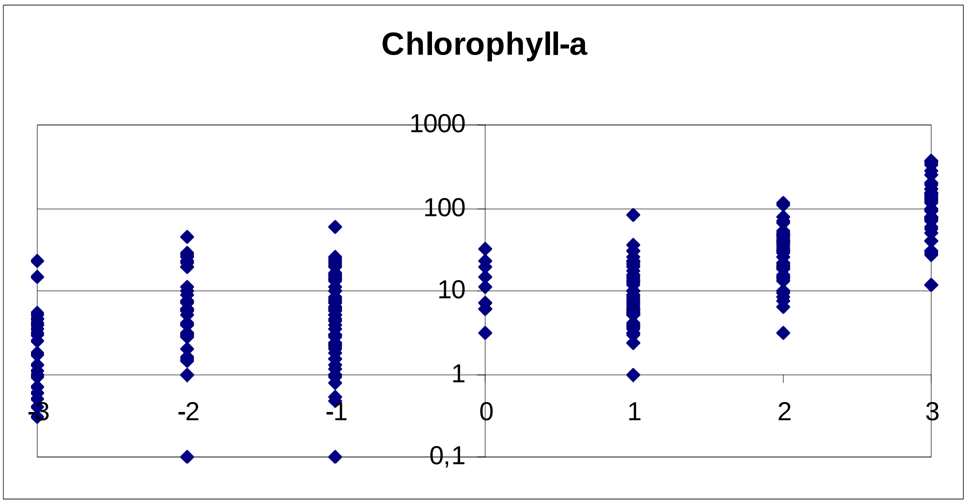


Figure 8. Distribution of Chlorophyll-a concentration (mg/m³) in the assessed water bodies broken down in the different status categories.

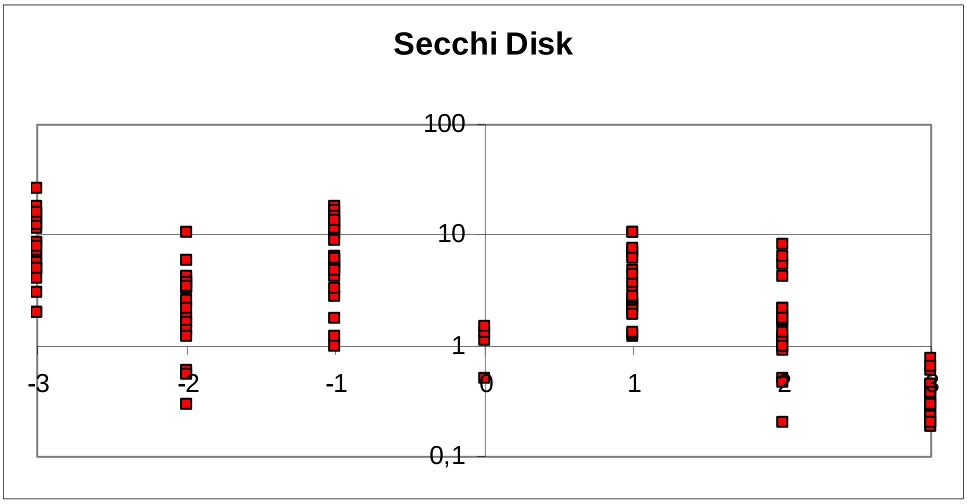


Figure 9. Distribution of turbidity expressed by the Secchi disk results (m) in the assessed water bodies broken down in the different status categories.

Although the TP concentration was not employed for the allocation of a site as G+ or G-, the plot of TP concentration *versus* the semi-quantitative classification offered an additional checking method in combination with the MorphoEdaphic Index (MEI based on conductivity) following Vighi, and Chiaudani, 1985.

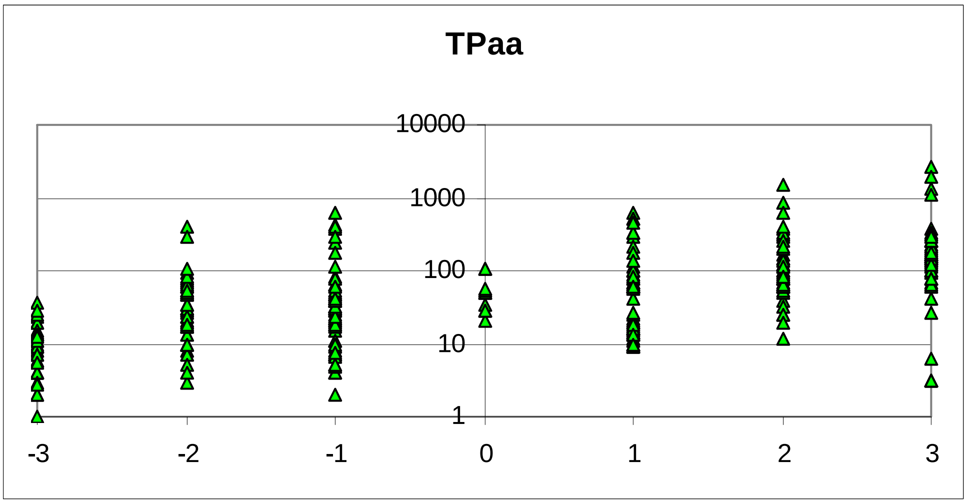


Figure 10. Distribution of TP annual average concentrations (µgP/l) in the assessed water bodies broken down in the different status categories.

Figure 10 presents an example of this plot. Whenever possible the MEI method was applied to the sites deviating from the general trend, which indicated a positive correlation between the semi-quantitative categories and the TP concentrations. The MEI method offers information on the expected natural (background) trophic status of a given lake. Good conditions with high TP concentrations are expected for lakes with a natural high trophic status, while non-good conditions at relatively low TP concentrations may be expected in naturally oligotrophic lakes.

Nevertheless other reasons, e.g. nitrogen-limited lakes, community adaptations, climatic conditions, etc., may also be responsible from deviations from the general rule. And therefore these additional methods were exclusively employed in the selection of sites/data where an additional confirmation of the initially proposed classification was required.

RESULTS: EFFECTS PROBABILITY DISTRIBUTIONS

The qualitative approach offers two sets of TP concentrations, one associated to assessed water bodies with good status (G+), and one associated to assessed water bodies with non good status (G-).
Each set of TP concentrations was fitted to a probability distribution using Crystal Ball software. The fitting result is a probability distribution of TP concentrations in areas with good (or better) status, and a probability distribution of TP concentrations in areas which do not achieved the criteria for good (or less than good) status conditions.

The obtained probability distributions may represent the conditional probabilities p(TP | G+) and p(TP | G-). In this case, p(TP | G+) represents the probability of a water body for having a certain TP concentration, given that the water body is in good status conditions, G+. Similarly, p(TP | G-) represents the probability of a water body for having a certain TP concentration, given that the water body is not in good status conditions, G-.

These conditional probabilities will be used in the risk characterization for quantifying the eutrophication risk associated to a given TP concentration.

DATA EVALUATION

The measured TP concentrations in the G+ sites and of G- sites were fitted to a set of distributions. Previous results suggested lognormal distributions as the most likely approach (presented in the former Six-months and First-year Reports). The results are presented in Tables 10 and 11.

Table 10. Fitting results for the conditional probabilities p(TP | G+)

Lognormal distribution with parameters:		
	Mean	44,54
	Standard Dev.	82,81
Selected range is from 0,00 to +Infinity		

Table 11. Fitting results for the conditional probabilities p(TP | G-)

Lognormal distribution with parameters:		
	Mean	179,03
	Standard Dev.	364,67
Selected range is from 0,00 to +Infinity		

The fitting to log-normal distributions was checked by using the Chi-square method. The fitting of G+ had a p-value=0.0008; and the fitting of G- sites had a p-value=0.26. Both fittings are below the suggested goodness-of-fit criteria for this specific method, which recommends a p-value higher than 0.5 for accepting that the data can be acceptably predicted from the distribution. Therefore, the uncertainty associated to the fitting procedure was evaluated.

UNCERTAINTY IN THE FITTING PROCEDURE

The uncertainty in the fitting procedure can be observed through the comparison of the distributions obtained using fitting and non-fitting procedures. The capability of Crystal Ball for creating non-fitting custom distributions based on the direct application of Monte Carlo random selection on raw data was used for these comparisons. A comparative assessment is presented in Figure 10.

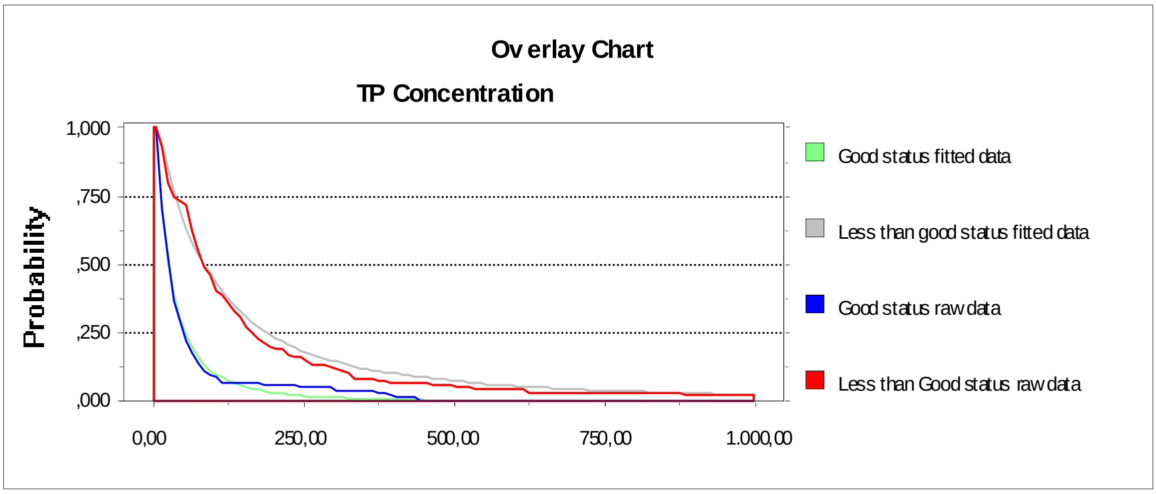


Figure 10. Reverse cumulative distributions of TP concentrations in G+ (good status) and G- (less-than-good status). Comparison of lognormal fitted and unfitted raw data distributions using Monte Carlo analysis.

It is obvious that the fitting distributions are relatively close to raw data distributions for some parts of the curve. However, in the critical area of the curves, below 250-500 µg P/l, the differences among the distributions for "G+", fitted versus raw data comparison, show that real data lie above the fitted values. Conversely, "G-" comparison shows that real field data are below the fitted ones. These observations confirm the results of the statistical analysis, suggesting that the fitting to log-normal distributions is not good enough to be used in the assessment.

INFLUENCE OF DIFFERENT ECOREGIONS AND ECOTYPES

A main issue of this project is the evaluation of potential differences in the effects assessment among the different European Ecoregions. Due to geographical, climatic and ecological differences the response of aquatic ecosystems to TP loads is expected to be different in different Ecoregions (i.e. ecological regions).

This issue was addressed focussing on three main Ecoregions: Central Europe, Atlantic Europe and the Mediterranean Europe regions. The preliminary assessment indicated differences in the probability distributions among the three regions (see Figures 11 and 12).

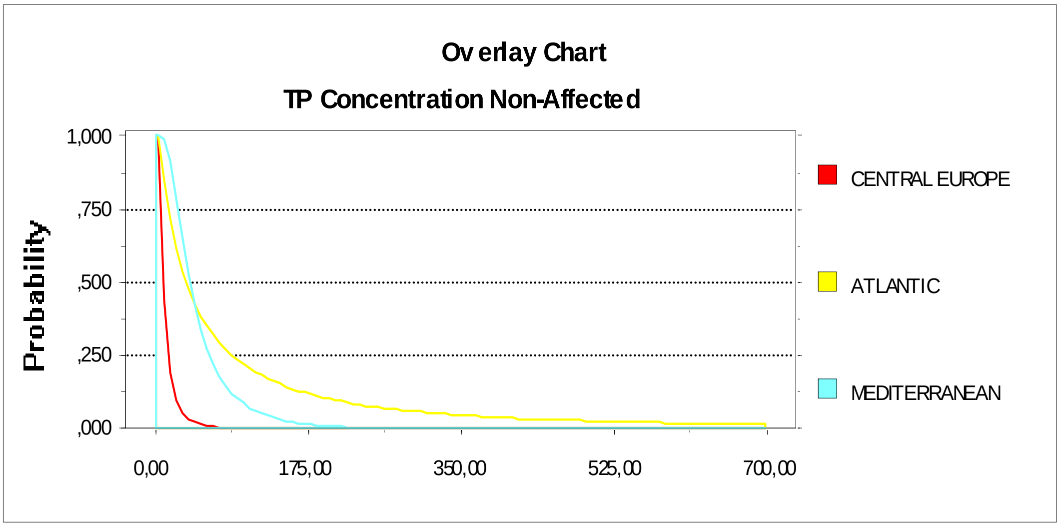


Figure 11. Fitting distribution for TP concentrations reported for three different Ecoregions with Good or better than Good status under the WFD.

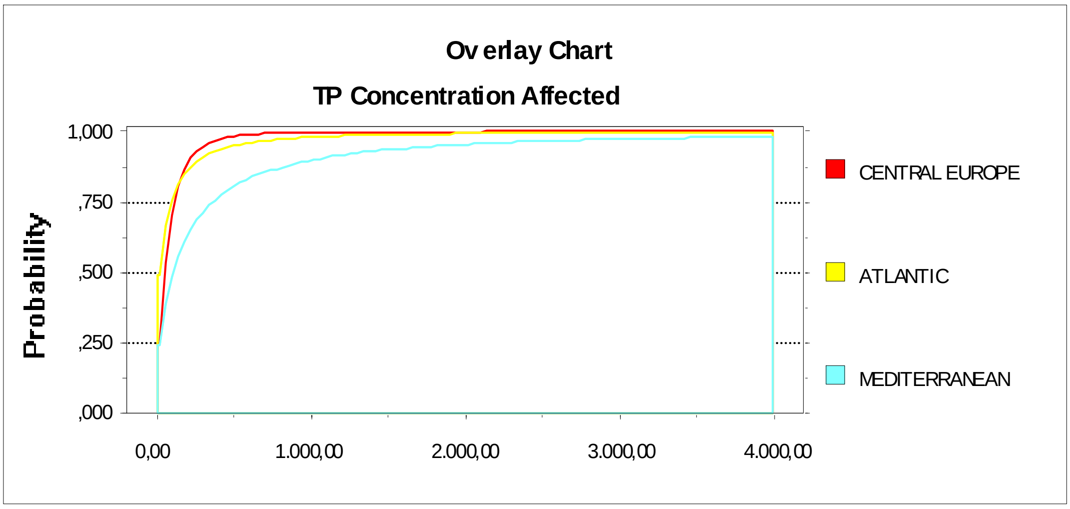


Figure 12. Fitting distribution for TP concentrations reported for three different Ecoregions with Less than Good status under the WFD.

The relevance of these questions was studied through the incorporation of additional data and different data analysis; and were presented to the Expert international panel for discussion last November 2005.

In that Workshop, it was agreed that the use of the European Ecoregions as defined in the WFD would be of no value. The Experts considered appropriate to combine Atlantic, Northern and Central Europe in a single ecological region, while the specific characteristics of the Mediterranean European ecosystems would require an independent analysis.

The need for independent analysis of water bodies ecotypes was also discussed at the Experts Workshop. The participants recommended to explore the differences among deep and shallow lakes, because of their different functioning in relation to eutrophication effects. This is particularly important in the case of sites from Atlantic and Central European regions, as shallow and deep lakes are completely different.

The criterion suggested for dividing the water bodies into deep and shallow lakes was the presence of thermal stratification in summer period. When that hydrological regime was present in the water body, it was considered a deep lake. On the contrary, a shallow lake does not have a stratification regime. When the limnological regime was not reported, the second criteria most used in literature is to consider deep lakes those that have mean depths of >5 m; water bodies <5 m are considered shallow lakes.

In the Mediterranean region that difference between these ecotypes was considered less important, and due to the relevance of wetlands and artificial reservoirs, more difficult to apply. Therefore it was considered appropriate to include all sensitive ecotypes in a single group in the case of the Mediterranean ecoregion. The CIS for WFD equals reservoirs and lakes as aquatic ecosystems to be protected with the same effort. Therefore, in the assessment reservoirs are considered the same as lakes.

Following this approach the database was distributed assuming two ecoregions:

- Atlantic, Northern and Central European water bodies.
- Mediterranean water bodies.

And two ecotypes

- Shallow lakes
- Deep lakes

These categories can be combined in “eco-region&type-classes”, e.g. the Atlantic, Northern and Central European deep lakes, representing a combination of ecoregions and ecotypes.

The same process described for the overall database, was repeated for each subset of data; estimating the conditional probabilities p(TP | G+) and p(TP | G-) for each ecoregion, eco-type and finally for eco-region&type-classes. The goodness-of-fit test indicated that for the majority of conditional probability distributions the fit to a log-normal distribution was not good enough. Therefore, it was decided to use raw data in all cases, instead of the fitting distributions. The distributions with raw data are presented in the following figures.

First, the influence of the ecoregions was analysed. Figures 13 and 14 confirm the differences among ecoregions.

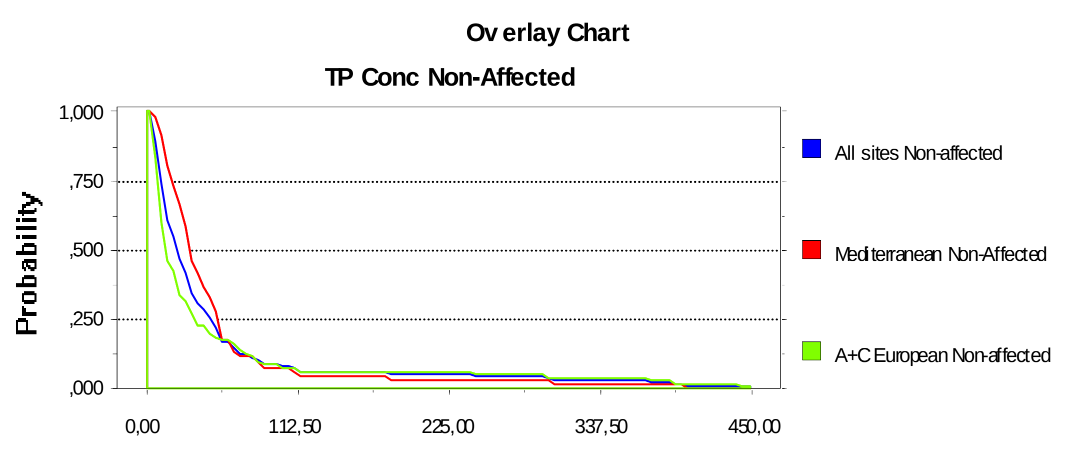


Figure 13. Reverse (1-p) cumulative conditional distributions p(TP | G+) for the two selected ecoregions. The legend indicates “Non-Affected” for G+ sites.

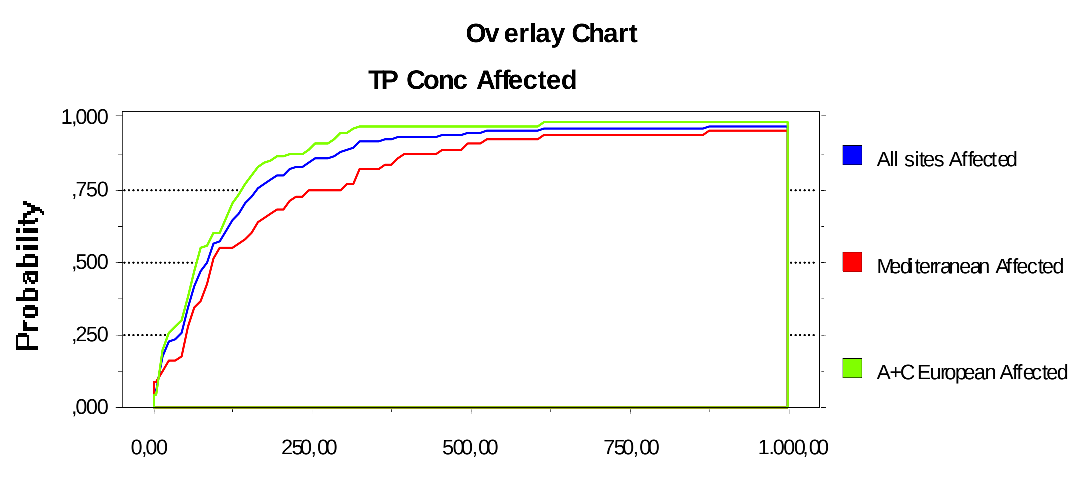


Figure 14. Cumulative conditional distributions p(TP | G-) for the two selected ecoregions. The legend indicates “Affected” for G- sites.

In the case of G- sites distributions, it is observed that Mediterranean water bodies have lower probabilities for the same TP level than the Atlantic lakes. This is fully in line with conclusions found in the literature review, as Mediterranean aquatic ecosystems showed, in general, higher trophic status than Atlantic or Central systems, i.e. they are naturally more nutrients-enriched waters, allowing the developing of more productive ecosystems. Then nutrient background levels are higher and the additional inflows to the system should have higher TP concentrations to produce the breakdown of the structure and, consequently, eutrophication related impairments.

The differences were more clear for the G- distributions, as shown in Figure 15.

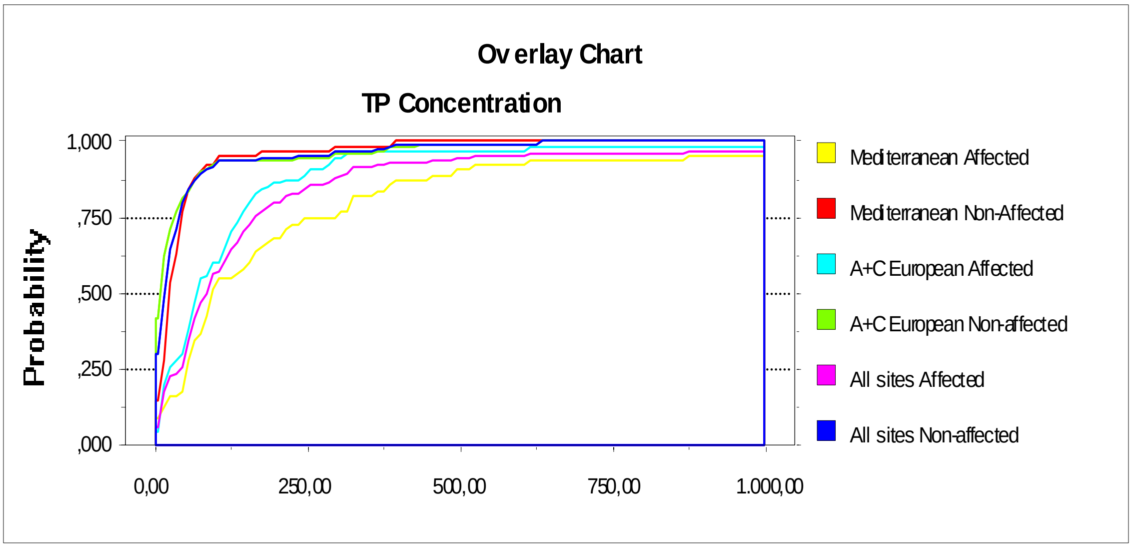


Figure 15. Cumulative probability distributions p(TP | G+) and p(TP | G-) for the three selected eco-region&type-classes. The legend indicates “Affected” for G- and “Non-affected” for G+ sites.

The difference associated to the ecotype alone was also explored and it is presented in figures 16 and 17.

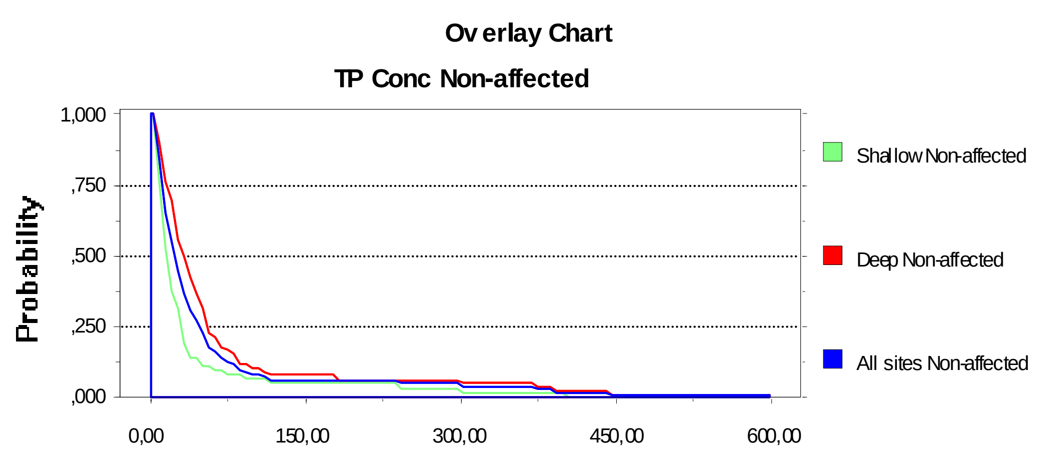


Figure 16. Reverse cumulative distributions for “Affected” sites (G-) allowing comparison among deep and shallow ecosystems.

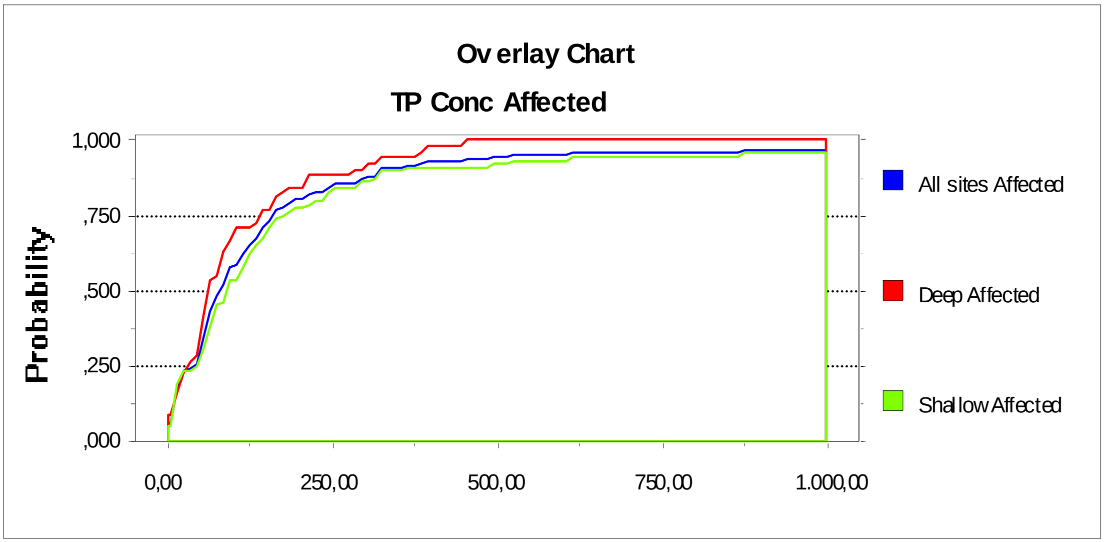


Figure 17. Cumulative distributions for “Non-affected” sites (G+) allowing comparison among deep and shallow ecosystems.

As expected, the differences among ecotypes show the ecological processes working in these water bodies. Shallow lakes tend to be more productive than deep lakes, because they are naturally more eutrophic. P inflows produce eutrophication related effects in deep lakes with TP concentrations lower than in shallow lakes. So the potential risk of a given TP concentration is higher for deep lakes than for shallow ones.

FINAL SELECTION OF THE EFFECT ASSESSMENT DISTRIBUTIONS

The analysis of the data base and the differences among ecoregions and ecotypes were fully in agreement with the recommendations from the Expert Workshop.

As already mentioned, the fit of the raw data to a lognormal or other distribution was not good enough and the final decision was to conduct the assessment based on raw data non-fitted distributions for avoiding the fitting uncertainty.

Figures 18 and 19 show the final six distributions selected for the effect assessment, representing the reverse (1-p) cumulative probability for p(TP | G+) and the cumulative probability for p(TP | G-) for the three selected eco-region&type classes:

- Atlantic, Northern and Central European shallow lakes
- Atlantic, Northern and Central European deep lakes
- Mediterranean water bodies.

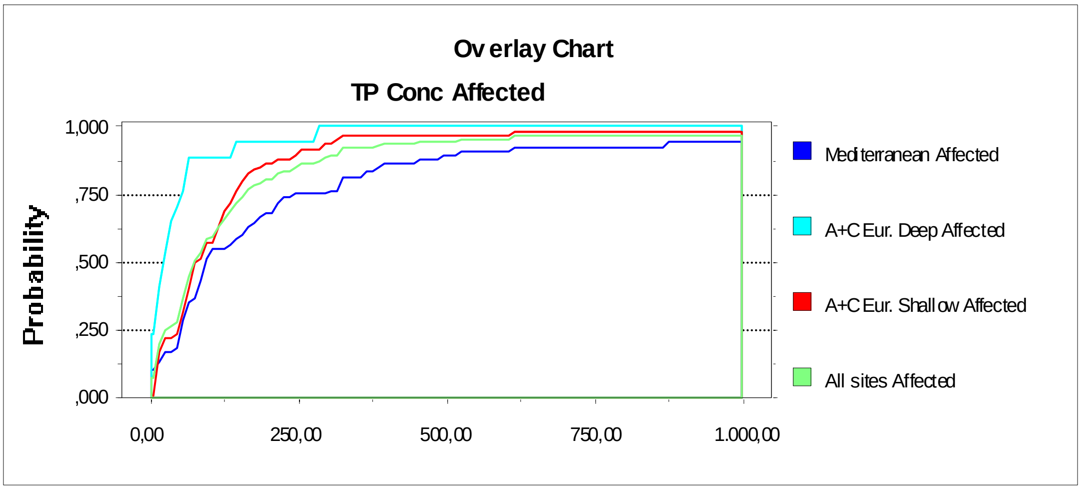


Figure 18. Cumulative conditional distributions p(TP | G-) for all sites and those of each eco-region&type-class. The legend indicates "Affected" for G- sites.

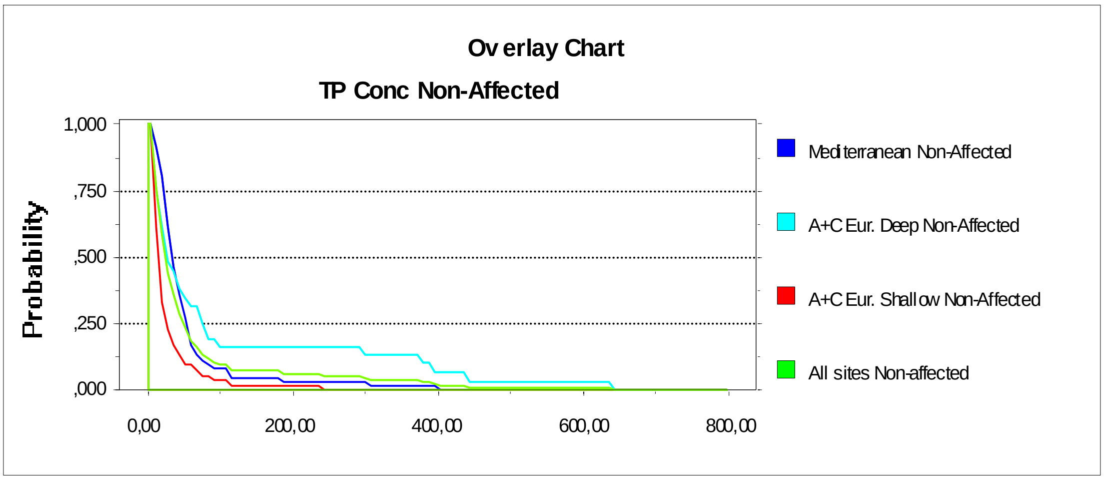


Figure 19. Reverse cumulative conditional distributions p(TP | G+) for all sites and those of each eco-region&type-class. The legend indicates "Non-Affected" for G+ sites.

Clear differences among the three distributions are observed, particularly for low TP concentrations.

These distributions will be used in the risk characterization, as the best representations for the conditional distributions 1- p(TP | G+) and p(TP | G-). It should be noted the lack of good fit to a statistical distribution. All available information has been employed and the addition of new raw data has provoked minor modifications in the estimated distributions. Nevertheless, as discussed during the Experts Workshop, the incorporation of the information compiled by the IES-JRC within the "Intercalibration" exercises for the CIS-WFD will represent a relevant source of additional information, extremely useful for validating/improving this effect assessment. Unfortunately the information is not available yet.

RISK CHARACTERIZATION

The risk characterization combines the information generated on the exposure levels and the effect assessment to estimate the likelihood and magnitude of the effects. The exposure assessment estimates TP concentrations; the effect assessment is also based on these annual averages. The developed model is a river basin model, estimating TP concentrations for a river basin. The risk is not integrated through the whole river basin as the development of eutrophication processes presents large differences for different types of ecosystems within the same river basin. Eutrophication is particularly relevant for lentic (stagnant water) systems such as lakes, ponds, reservoirs and shallow water bodies, where the reduced water lineal speed allows a rapid development of algae and plants. The protection of these ecosystems is essential for an overall protection of the river basin, and, therefore, the effect assessment focused on these types of water bodies. These aspects were particularly discussed during the Experts Workshop. Opposite to GIS-based model, a generic risk characterization, as proposed in this study, should offer a conservative approach, focusing on the most sensitive aquatic communities within the river basin. Consequently, the effect assessment is based on these sensitive water bodies.

The sensitivity of the different ecosystem types was discussed during the Experts Workshop. The most relevant ecosystem types for the assessment of eutrophication are lakes and other stagnant waters. According to the Experts' opinions, artificial reservoirs may be assimilated to lakes for the purpose of this assessment. For large lakes and reservoirs, the in-lake concentrations are lower that the in-flow concentrations estimated by the model, thus this proposal represents a worst case approach. Following the Experts' advice, this worst case approach guarantees that the risk characterization based on the effects estimated from lakes and reservoirs covers all river basin ecosystems including running waters, meanders, low flow areas and estuaries.

Following this rationale, the risk characterization has been done through the comparison of the estimated TP concentration for the river basin, and the likelihood for not fulfilling the "Good status" conditions for eutrophication, according to the proposal developed for the WFD. The proposal has been developed considering the most sensitive ecosystem types within the river basin, and it is overprotective as the real annual TP concentration in these systems is lower than that estimated from the emission model due to the buffer capacity and the sedimentation of P in these systems. Monitoring data confirms that the measured concentrations in lakes and reservoirs are generally lower that those observed for the input water. The differences are case specific and no generic quantifications can be done. As a consequence, this worst case assessment is selected as the most relevant model offering the maximum potentially achievable risk, which will become realistic only in a few cases.

The exposure assessment employed in this risk characterization was initially estimated as realistic averaged values based on a selection of P export coefficients. Then, those values were transformed into probabilistic estimations through the use of Monte Carlo estimations and distributions, based on a combination of data analysis and expert judgement.

The effect assessment is directly based on probability distributions presenting the likelihood for effects. As a consequence, the risk characterization is not based on risk quotients but on the straight and quantitative assignment of the probability for effects associated to each TP concentration value.

As explained in the effect assessment chapter (see page 29), two related conditional distributions were developed for the evaluation. In this section the best way for using these distributions will be presented.

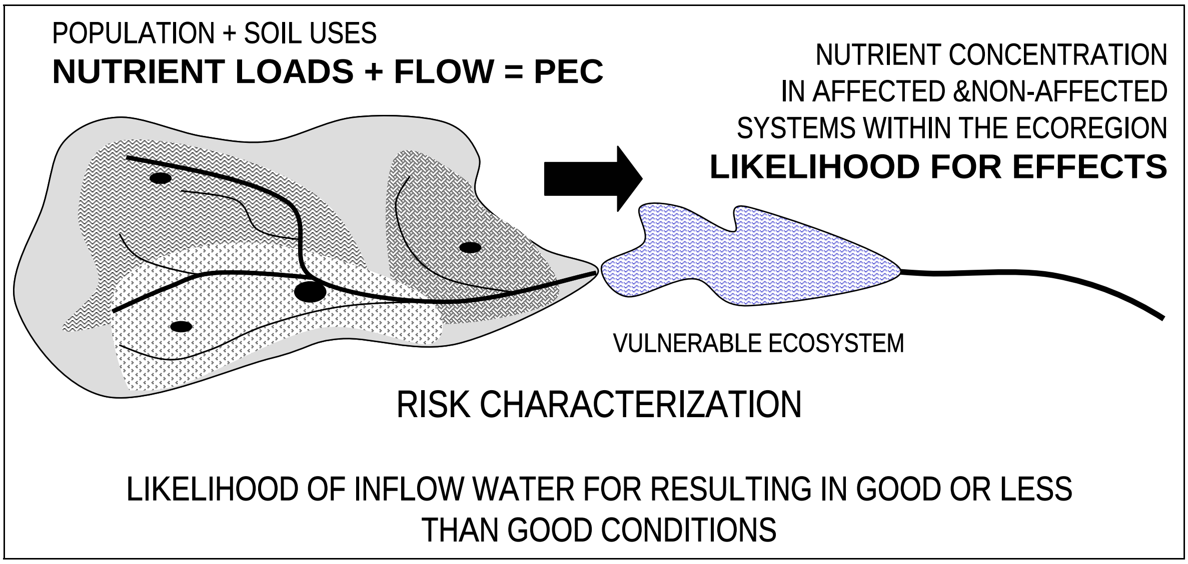


Figure 20: Conceptual model for a generic assessment of the eutrophication risk of nutrients. In the Exposure part, the loads and flow allows the estimation of the Predicted Environmental Concentration (PEC) entering a vulnerable ecosystem. The Effect assessment is based on the analysis of status conditions and nutrient concentration in vulnerable systems within a particular ecological region. The risk is defined by the probabilities for resulting in good or less than good conditions associated to the in-flow nutrient concentration.

The need for communicating the outcome of a complex risk characterization, including innovative probabilistic estimations and comparative risk assessment pointed out the need for an specific risk communication exercise. The details of this exercise and its outcome were included in the first phase report and presented at the expert workshop.

QUANTITATIVE CHARACTERIZATION OF THE EUTROPHICATION RISK.

It was very clear from the literature review that the collected data cannot be considered a random sample of water bodies. As a consequence the conditional probability of a water body to be in less than good status given a certain TP concentration, p(G- | TP) cannot be directly estimated from the data base.

The risk characterization has been quantified through the estimation of a probability range and the most likely value, between the maximum and minimum values of the range.

For each exposure assessment estimation, TP, the eutrophication risk associated to that concentration is defined as the likelihood of a sensitive site, susceptible to eutrophication, to be in less-than-good eutrophication status. This value is represented by the joint probability for having a certain TP concentration and being in less-than-good status corrected by the percentage of sites in the area with potential for suffering eutrophication problems if enough amounts of nutrients are provided. This likelihood value can be represented as $p(TP \cap G-)/(p(G-)max)$. The correction by the maximum value of p(G-) provides a risk value ranging from 0 to 1 (or 0% to 100% when expressed as percentage).

Estimation of the probability range

The risk value offers the probability for water bodies with potential for becoming eutrophic, and range from 0 to 1 (or 0% to 100% when expressed as percentage). This risk does not cover non-sensitive water bodies; thus, for example, if in a given area, 40% of the water bodies have potential for eutrophication, the risk refers exclusively to this 40%, not to all water bodies.

Considering that

$$p(TP \cap G-) = p(TP \mid G-) \cdot p(G-)$$

$$p(TP \cap G-)/(p(G-)max). = p(TP \mid G-) \cdot p(G-) / p(G-)max$$

the maximum (based on cumulative TP; which becomes the minimum based on reverse cumulative TP) possible value for $p(TP \cap G-)/(p(G-)max)$ is $p(TP \mid G-)$.

In addition, the likelihood for less than good status may be expressed as the opposite to be in good status,

$$1- p(TP \cap G+)/(p(G+)max)$$

and following a similar rationale, the minimum (based on cumulative TP; which becomes the maximum based on reverse cumulative TP) possible value for this likelihood is $1- p(TP \mid G+)$.

Estimation of the “most likely probability” value

The “Most Likely Probability” value, mlp, was estimated from the combination of the probability distributions obtained for the conditional probabilities p(TP | G-) and p(TP | G+), and the most likely probability value for the number of sites with less than good status, expressed as mlp(G-). The principles of this estimation are described below.

By definition:

$$p(G- \mid TP) = p(G- \cap TP) / p(TP).$$

And similarly

$$p(TP \mid G+) = p(TP \cap G+) / p(G+)$$
$$p(TP \mid G-) = p(TP \cap G-) / p(G-)$$

It must be considered that

$$p(G- \cap TP) = p(TP \cap G-)$$

The conditions of being or not in good status exclude each other and cover the whole spectrum, therefore.

$$p(G+) + p(G-) = 1$$

$$p(G+ \cap G-) = 0$$

As a consequence

$$p(TP) = p(TP \cap G+) + p(TP \cap G-)$$

The most likely probability value for being in less than good status given a certain TP concentration, mlp(G- | TP) can be estimated from an assumption on the most likely probability value for the number of sites in less than good status mlp(G-).

$$mlp(G- \mid TP) = p(TP \mid G-)\, mlp(G-) / p(TP)$$

A proper value for mlp(G-) is essential for the estimation of the mlp values.

RESULTS

The eutrophication risk is presented as a range obtained from the conditional distributions p(TP | G+) and p(TP | G-) estimated in the effect assessment section. The most likely probability value for being in less than good status at a certain concentration of total phosphate represented by the conditional probability "mlp(G- | TP)" is also estimated as described above. The selected value for mlp(G-) is critical for the estimation of mlp(G- | TP). In addition, the fitting process of the effect dataset to the p(TP | G+) and p(TP | G-) distributions adds uncertainty. As a consequence, the calculation of mlp(G- | TP) may gives values outside the expected range.

As explained in the effect assessment part, the differences among ecoregions and water bodies' ecotypes have been considered. Following the suggestions from the experts' workshop, two main eco-Ecoregions should be considered, the Atlantic, Northern and Central European region and the Mediterranean region. Regarding the ecological types the experts also recommended to consider two different ecotypes in the case of the Atlantic, Northern and Central European region, differentiating between shallow and deep lakes.

This difference was not considered necessary for the Mediterranean region, and it was also agreed to combine lakes and reservoirs.

The quantitative characterizations of the eutrophication risk are presented in Figures 21 and 22 for Atlantic, Northern and Central European shallow lakes, and Mediterranean water bodies respectively. In the case of Atlantic, Northern and Central European deep lakes, the lack of good fitting and the insufficient amount of data did not allow to produce a correct risk characterization. Therefore this ecoregions&type class has not been longer considered in the risk characterization.

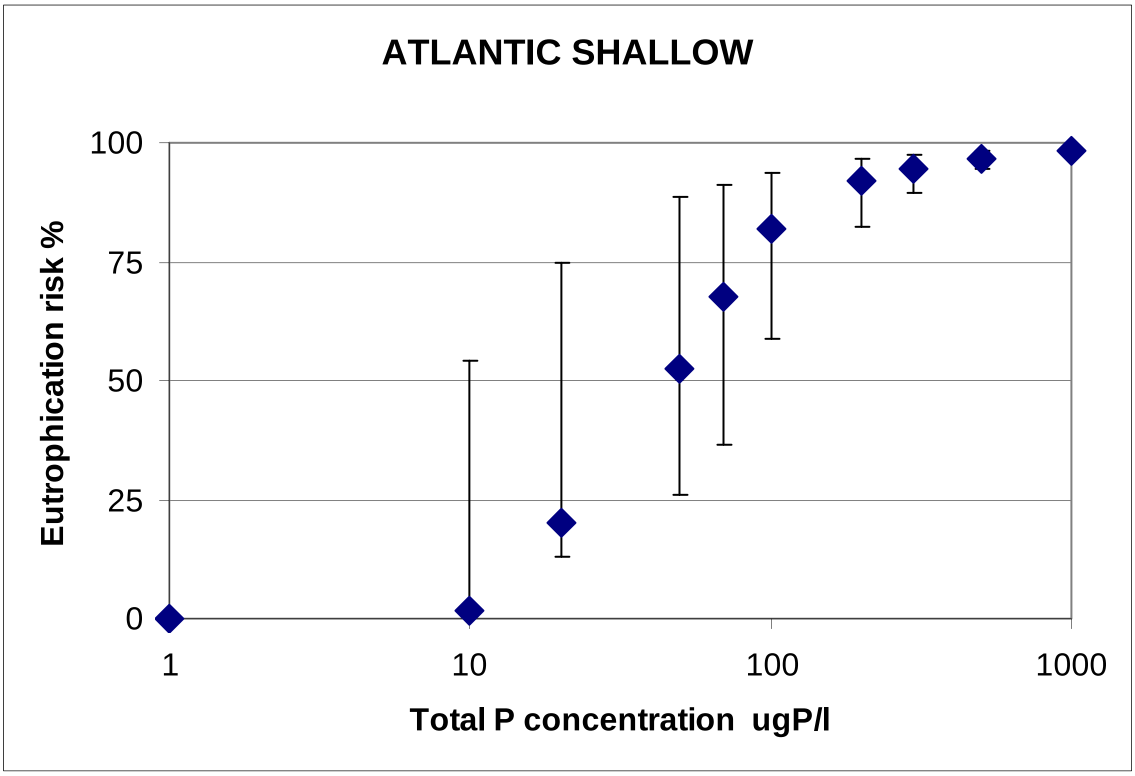


Figure 21. The eutrophication risk of Atlantic, Northern and Central European shallow lakes as a function of the TP concentration. The lines indicate the range between p(TP | G-) and 1- p(TP | G+); the rhombus is the mlp(G-) value estimated for the assumption that 33% of the sensitive water bodies in the area are in less-than-good status.

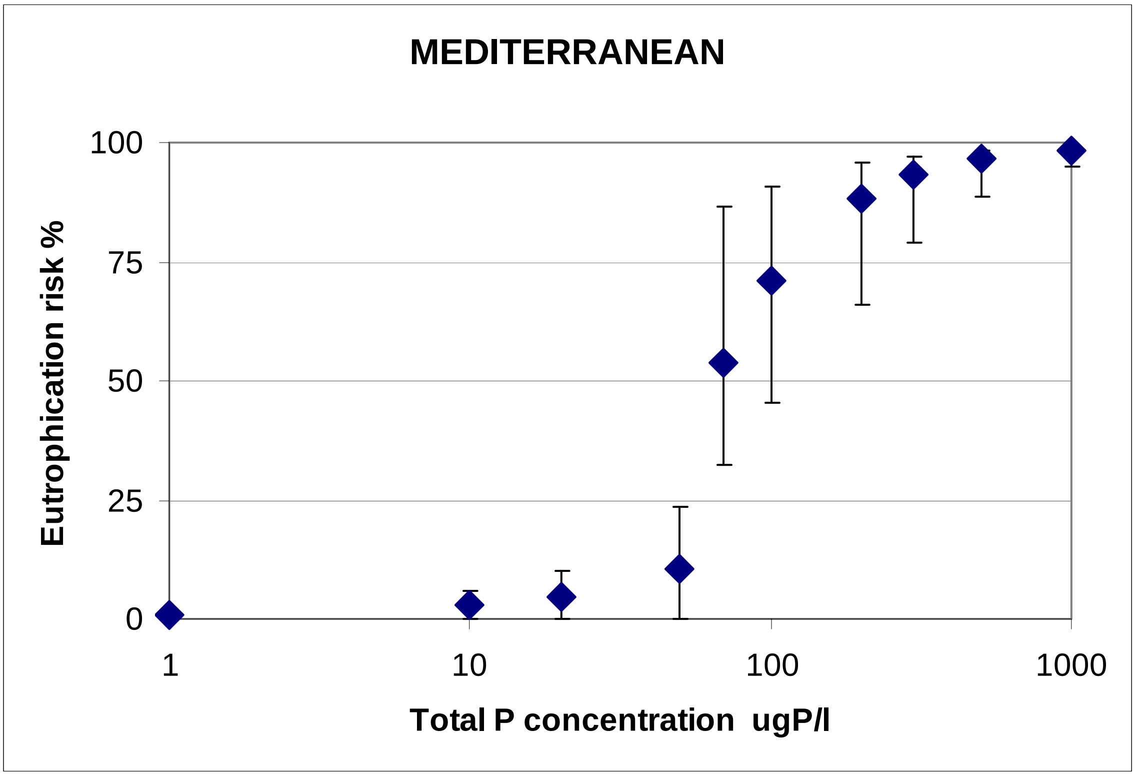


Figure 22. The eutrophication risk of Mediterranean water bodies as a function of the TP concentration. The lines indicate the range between p(TP | G-) and 1- p(TP | G+); the rhombus is the mlp(G-) value estimated for the assumption that 33% of the sensitive water bodies in the area are in less-than-good status.

Figure 23 offers a comparison of the distributions obtained for the two eco-region&type classes.

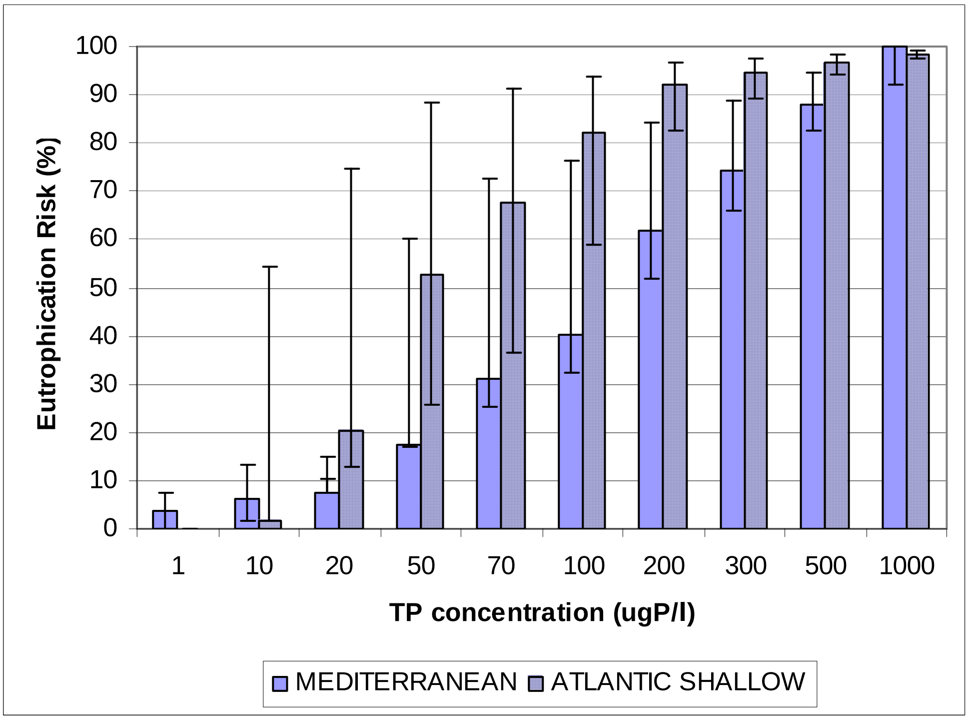


Figure 23. Comparison of the eutrophication risk estimations for each eco-region&type-class. The bars show the mlp(G-) value and the lines indicate the range.

COMPARATIVE RISK ASSESSMENT AND RISK COMMUNICATION OPTIONS.

As for other complex and higher tier ecological risk assessments, the alternatives for communicating the results of the risk characterization become a crucial issue. The proposed methodology allows several options. A survey among environmental experts was conducted using a questionnaire specifically developed for this project. The questionnaire and the results are available in the report of Phase I of this study: Green Planet Report EC-CEEP-05-2-Final

The participants were 38 persons with university degrees in environmental sciences. Participants were selected from the INIA Department of the Environment and from the participants at the SETAC Europe Annual Meeting at Lille. The sample covered persons with very different levels of expertise, from PhD students to high level experts and it was well balanced in terms of gender and education level (graduated and PhD). Participants covered a wide range of education backgrounds (mostly chemistry and biological sciences), age, and sector (academic, business, government).

The consultation focused on the amount of information, understanding capability, comprehension and preferences of six alternative graphic methods for presenting the results of probabilistic protocols for assessing the risk of nutrients. The experts' opinion on general issues for presenting probabilistic risk assessment results was also requested.

Two alternatives (1 and 2) covered the exposure assessment of chemicals with multi-exposure and background concentrations, such as nutrients; focusing on the specific assessment of the additional risk associated to one anthropogenic activity. Alternative 1 presented the probabilistic estimations of the predicted concentrations (PECs) with and without the activity, representing both curves in the same figure. Alternative 2 presented a single curve, representing the probability associated to each increment in the PEC background.

Two alternatives (A and B) covered the effect assessment part. Alternative A was the representation of "p" (likelihood for good status) and "q" (likelihood for less than good status) for a concentration equal to or lower than the X value. Alternative B was the representation of the corrected value for "1-p_c" (most likely value for having less than good status obtained from the combination of "p" and "q") were the likelihood for having good status is just "p_c".

Two alternatives (I and II) covered the combined presentation of exposure and effects; with graphics representing directly the results of the risk characterization. In the first option (I) alternatives 1 and A are combined and the probability for exceeding each nutrient concentration is plotted against the probability for being at "less-than-good status" conditions at that particular concentration. In the second option (II), alternatives 1 and B are combined and the increase in the probability for being in "less-than-good status" provoked by the emissions of the assessed activity is plotted against the initial background concentration

The results of the risk characterization can be done through the combination of exposure and effect curves or through the direct use of risk characterization graphs. The experts' preferences were specifically asked for. Figures 24 and 25 present the overall preferences for presenting the risk characterization results and the distribution of these preferences for the PhD and non-PhD groups, respectively.

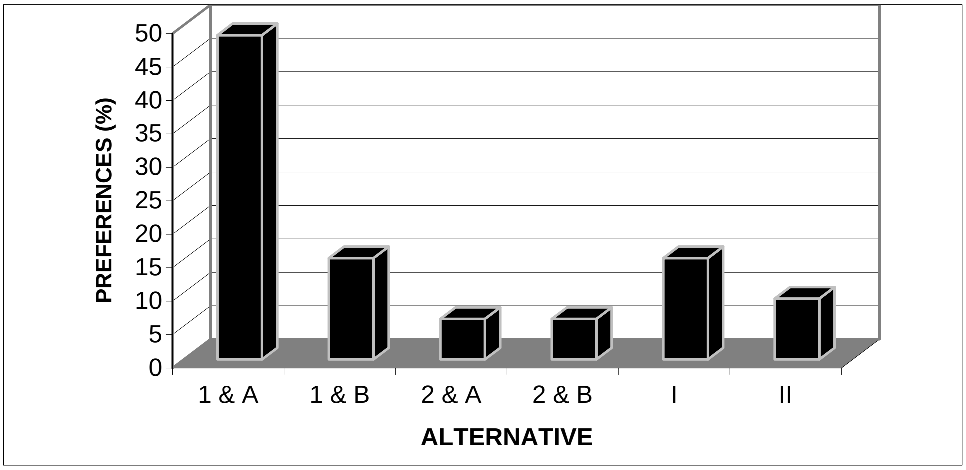


Figure 24. Preferences for presenting the risk characterization results.

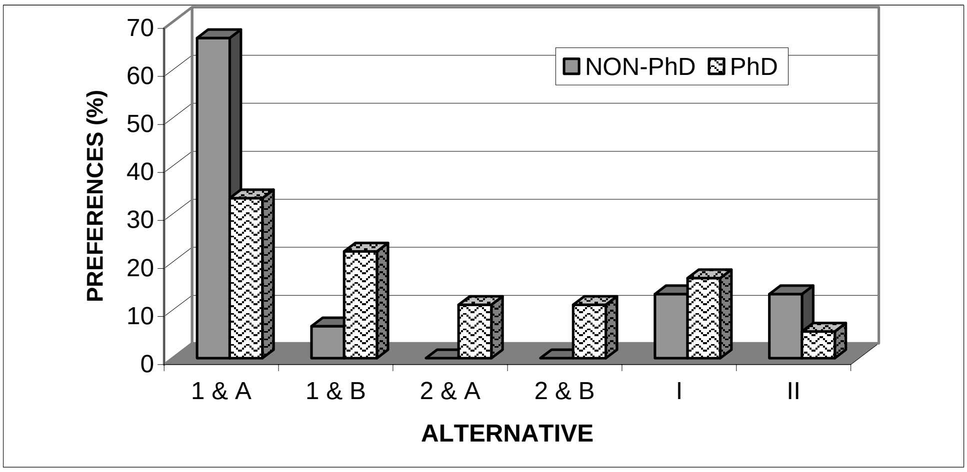


Figure 25. Preferences for presenting the risk characterization results by non-PhD and PhD participants.

There is a clear preference for the combination of alternatives 1 and A. This combination represents the most complex graphic alternative, with four different probability curves, but also offers the maximum amount of information. The alternative graphic presentations can be obtained from this combination, but not the opposite. At the same time, alternatives 1 and A are those considered by the experts as those presenting an adequate level of information and those most easily understood. In fact the interpretation of each curve in this combination is simple as each line represents the probability associated to the nutrient concentration. This approach is mostly the preferred one by the non-PhD group, while the more experienced group have a higher diversity regarding their preferences.

The combination of preferences and comprehension indicates a clear coherence and for a vast majority of cases the participants selected an alternative he / she was able to answer correctly.

Regarding the generic consultation on the best approaches for presenting results from probabilistic risk assessments, the opinions from the experts can be summarised as follows:

- Results should be presented using graphic approaches offering as much information as possible, including information on the uncertainty of the assessment, even if these graphic forms require a more complex interpretation. However, if a high level of risk is identified, requiring urgent risk management measures, simplified graphics presenting the risk in a clear way are preferred.
- For avoiding misinterpretations, probabilistic graphics should always be presented with additional information allowing a proper interpretation of the data by the users.
- There is a tendency for considering that the same graphics should be used for presenting the results to risk assessors and risk managers.
- Most experts considered that the complexity of probabilistic graphic representations is not an inconvenient if the interpretation of the results is done by experts.

These results were presented at the expert workshop and it was agreed to follow the preferences; presenting the results as individual distributions.

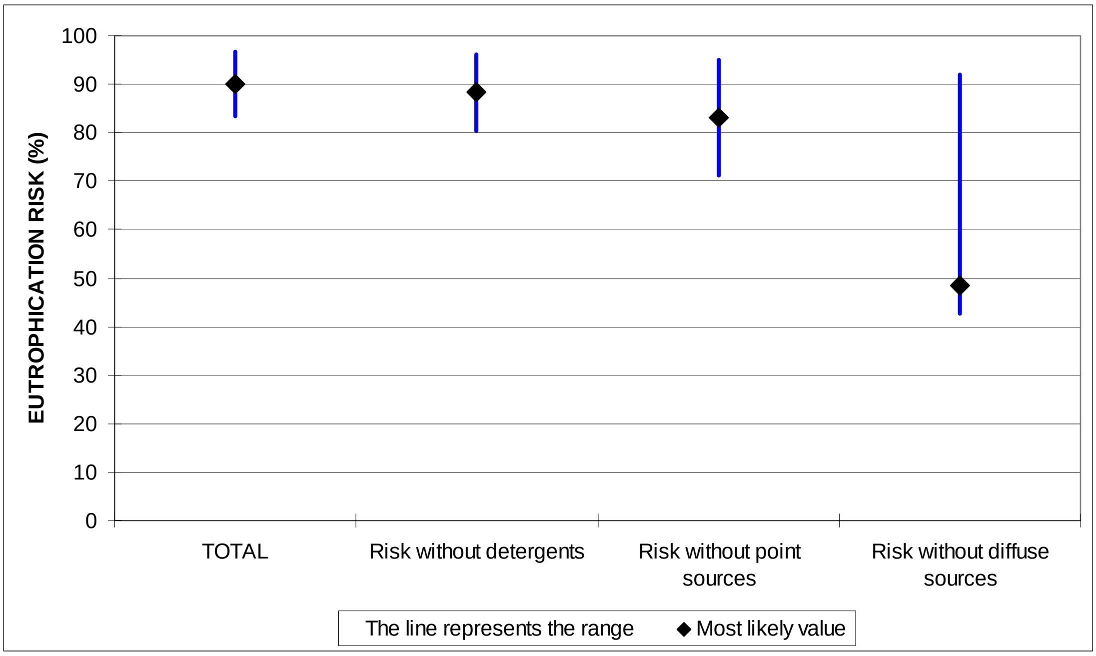


Figure 26. Example of the presentation of the risk characterization output. For risks (range and most likely probability value) are presented covering the total (overall) risk, the predicted risk eliminating the contribution of detergents, the predicted risk eliminating the contribution of point sources and the predicted risk eliminating the contribution of diffuse sources.

Additional management options may also be considered.

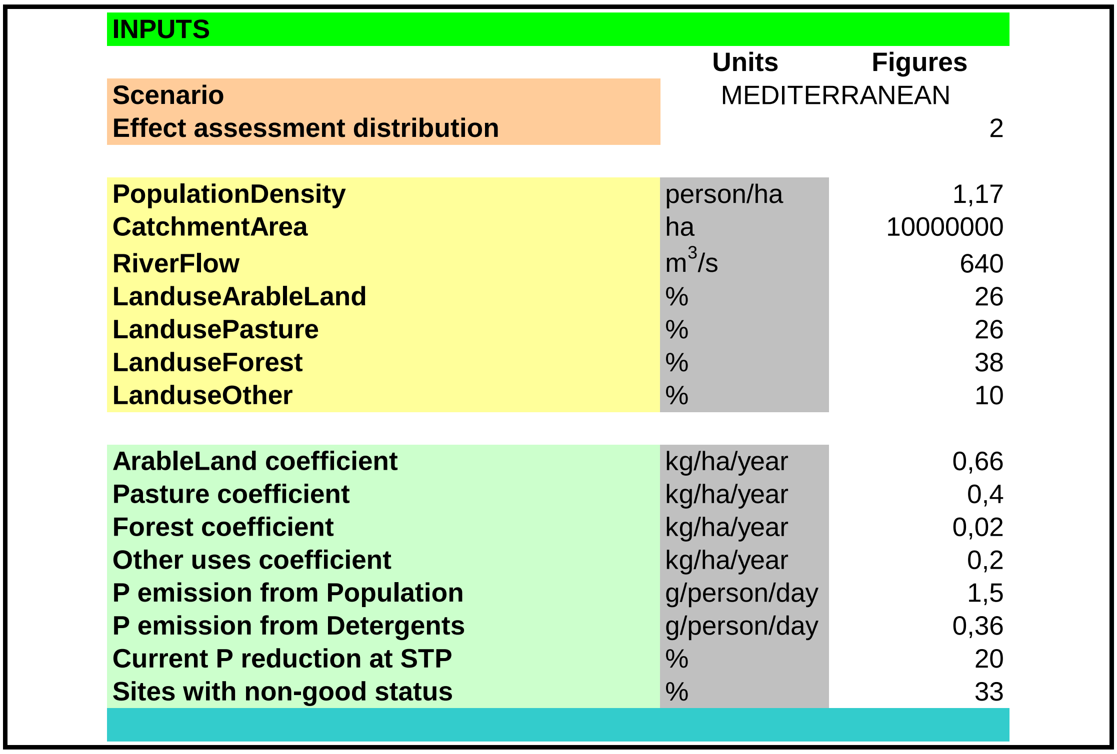
SECTION 2.

MODEL IMPLEMENTATION AND RISK CHARACTERIZATION RESULTS OBTAINED FOR A SET OF GENERIC EUROPEAN SCENARIOS

MODEL IMPLEMENTATION

The exposure scenarios, effects estimation and risk characterization approach has been initially implemented in an Excel datasheet providing deterministic exposure estimations based on default values, and probabilistic risk estimations combining the exposure estimations and the effect assessment distributions.

The required input data are presented in Figure 28. Three main information blocks are required, the selected eco-region&type-classes; the characteristics of the river basin (population density, catchment area, river flow, land use pattern) and the P export coefficients (for diffuse and point sources including the specific contributions of detergents, the capability of the sewage treatment plant, and the selected value for p(G-)max).



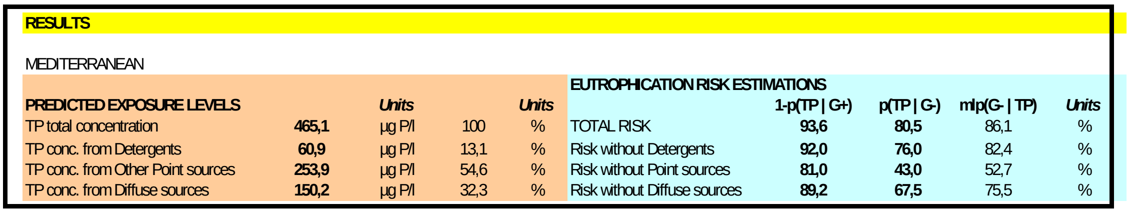
INPUTS		
	Units	**Figures**
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

Figure 27. Example of the Input module of the risk assessment calculator.

The model results show:

- the predicted exposure concentrations (TP concentration in µg/l),
- the specific contribution of domestic detergents (in µgP/l and in percentage of the total TP contribution), considering the removal of P at the sewage treatment plant for the estimation of loads from point sources.
- the contribution of other point sources, excluding detergents, (in µg/l and in percentage of the total P contribution), considering the removal of P at the sewage treatment plant for the estimation of loads from point sources.
- the contribution of diffuse sources (in µg/l and in percentage of the total P contribution),
- the eutrophication risk estimations (in percentage of total probability) showing the maximum (p(TP | G-), and minimum (1- p(TP | G+)) of the range, and the most likely value (mlp(G-| TP)).

Figure 28 presents an example of the obtained model results.



RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*	**EUTROPHICATION RISK ESTIMATIONS**	1-p(TP | G+)	p(TP | G-)	mlp(G- | TP)	*Units*
TP total concentration	**465,1**	µg P/l	100	%	TOTAL RISK	**93,6**	**80,5**	86,1	%
TP conc. from Detergents	**60,9**	µg P/l	13,1	%	Risk without Detergents	**92,0**	**76,0**	82,4	%
TP conc. from Other Point sources	**253,9**	µg P/l	54,6	%	Risk without Point sources	**81,0**	**43,0**	52,7	%
TP conc. from Diffuse sources	**150,2**	µg P/l	32,3	%	Risk without Diffuse sources	**89,2**	**67,5**	75,5	%

Figure 28. Example of the Output module of the risk assessment calculator.

In addition, the risk characterization is presented in a graphic form, as shown in Figure 29. These estimations cover the total risk based on the estimation of total phosphorous concentration, the risk from all sources excluding detergents (zero contribution of detergents), the risk excluding point sources (zero contribution from point sources) and the risk excluding diffuse sources (zero contribution from diffuse sources).

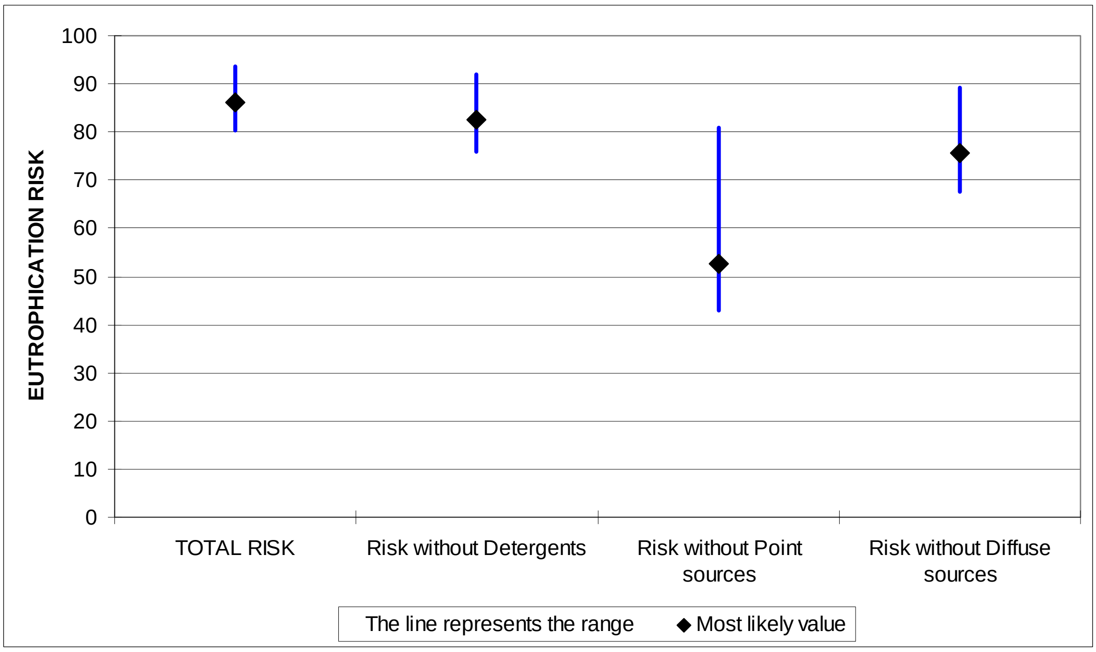


Figure 29. Example of the Graphic Output module of the risk assessment calculator.

Furthermore, the calculator offers estimations for three management options, allowing specific assessments for further reductions in P-based detergents, implementation of P-removal techniques at the STP, or management of diffuse sources. However, these estimations are not presented in this report.

The following pages present a number of examples of the potentiality of the implemented model. The figures show different combinations of parameters that define several generic scenarios covering a range of total P concentration and point and diffuse sources contributions, and two levels of detergent contribution and implementation of P-removal at the sewage treatment plant.

NOTE: The effect assessment model estimates the potential risk based on the complementary assessment of two distributions, and therefore the eutrophication risk is presented as a range. The process selected for setting the mlp(G-| TP) value requires an assessment of the mlp(G-) introducing additional uncertainties. The estimation of the mlp(G-| TP) value has been maintained as it can be useful when proper information on the percentage of sites with non-good status is available. This piece of information will be obtained through the implementation of the WFD process. In the mean time, unless validated information could be obtained for an area or scenario, the authors strongly suggest to base the comparisons on the probability ranges instead of on the most likely probability values.

A summary of the main inputs considered for the selected generic scenarios is presented below.

Examples 1a, 1b, 1c, 1d:

- European average consumption of P-based detergents (1a, 1b);
- European highest national consumption of P-based detergents (1c, 1d);
- Mediterranean effect assessment (1a, 1c);
- Atlantic shallow lakes effect assessment (1b, 1d);
- Average European values for Population density, River flow, and Agricultural intensity.

Examples 2a, 2b, 2c, 2d:

- European average consumption of P-based detergents (2a, 2b);
- European highest national consumption of P-based detergents (2c, 2d);
- Mediterranean effect assessment (2a, 2c);
- Atlantic shallow lakes effect assessment (2b, 2d);
- Average European values for Population density and Agricultural intensity;
- 2x European average River flow.

Examples 3a, 3b, 3c, 3d:

- European average consumption of P-based detergents (3a, 3b);
- European highest national consumption of P-based detergents (3c, 3d);
- Mediterranean effect assessment (3a, 3c);
- Atlantic shallow lakes effect assessment (3b, 3d);
- Average European values for River flow and Agricultural intensity;
- 1/3 x European average Population density.

Examples 4a, 4b, 4c, 4d:

- European average consumption of P-based detergents (4a, 4b);
- European highest national consumption of P-based detergents (4c, 4d);
- Mediterranean effect assessment (4a, 4c);
- Atlantic shallow lakes effect assessment (4b, 4d);
- Average European values for River flow;
- 1/3 x European average Population density
- Low Agricultural intensity.

Examples 5a, 5b, 5c, 5d:

- European average consumption of P-based detergents (5a, 5b);
- European highest national consumption of P-based detergents (5c, 5d);
- Mediterranean effect assessment (5a, 5c);
- Atlantic shallow lakes effect assessment (5b, 5d);
- Average European values for Population density and Agricultural intensity;
- 2x European average River flow.
- 3 x Current P reduction at STP.

EXAMPLE 1a: Generic assessment based on:

- Average European values
- Mediterranean lakes Effect Assessment
- European average consumption of P-based detergents

INPUTS

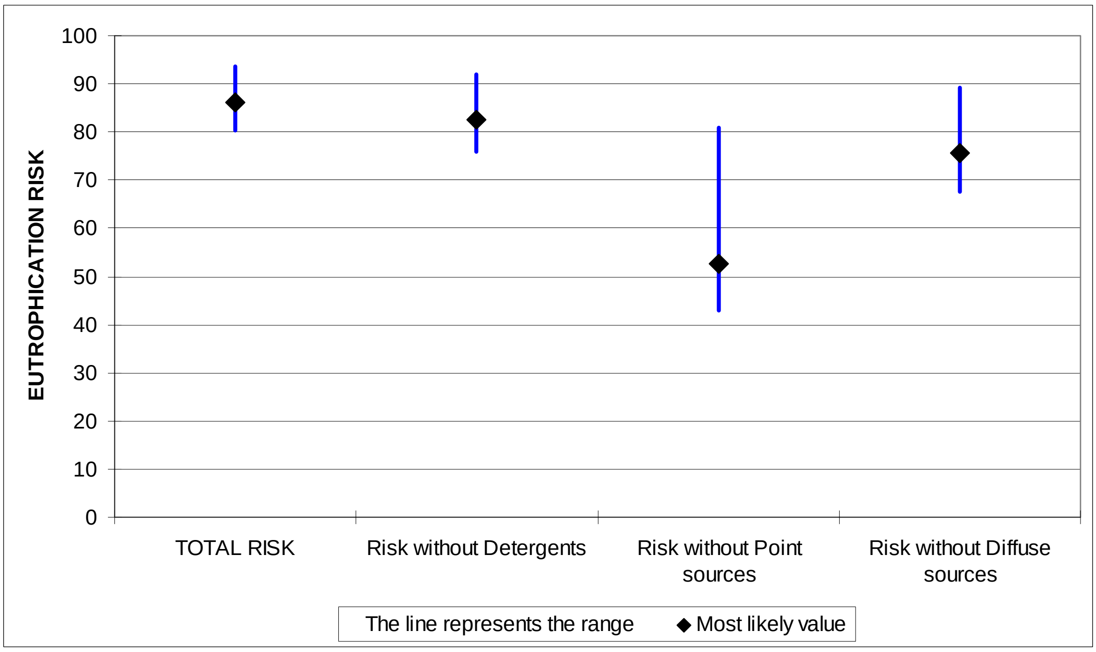
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**465,1**	µg P/l	100	%
TP conc. from Detergents	**60,9**	µg P/l	13,1	%
TP conc. from Other Point sources	**253,9**	µg P/l	54,6	%
TP conc. from Diffuse sources	**150,2**	µg P/l	32,3	%

EUTROPHICATION RISK ESTIMATIONS	**1-p(TP | G+)**	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**93,6**	**80,5**	86,1	%
Risk without Detergents	**92,0**	**76,0**	82,4	%
Risk without Point sources	**81,0**	**43,0**	52,7	%
Risk without Diffuse sources	**89,2**	**67,5**	75,5	%



EXAMPLE 1b: Generic assessment based on:

- Average European values
- Atlantic Shallow lakes Effect Assessment
- European average consumption of P-based detergents

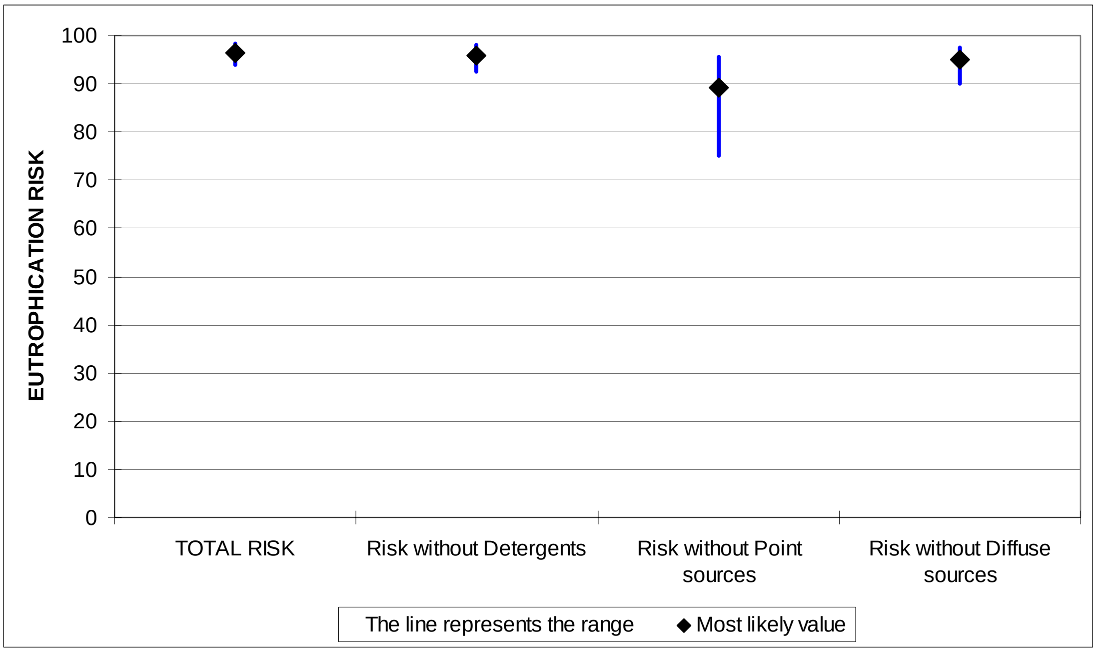
INPUTS		
	Units	**Figures**
Scenario	ATLANTIC SHALLOW	
Effect assessment distribution		4
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		***Units***		***Units***
TP total concentration	**465,1**	µg P/l	100	%
TP conc. from Detergents	**60,9**	µg P/l	13,1	%
TP conc. from Other Point sources	**253,9**	µg P/l	54,6	%
TP conc. from Diffuse sources	**150,2**	µg P/l	32,3	%

EUTROPHICATION RISK ESTIMATIONS	**1-p(TP | G+)**	**p(TP | G-)**	**mlp(G- | TP)**	***Units***
TOTAL RISK	**98,3**	**93,8**	96,4	%
Risk without Detergents	**98,1**	**92,6**	95,9	%
Risk without Point sources	**95,5**	**75,2**	89,2	%
Risk without Diffuse sources	**97,6**	**90,0**	94,9	%



EXAMPLE 1c: Generic assessment based on:

- Average European values
- Mediterranean lakes Effect Assessment
- European highest national consumption of P-based detergents

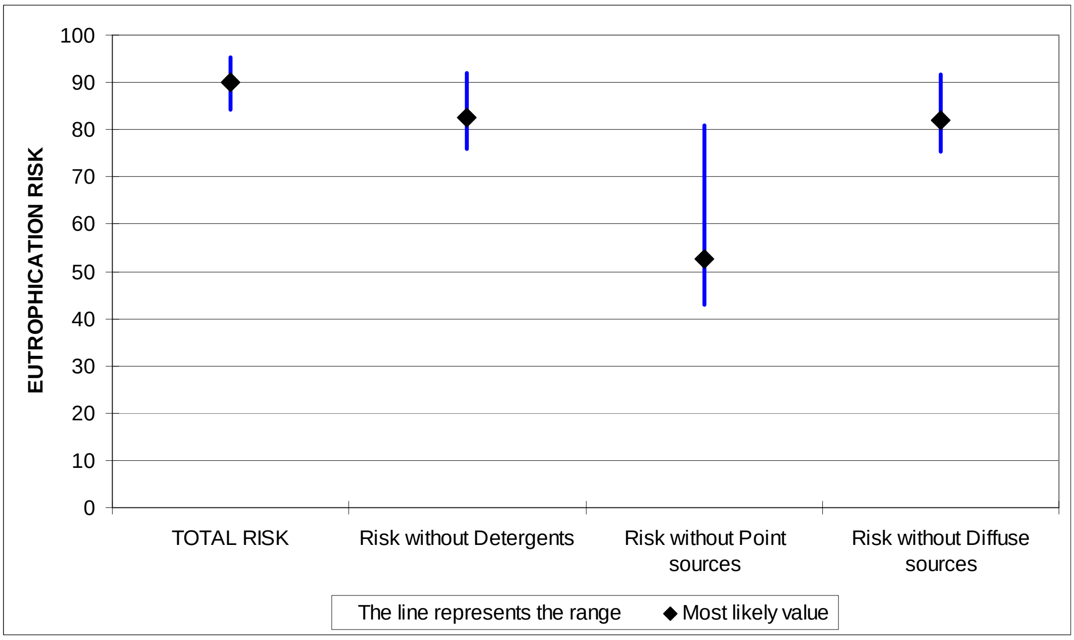
INPUTS		
	Units	**Figures**
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		***Units***		***Units***
TP total concentration	**546,3**	µg P/l	100	%
TP conc. from Detergents	**142,2**	µg P/l	26,0	%
TP conc. from Other Point sources	**253,9**	µg P/l	46,5	%
TP conc. from Diffuse sources	**150,2**	µg P/l	27,5	%

EUTROPHICATION RISK ESTIMATIONS				
	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	***Units***
TOTAL RISK	**95,4**	**84,1**	90,0	%
Risk without Detergents	**92,0**	**76,0**	82,4	%
Risk without Point sources	**81,0**	**43,0**	52,7	%
Risk without Diffuse sources	**91,8**	**75,3**	81,9	%



EXAMPLE 1d: Generic assessment based on:

- Average European values
- Atlantic Shallow lakes Effect Assessment
- European highest national consumption of P-based detergents

INPUTS

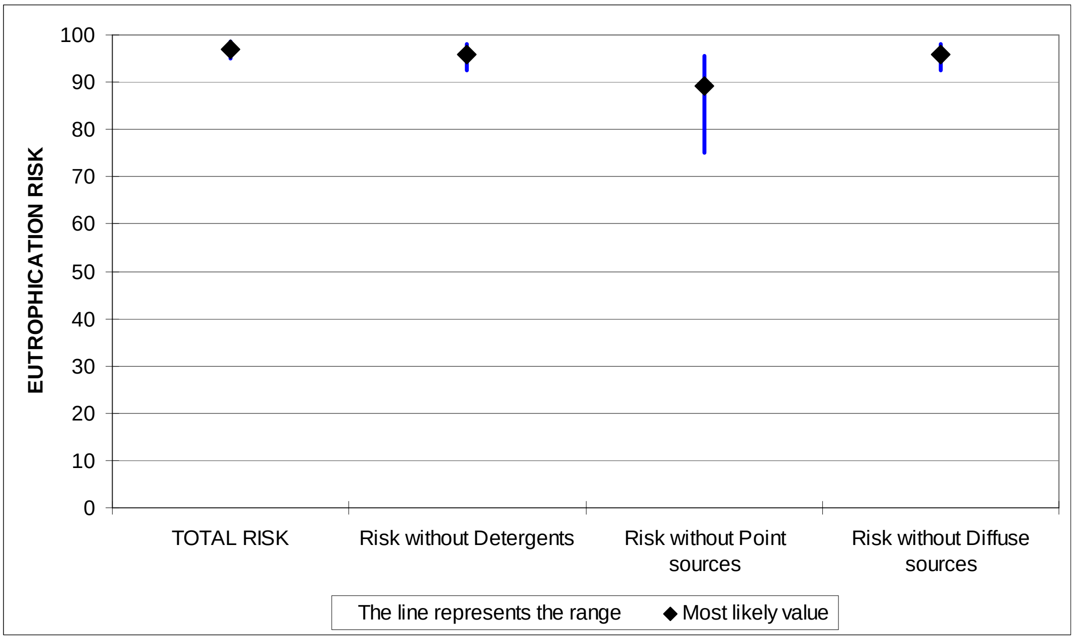
	Units	Figures
Scenario		ATLANTIC SHALLOW
Effect assessment distribution		4
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**546,3**	µg P/l	100	%
TP conc. from Detergents	**142,2**	µg P/l	26,0	%
TP conc. from Other Point sources	**253,9**	µg P/l	46,5	%
TP conc. from Diffuse sources	**150,2**	µg P/l	27,5	%

EUTROPHICATION RISK ESTIMATIONS				
	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**98,5**	**94,9**	96,9	%
Risk without Detergents	**98,1**	**92,6**	95,9	%
Risk without Point sources	**95,5**	**75,2**	89,2	%
Risk without Diffuse sources	**98,0**	**92,5**	95,9	%



EXAMPLE 2a: Generic assessment based on:

- 2 x average River Flow
- Mediterranean Effect Assessment
- European average consumption of P-based detergents

INPUTS

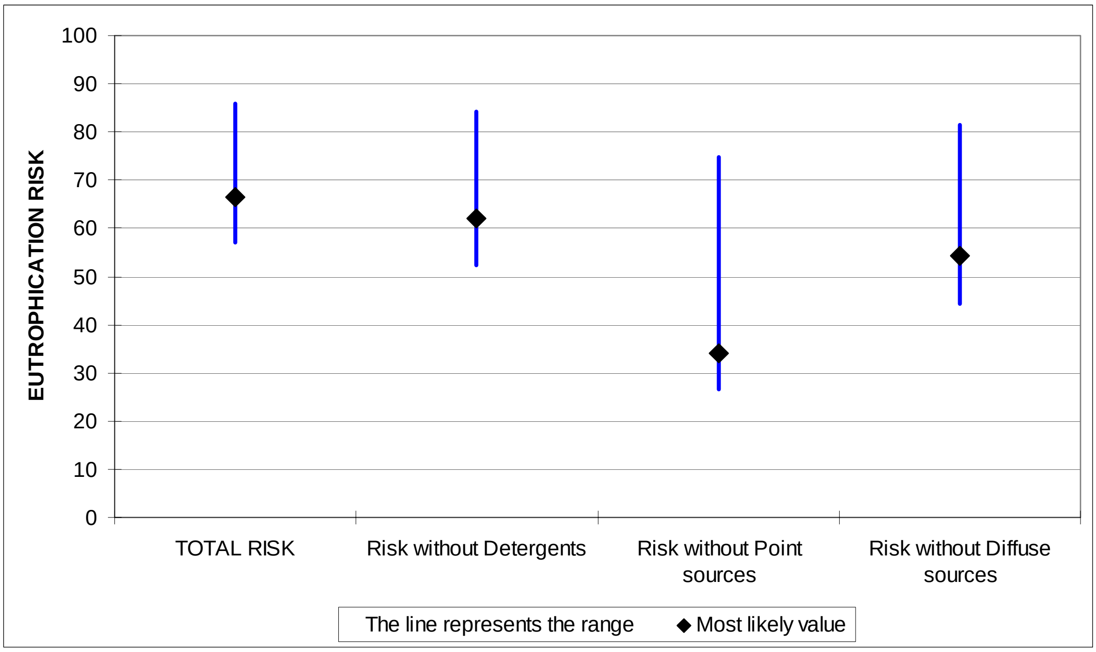
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**232,5**	µg P/l	100	%
TP conc. from Detergents	**30,5**	µg P/l	13,1	%
TP conc. from Other Point sources	**127,0**	µg P/l	54,6	%
TP conc. from Diffuse sources	**75,1**	µg P/l	32,3	%

EUTROPHICATION RISK ESTIMATIONS	1-p(TP | G+)	p(TP | G-)	mlp(G- | TP)	*Units*
TOTAL RISK	**85,9**	**56,9**	66,5	%
Risk without Detergents	**84,3**	**52,2**	62,1	%
Risk without Point sources	**74,7**	**26,5**	34,0	%
Risk without Diffuse sources	**81,5**	**44,4**	54,2	%



EXAMPLE 2b: Generic assessment based on:

- 2 x average River Flow
- Atlantic Shallow lakes Effect Assessment
- European average consumption of P-based detergents

INPUTS

	Units	Figures
Scenario		ATLANTIC SHALLOW
Effect assessment distribution		4
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

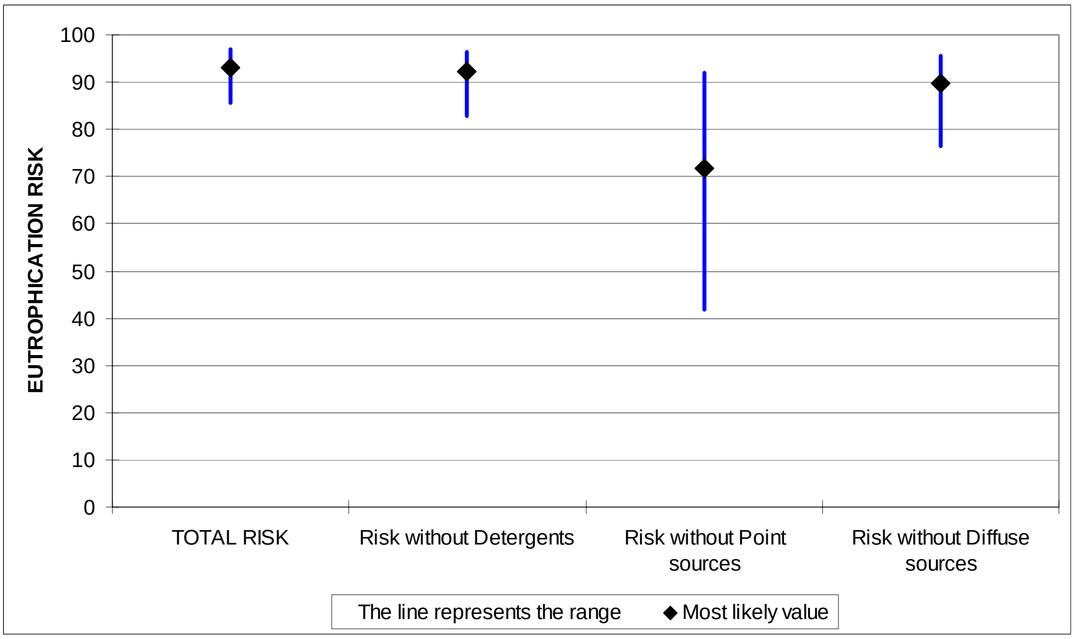
RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**232,5**	µg P/l	100	%
TP conc. from Detergents	**30,5**	µg P/l	13,1	%
TP conc. from Other Point sources	**127,0**	µg P/l	54,6	%
TP conc. from Diffuse sources	**75,1**	µg P/l	32,3	%

EUTROPHICATION RISK ESTIMATIONS

	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**96,9**	**85,5**	93,2	%
Risk without Detergents	**96,5**	**82,7**	92,1	%
Risk without Point sources	**91,9**	**41,7**	71,6	%
Risk without Diffuse sources	**95,7**	**76,5**	89,7	%



EXAMPLE 2c: Generic assessment based on:

- 2 x average River Flow
- Mediterranean lakes Effect Assessment
- European highest national consumption of P-based detergents

INPUTS

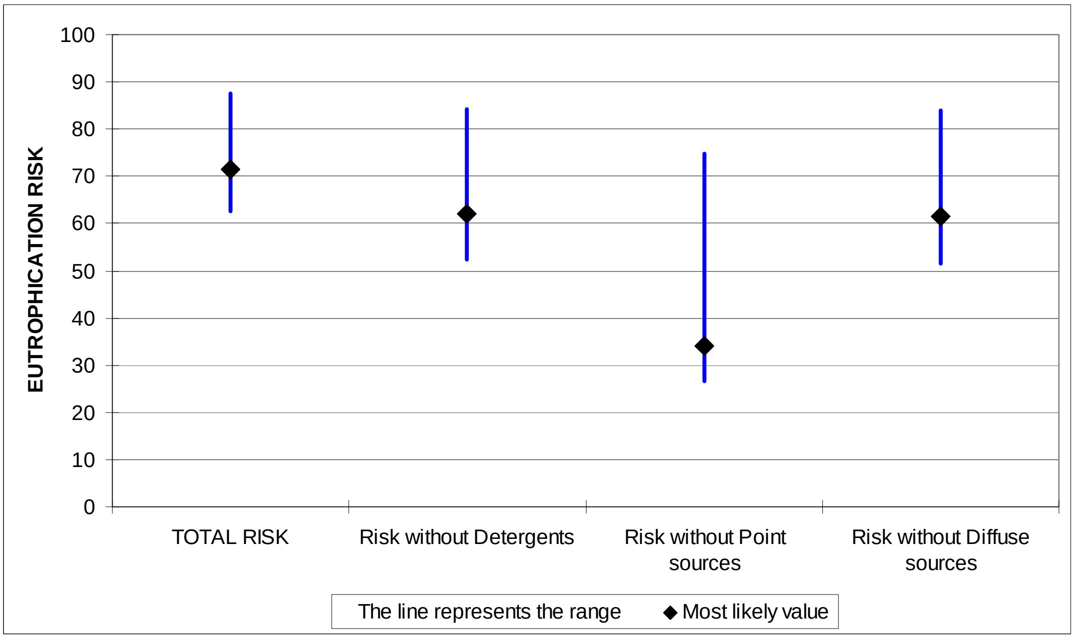
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**273,2**	µg P/l	100	%
TP conc. from Detergents	**71,1**	µg P/l	26,0	%
TP conc. from Other Point sources	**127,0**	µg P/l	46,5	%
TP conc. from Diffuse sources	**75,1**	µg P/l	27,5	%

EUTROPHICATION RISK ESTIMATIONS	**1-p(TP | G+)**	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**87,7**	**62,5**	71,4	%
Risk without Detergents	**84,3**	**52,2**	62,1	%
Risk without Point sources	**74,7**	**26,5**	34,0	%
Risk without Diffuse sources	**84,1**	**51,6**	61,5	%



EXAMPLE 2d: Generic assessment based on:

- 2 x average River Flow
- Atlantic Shallow lakes Effect Assessment
- European highest national consumption of P-based detergents

INPUTS

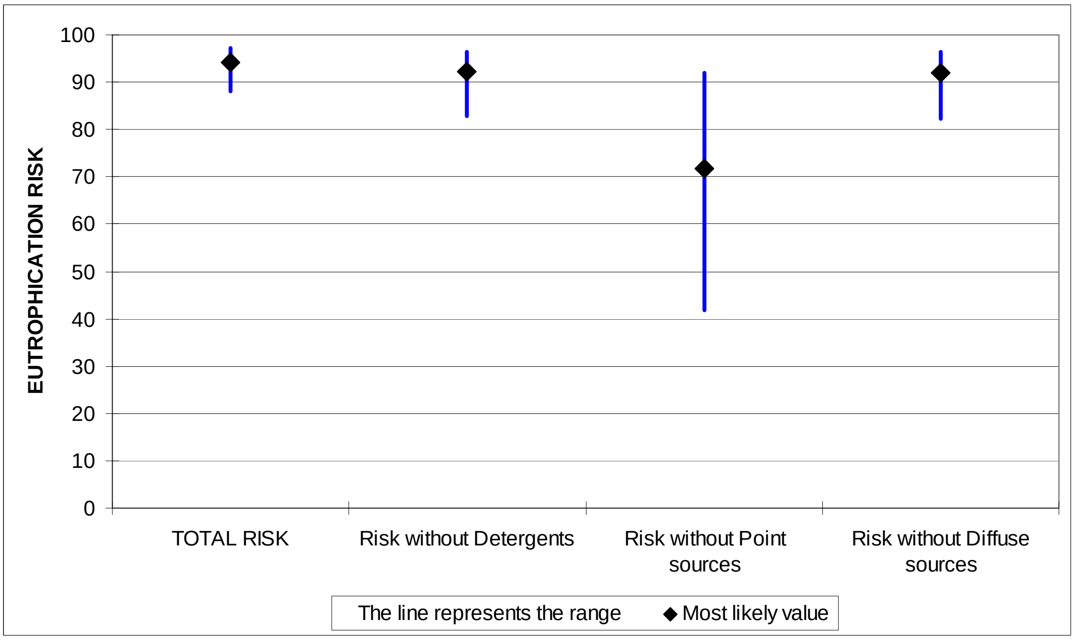
	Units	Figures
Scenario	ATLANTIC SHALLOW	
Effect assessment distribution		4
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**273,2**	µg P/l	100	%
TP conc. from Detergents	**71,1**	µg P/l	26,0	%
TP conc. from Other Point sources	**127,0**	µg P/l	46,5	%
TP conc. from Diffuse sources	**75,1**	µg P/l	27,5	%

EUTROPHICATION RISK ESTIMATIONS	1-p(TP | G+)	p(TP | G-)	mlp(G- | TP)	*Units*
TOTAL RISK	**97,3**	**88,1**	94,1	%
Risk without Detergents	**96,5**	**82,7**	92,1	%
Risk without Point sources	**91,9**	**41,7**	71,6	%
Risk without Diffuse sources	**96,4**	**82,3**	91,9	%



EXAMPLE 3a: Generic assessment based on:

- 1/3 x average Population density
- Mediterranean Effect Assessment
- European average consumption of P-based detergents

INPUTS

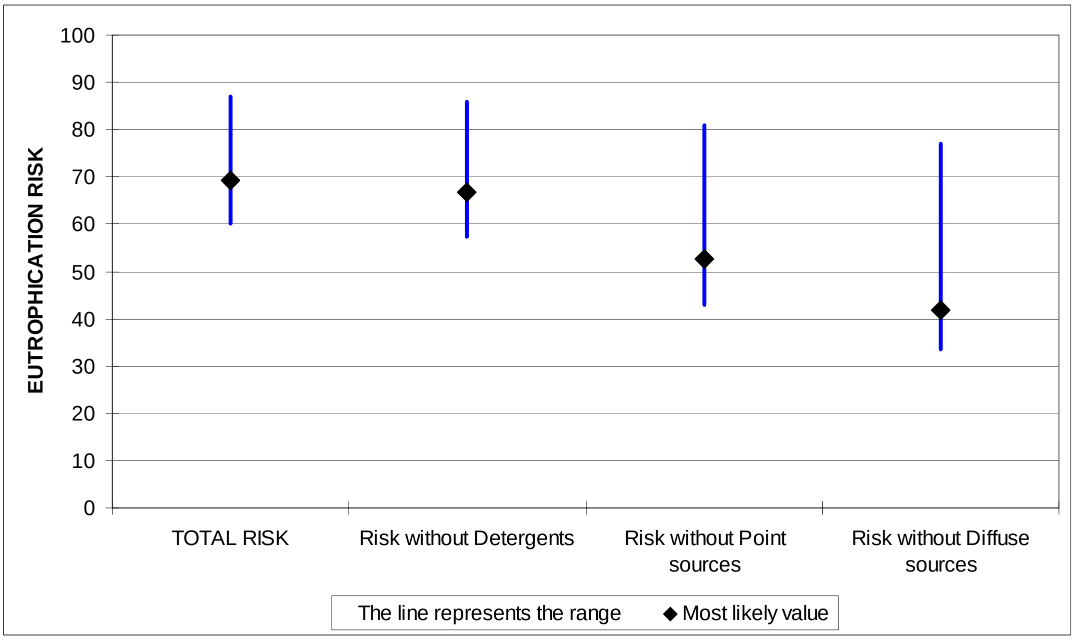
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**255,2**	µg P/l	100	%
TP conc. from Detergents	**20,3**	µg P/l	8,0	%
TP conc. from Other Point sources	**84,6**	µg P/l	33,2	%
TP conc. from Diffuse sources	**150,2**	µg P/l	58,9	%

EUTROPHICATION RISK ESTIMATIONS	1-p(TP | G+)	p(TP | G-)	mlp(G- | TP)	*Units*
TOTAL RISK	**86,9**	**60,1**	69,3	%
Risk without Detergents	**86,0**	**57,3**	66,8	%
Risk without Point sources	**81,0**	**43,0**	52,7	%
Risk without Diffuse sources	**77,0**	**33,6**	41,8	%



EXAMPLE 3b: Generic assessment based on:

- 1/3 x average Population density
- Atlantic Shallow Effect lakes Assessment
- European average consumption of P-based detergents

INPUTS

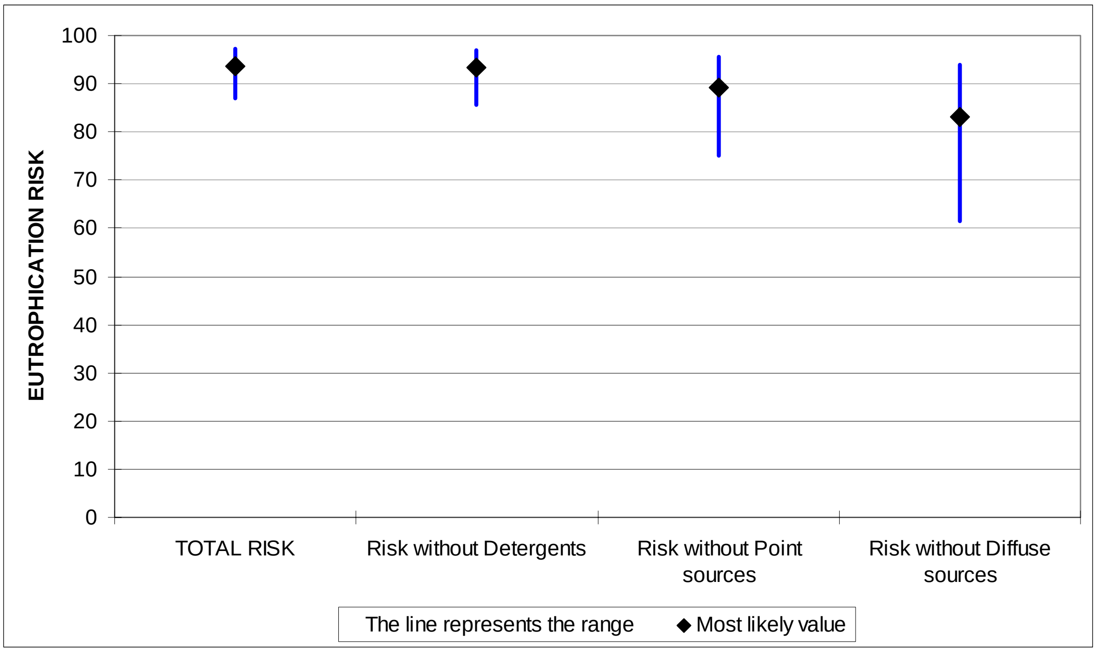
	Units	Figures
Scenario	ATLANTIC SHALLOW	
Effect assessment distribution		4
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**255,2**	µg P/l	100	%
TP conc. from Detergents	**20,3**	µg P/l	8,0	%
TP conc. from Other Point sources	**84,6**	µg P/l	33,2	%
TP conc. from Diffuse sources	**150,2**	µg P/l	58,9	%

EUTROPHICATION RISK ESTIMATIONS				
	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	***Units***
TOTAL RISK	**97,1**	**87,1**	93,8	%
Risk without Detergents	**96,9**	**85,7**	93,2	%
Risk without Point sources	**95,5**	**75,2**	89,2	%
Risk without Diffuse sources	**93,9**	**61,4**	83,2	%



EXAMPLE 3c: Generic assessment based on:

- 1/3 x average Population density
- Mediterranean Effect Assessment
- European highest national consumption of P-based detergents

INPUTS

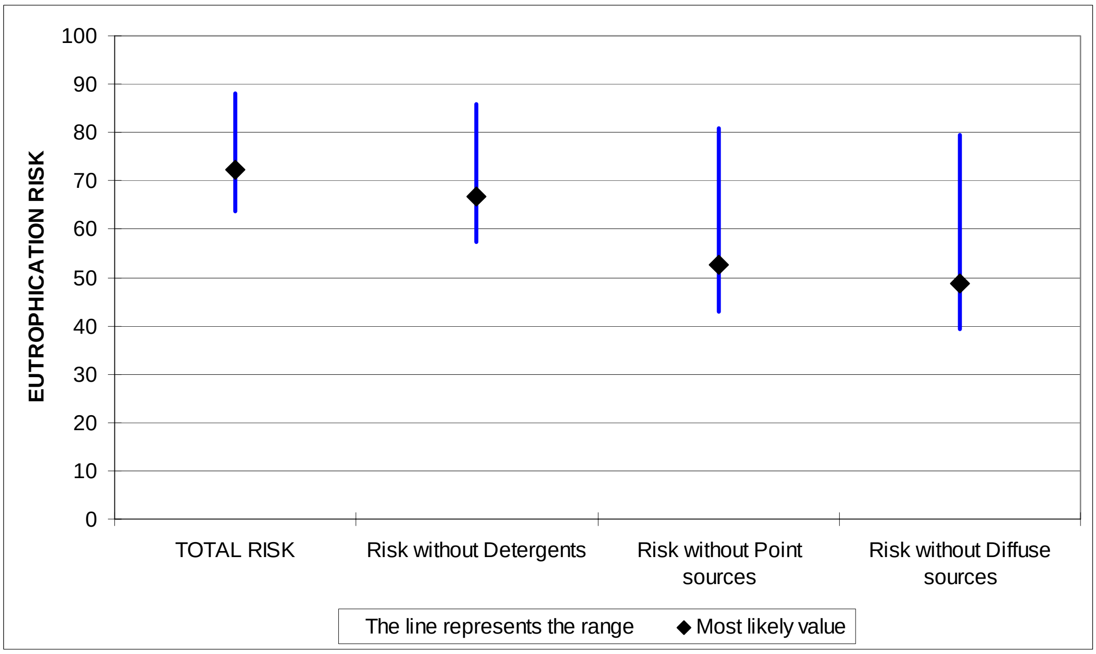
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		***Units***		***Units***
TP total concentration	**282,3**	µg P/l	100	%
TP conc. from Detergents	**47,4**	µg P/l	16,8	%
TP conc. from Other Point sources	**84,6**	µg P/l	30,0	%
TP conc. from Diffuse sources	**150,2**	µg P/l	53,2	%

EUTROPHICATION RISK ESTIMATIONS				
	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	***Units***
TOTAL RISK	**88,0**	**63,6**	72,3	%
Risk without Detergents	**86,0**	**57,3**	66,8	%
Risk without Point sources	**81,0**	**43,0**	52,7	%
Risk without Diffuse sources	**79,5**	**39,4**	48,7	%



EXAMPLE 3d: Generic assessment based on:

- 1/3 x average Population density
- Atlantic Shallow lakes Effect Assessment
- European highest national consumption of P-based detergents

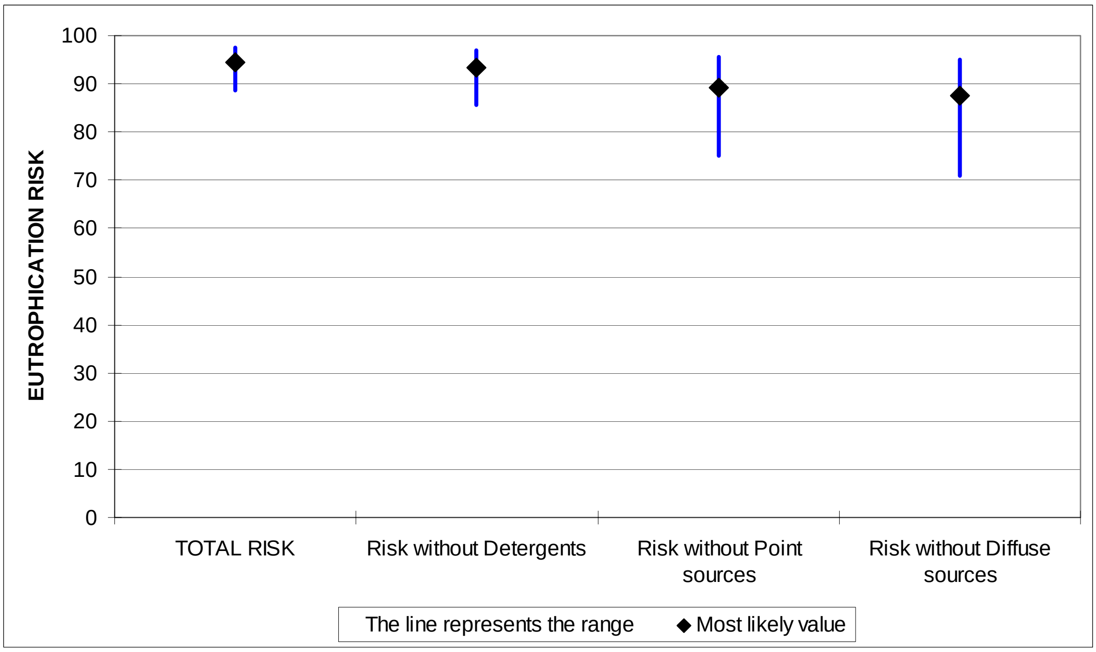
INPUTS		
	Units	**Figures**
Scenario	ATLANTIC SHALLOW	
Effect assessment distribution		4
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**282,3**	µg P/l	100	%
TP conc. from Detergents	**47,4**	µg P/l	16,8	%
TP conc. from Other Point sources	**84,6**	µg P/l	30,0	%
TP conc. from Diffuse sources	**150,2**	µg P/l	53,2	%

EUTROPHICATION RISK ESTIMATIONS				
	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**97,4**	**88,6**	94,3	%
Risk without Detergents	**96,9**	**85,7**	93,2	%
Risk without Point sources	**95,5**	**75,2**	89,2	%
Risk without Diffuse sources	**95,0**	**70,9**	87,4	%



EXAMPLE 4a: Generic assessment based on:

- 1/3 x average Population density and low agricultural intensity
- Mediterranean Effect Assessment
- European average consumption of P-based detergents

INPUTS

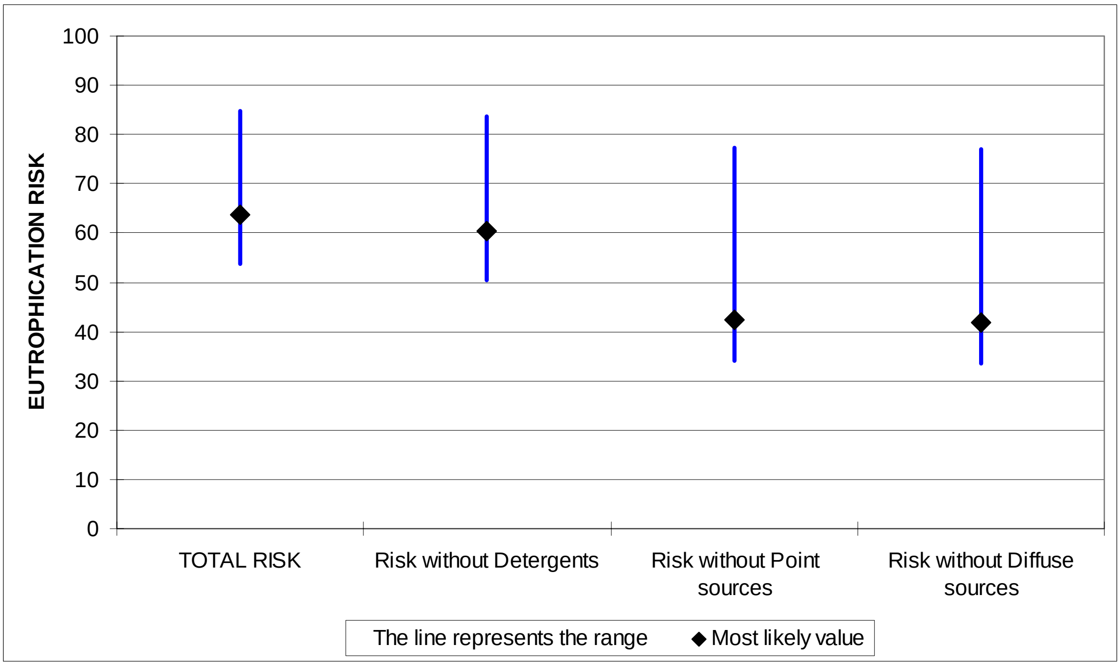
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	10
LandusePasture	%	30
LanduseForest	%	50
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**212,0**	µg P/l	100	%
TP conc. from Detergents	**20,3**	µg P/l	9,6	%
TP conc. from Other Point sources	**84,6**	µg P/l	39,9	%
TP conc. from Diffuse sources	**107,0**	µg P/l	50,5	%

EUTROPHICATION RISK ESTIMATIONS	**1-p(TP | G+)**	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**84,8**	**53,8**	63,6	%
Risk without Detergents	**83,7**	**50,5**	60,4	%
Risk without Point sources	**77,2**	**34,0**	42,4	%
Risk without Diffuse sources	**77,0**	**33,6**	41,8	%



EXAMPLE 4b: Generic assessment based on:

- 1/3 x average Population density and low agricultural intensity
- Atlantic Shallow lakes Effect Assessment
- European average consumption of P-based detergents

INPUTS

	Units	Figures
Scenario		ATLANTIC SHALLOW
Effect assessment distribution		4
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	10
LandusePasture	%	30
LanduseForest	%	50
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	20
Sites with non-good status	%	33

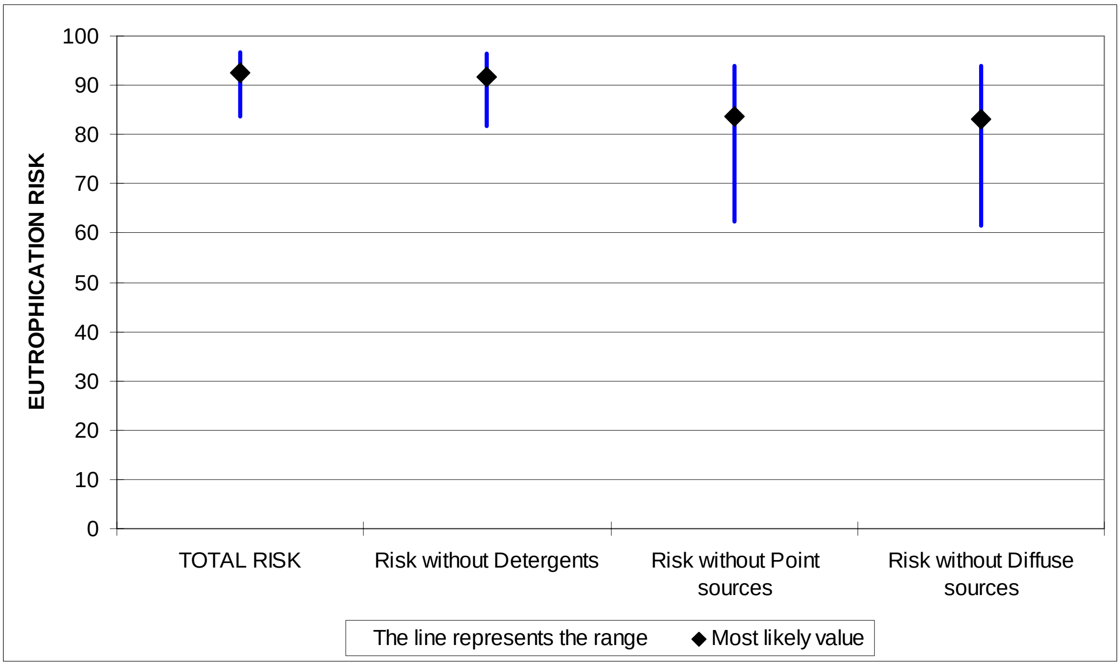
RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**212,0**	µg P/l	100	%
TP conc. from Detergents	**20,3**	µg P/l	9,6	%
TP conc. from Other Point sources	**84,6**	µg P/l	39,9	%
TP conc. from Diffuse sources	**107,0**	µg P/l	50,5	%

EUTROPHICATION RISK ESTIMATIONS

	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**96,7**	**83,7**	92,5	%
Risk without Detergents	**96,3**	**81,6**	91,7	%
Risk without Point sources	**94,0**	**62,3**	83,6	%
Risk without Diffuse sources	**93,9**	**61,4**	83,2	%



EXAMPLE 4c: Generic assessment based on:

- 1/3 x average Population density and low agricultural intensity
- Mediterranean Effect Assessment
- European highest national consumption of P-based detergents

INPUTS

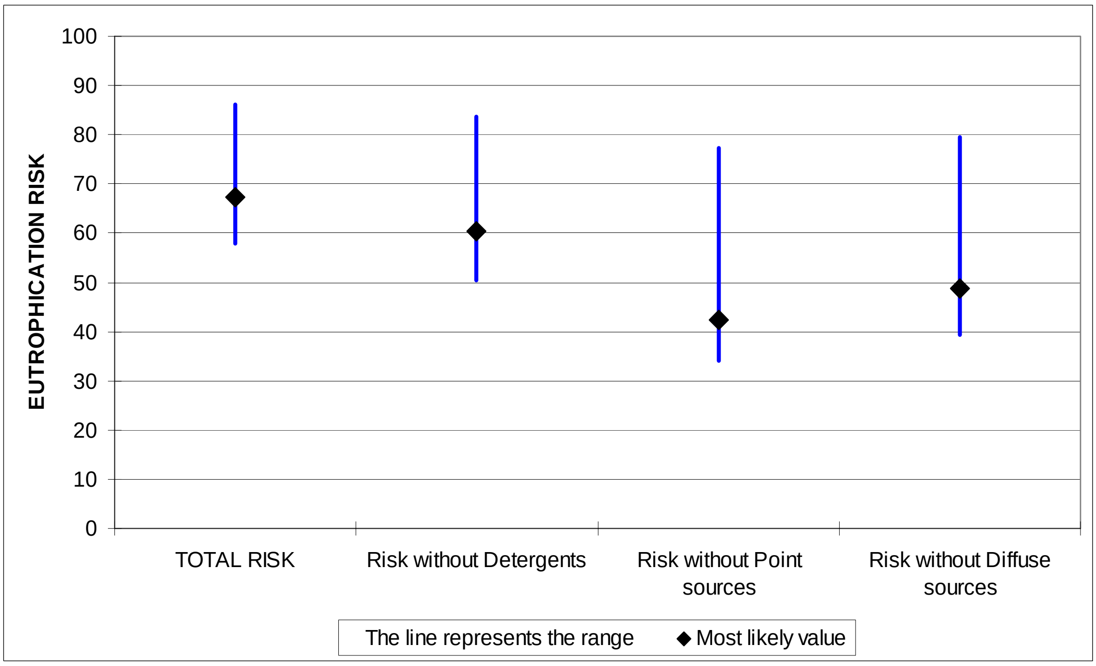
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	10
LandusePasture	%	30
LanduseForest	%	50
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**239,1**	µg P/l	100	%
TP conc. from Detergents	**47,4**	µg P/l	19,8	%
TP conc. from Other Point sources	**84,6**	µg P/l	35,4	%
TP conc. from Diffuse sources	**107,0**	µg P/l	44,8	%

EUTROPHICATION RISK ESTIMATIONS	1-p(TP | G+)	p(TP | G-)	mlp(G- | TP)	*Units*
TOTAL RISK	**86,2**	**57,9**	67,3	%
Risk without Detergents	**83,7**	**50,5**	60,4	%
Risk without Point sources	**77,2**	**34,0**	42,4	%
Risk without Diffuse sources	**79,5**	**39,4**	48,7	%



EXAMPLE 4d: Generic assessment based on:

- 1/3 x average Population density and low agricultural intensity
- Atlantic Shallow lakes Assessment
- European highest national consumption of P-based detergents

INPUTS

	Units	Figures
Scenario	ATLANTIC SHALLOW	
Effect assessment distribution		4
PopulationDensity	person/ha	0,39
CatchmentArea	ha	10000000
RiverFlow	m^3/s	640
LanduseArableLand	%	10
LandusePasture	%	30
LanduseForest	%	50
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	20
Sites with non-good status	%	33

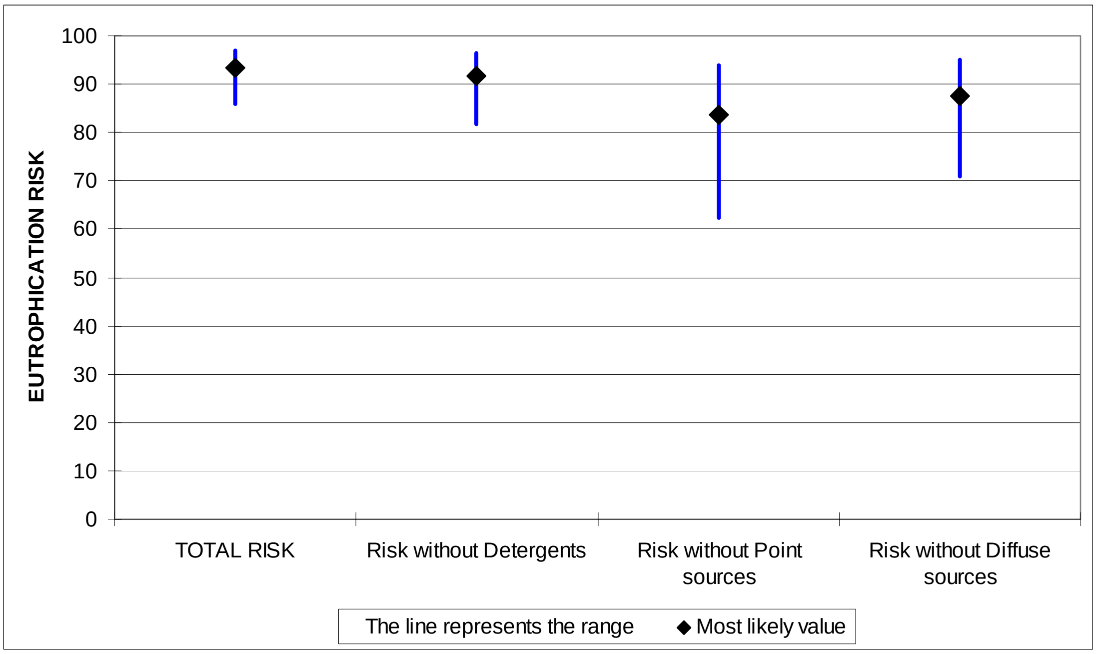
RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**239,1**	µg P/l	100	%
TP conc. from Detergents	**47,4**	µg P/l	19,8	%
TP conc. from Other Point sources	**84,6**	µg P/l	35,4	%
TP conc. from Diffuse sources	**107,0**	µg P/l	44,8	%

EUTROPHICATION RISK ESTIMATIONS

	1-p(TP | G+)	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**97,0**	**86,0**	93,3	%
Risk without Detergents	**96,3**	**81,6**	91,7	%
Risk without Point sources	**94,0**	**62,3**	83,6	%
Risk without Diffuse sources	**95,0**	**70,9**	87,4	%



EXAMPLE 5a: Generic assessment based on:

- 2 x average River Flow
- Mediterranean Effect Assessment
- European average consumption of P-based detergents
- 3 x Current P reduction at STP

INPUTS

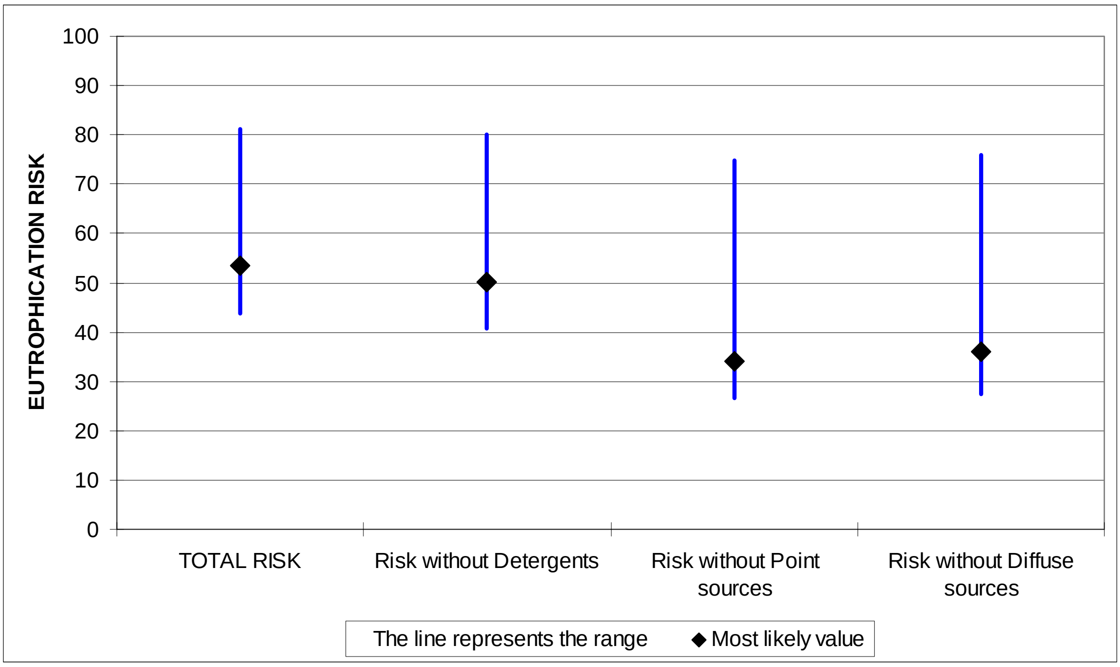
	Units	Figures
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	60
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**153,8**	µg P/l	100	%
TP conc. from Detergents	**15,2**	µg P/l	9,9	%
TP conc. from Other Point sources	**63,5**	µg P/l	41,3	%
TP conc. from Diffuse sources	**75,1**	µg P/l	48,8	%

EUTROPHICATION RISK ESTIMATIONS	1-p(TP | G+)	p(TP | G-)	mlp(G- | TP)	*Units*
TOTAL RISK	**81,2**	**43,7**	53,4	%
Risk without Detergents	**80,1**	**40,7**	50,2	%
Risk without Point sources	**74,7**	**26,5**	34,0	%
Risk without Diffuse sources	**75,9**	**27,4**	35,9	%



EXAMPLE 5b: Generic assessment based on:

- 2 x average River Flow
- Atlantic Shallow lakes Effect Assessment
- European average consumption of P-based detergents
- 3 x Current P reduction at STP

INPUTS

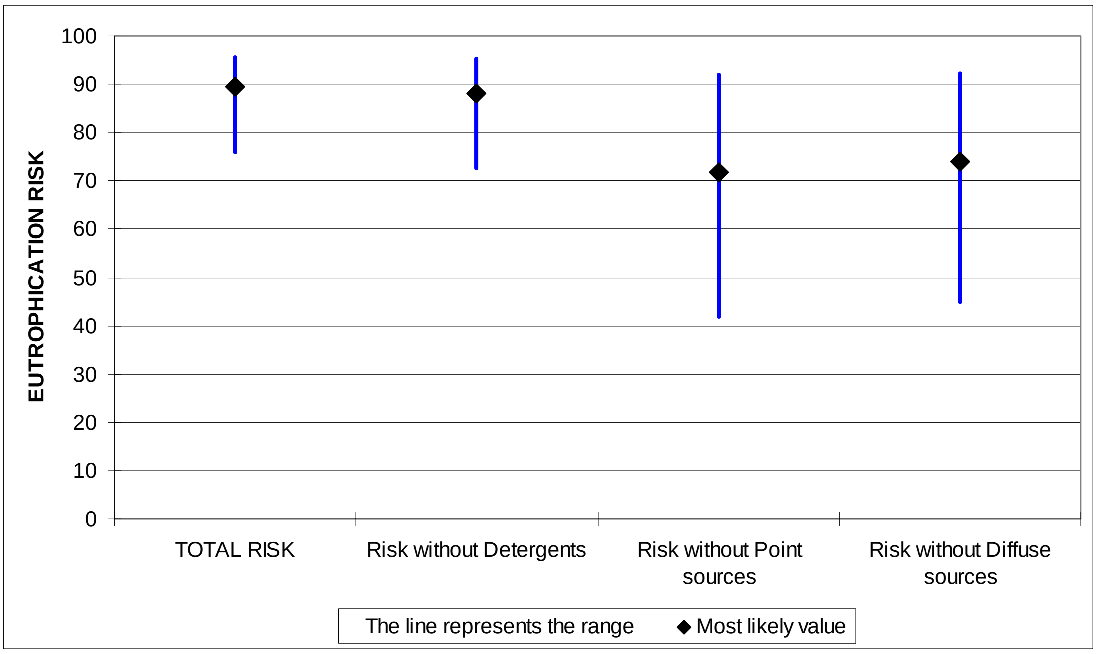
	Units	Figures
Scenario	ATLANTIC SHALLOW	
Effect assessment distribution		4
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,36
Current P reduction at STP	%	60
Sites with non-good status	%	33

RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		*Units*		*Units*
TP total concentration	**153,8**	µg P/l	100	%
TP conc. from Detergents	**15,2**	µg P/l	9,9	%
TP conc. from Other Point sources	**63,5**	µg P/l	41,3	%
TP conc. from Diffuse sources	**75,1**	µg P/l	48,8	%

EUTROPHICATION RISK ESTIMATIONS	**1-p(TP | G+)**	**p(TP | G-)**	**mlp(G- | TP)**	*Units*
TOTAL RISK	**95,6**	**75,9**	89,5	%
Risk without Detergents	**95,2**	**72,6**	88,1	%
Risk without Point sources	**91,9**	**41,7**	71,6	%
Risk without Diffuse sources	**92,2**	**45,0**	73,9	%



EXAMPLE 5c: Generic assessment based on:

- 2 x average River Flow
- Mediterranean lakes Effect Assessment
- European highest national consumption of P-based detergents
- 3 x Current P reduction at STP

INPUTS

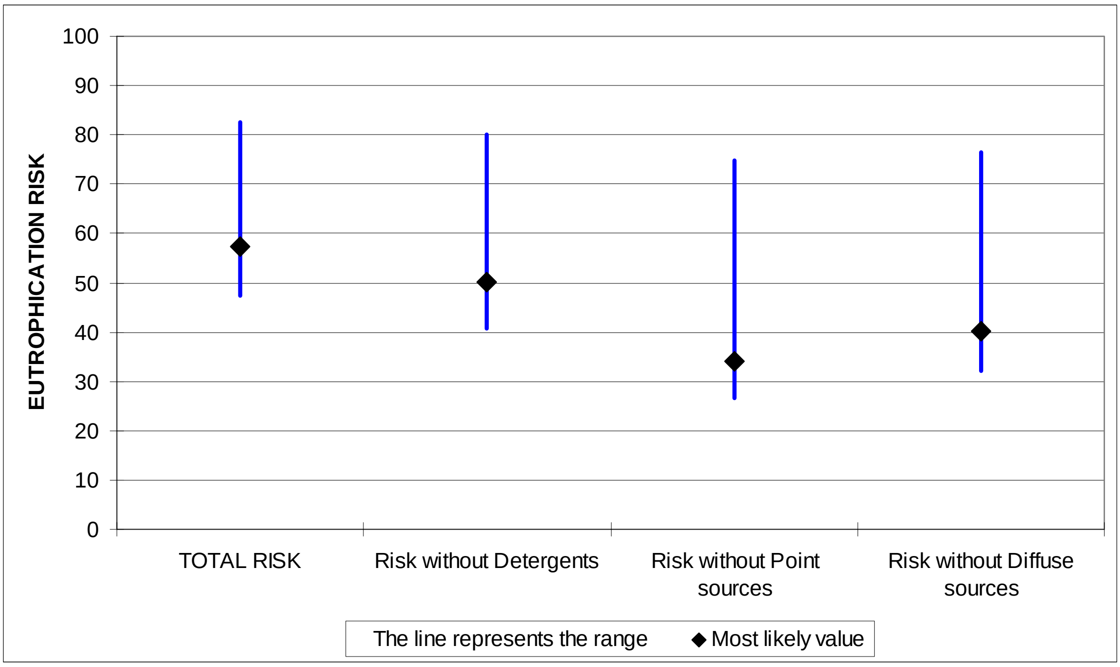
	Units	**Figures**
Scenario	MEDITERRANEAN	
Effect assessment distribution		2
PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	60
Sites with non-good status	%	33

RESULTS

MEDITERRANEAN

PREDICTED EXPOSURE LEVELS		***Units***		***Units***
TP total concentration	**174,1**	µg P/l	100	%
TP conc. from Detergents	**35,5**	µg P/l	20,4	%
TP conc. from Other Point sources	**63,5**	µg P/l	36,5	%
TP conc. from Diffuse sources	**75,1**	µg P/l	43,1	%

EUTROPHICATION RISK ESTIMATIONS	**1-p(TP | G+)**	**p(TP | G-)**	**mlp(G- | TP)**	***Units***
TOTAL RISK	**82,6**	**47,5**	57,4	%
Risk without Detergents	**80,1**	**40,7**	50,2	%
Risk without Point sources	**74,7**	**26,5**	34,0	%
Risk without Diffuse sources	**76,3**	**32,2**	40,1	%



EXAMPLE 5d: Generic assessment based on:

- 2 x average River Flow
- Atlantic Shallow lakes Effect Assessment
- European highest national consumption of P-based detergents
- 3 x Current P reduction at STP

INPUTS

	Units	Figures
Scenario	ATLANTIC SHALLOW	
Effect assessment distribution		4

PopulationDensity	person/ha	1,17
CatchmentArea	ha	10000000
RiverFlow	m^3/s	1280
LanduseArableLand	%	26
LandusePasture	%	26
LanduseForest	%	38
LanduseOther	%	10

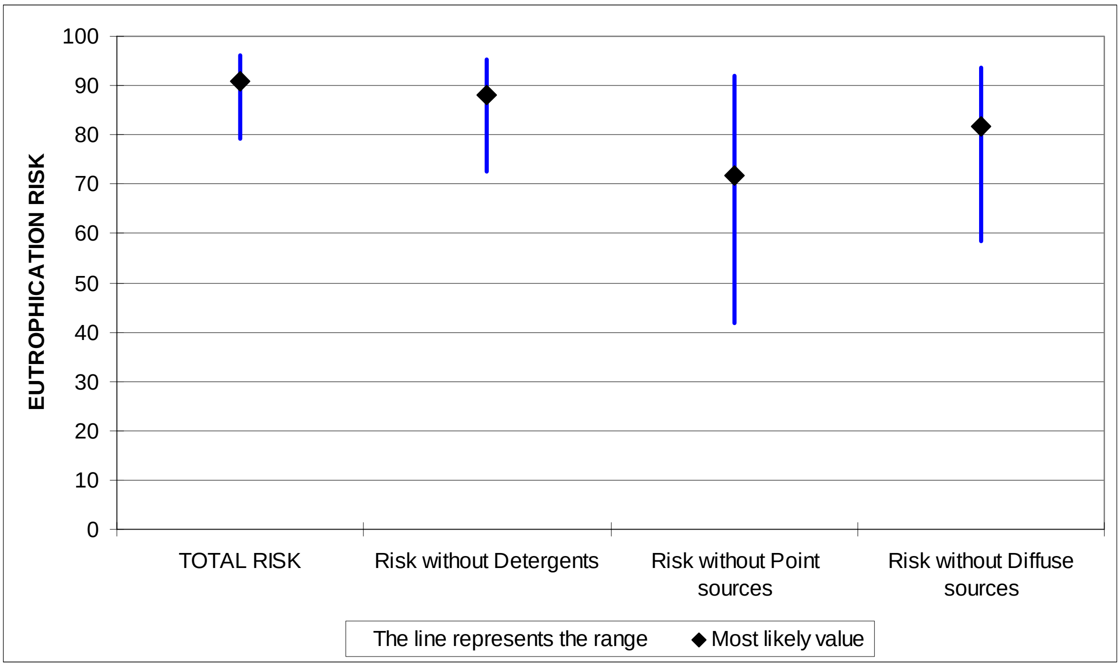
ArableLand coefficient	kg/ha/year	0,66
Pasture coefficient	kg/ha/year	0,4
Forest coefficient	kg/ha/year	0,02
Other uses coefficient	kg/ha/year	0,2
P emission from Population	g/person/day	1,5
P emission from Detergents	g/person/day	0,84
Current P reduction at STP	%	60
Sites with non-good status	%	33

RESULTS

ATLANTIC SHALLOW

PREDICTED EXPOSURE LEVELS		***Units***		***Units***
TP total concentration	**174,1**	µg P/l	100	%
TP conc. from Detergents	**35,5**	µg P/l	20,4	%
TP conc. from Other Point sources	**63,5**	µg P/l	36,5	%
TP conc. from Diffuse sources	**75,1**	µg P/l	43,1	%

EUTROPHICATION RISK ESTIMATIONS	**1-p(TP | G+)**	**p(TP | G-)**	**mlp(G- | TP)**	***Units***
TOTAL RISK	**96,0**	**79,3**	90,8	%
Risk without Detergents	**95,2**	**72,6**	88,1	%
Risk without Point sources	**91,9**	**41,7**	71,6	%
Risk without Diffuse sources	**93,6**	**58,5**	81,8	%



PROBABILISTIC IMPLEMENTATION

The probabilistic model implementation has been done by using Crystal Ball software for conducting a Monte Carlo analysis.

The following input values have been transformed into distributions:

- Population density: triangular distribution based on minimum (Finland), EU average and maximum (The Netherlands, Malta has been excluded).

- River flow: triangular distribution of the flow to area ratio based on minimum, average and maximum from Figure 2

- P contribution from P metabolism: normal distribution

- P contribution from domestic detergents: triangular distribution based zero use of P-base detergents, EU average, and maximum contribution (Hungary, Slovak Republic has been excluded because it is not a representative country situation for EU-25))

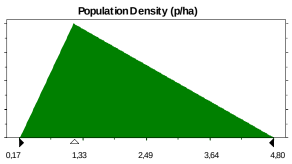
- P reduction at STP: The employed distribution: triangular distribution based on minimum (Greece), EU average, and maximum for countries allowing P-based detergents (Denmark).

The distributions are presented below:

Assumption: Population Density (p/ha)

Triangular distribution with parameters:

Minimum	0.17
Likeliest	1.17
Maximum	4.80

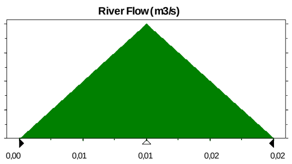


Selected range is from 0.17 to 4.80

Assumption: Ratio River Flow / Catchment area

Triangular distribution with parameters:

Minimum	0.0021
Likeliest	0.0064
Maximum	0.0191

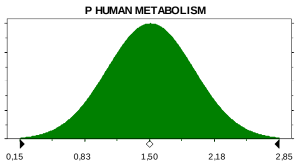


Selected range is from 0.0021 to 0.0191

Assumption: P from Human metabolism (g/person/day)

Normal distribution with parameters:

Mean	1.50
Standard Dev.	0.45

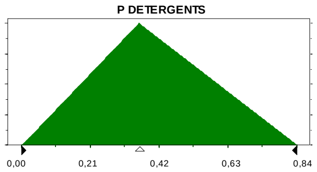


Selected range is from -Infinity to +Infinity

Assumption: P from Detergents (g/person/day)

Triangular distribution with parameters:

Minimum	0.00
Likeliest	0.36
Maximum	0.84

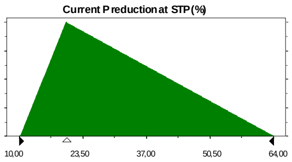


Selected range is from 0.00 to 1.21

Assumption: Current P reduction at STP (%)

Triangular distribution with parameters:

Minimum	10.00
Likeliest	20.00
Maximum	64.00



Selected range is from 10.00 to 64.00

The probabilistic results using the Mediterranean effect assessment distributions are presented in the Figures below.

For each assessment the risk is presented as a distribution range with a mlp estimation. The results obtained for the total risk and the risk without P-based detergents is presented in Figures 30 and 31.

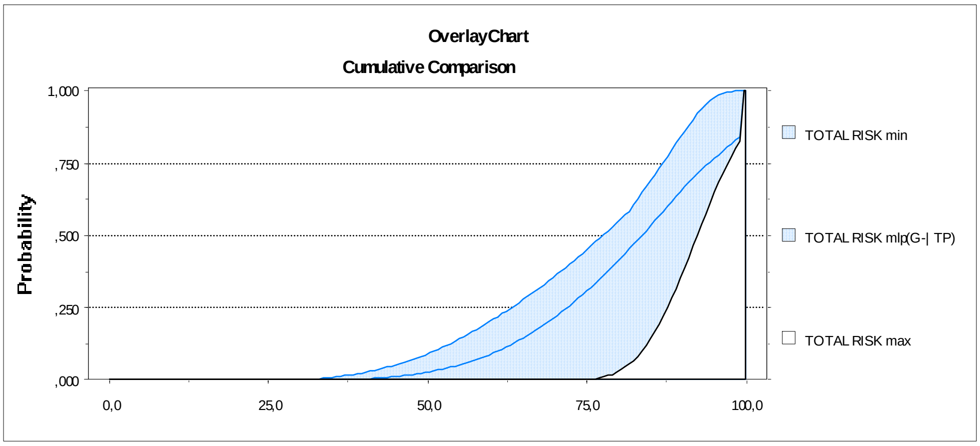


Figure 30. Probabilistic estimation of the Total Eutrophication risk using the Mediterranean effects assessment scenario. Max and min represents the upper and lower bounds for the estimated risk range (represented by the dotted area). The internal line represents the most likely probability distribution.

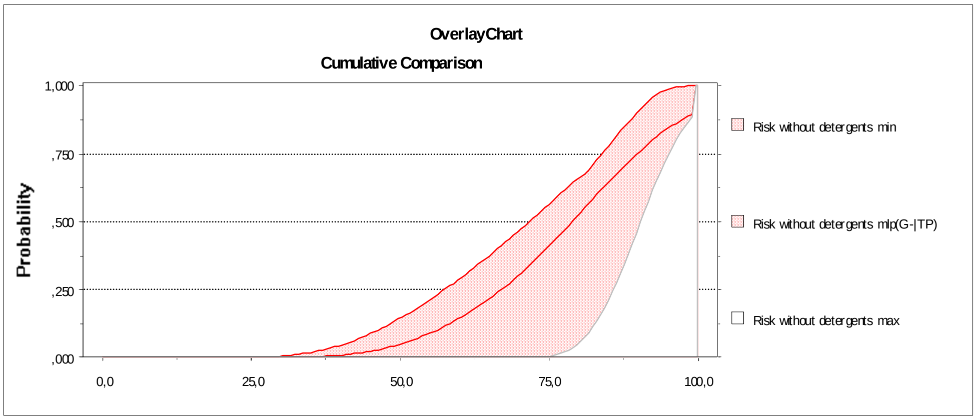


Figure 31. Probabilistic estimation of the Eutrophication risk without P-Detergent contribution using the Mediterranean effects assessment scenario. Max and min represents the upper and lower bounds for the estimated risk range (represented by the dotted area). The internal line represents the most likely probability distribution.

The estimated contribution for P-based detergents can be estimated from the differences between the ranges, and between the mlp distributions. These comparisons are presented in Figures 32 and 33.

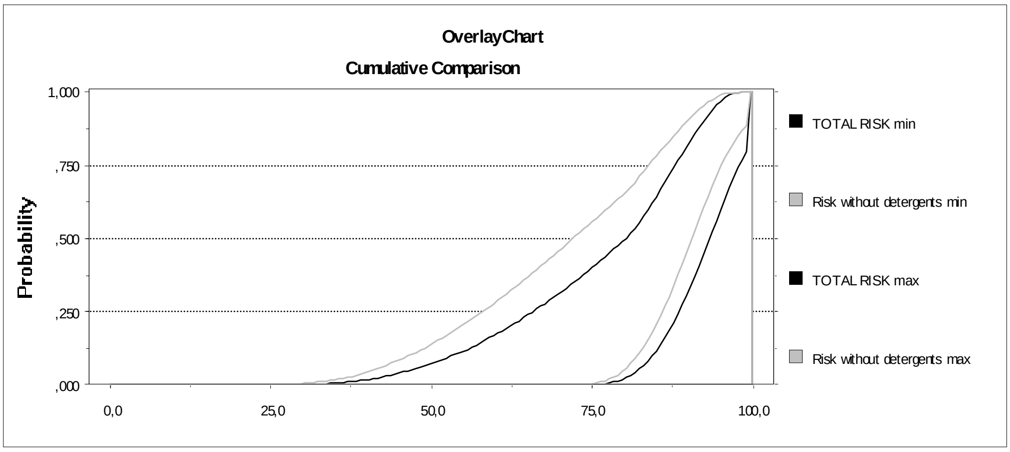


Figure 32. Mediterranean effects assessment scenario. Comparison between "Total Eutrophication Risk" (black lines) and "Eutrophication Risk without P-Detergent contribution" (grey lines) ranges. Max and min represents the upper and lower bounds respectively.

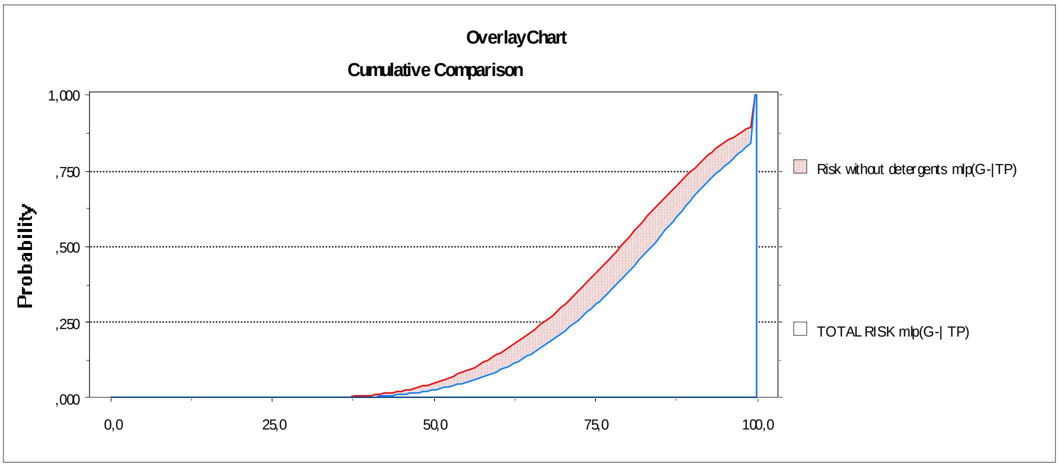


Figure 33. Mediterranean effects assessment scenario. The dotted area represents the difference between the estimations for the "Total Eutrophication Risk" (blue line) and for the "Eutrophication Risk without P-Detergent contribution" (red line) most likely probability (mlp) distributions.

The same approach has been applied using the Atlantic-N&Central shallow lakes effect assessment. The results are presented in Figures 34 to 37.

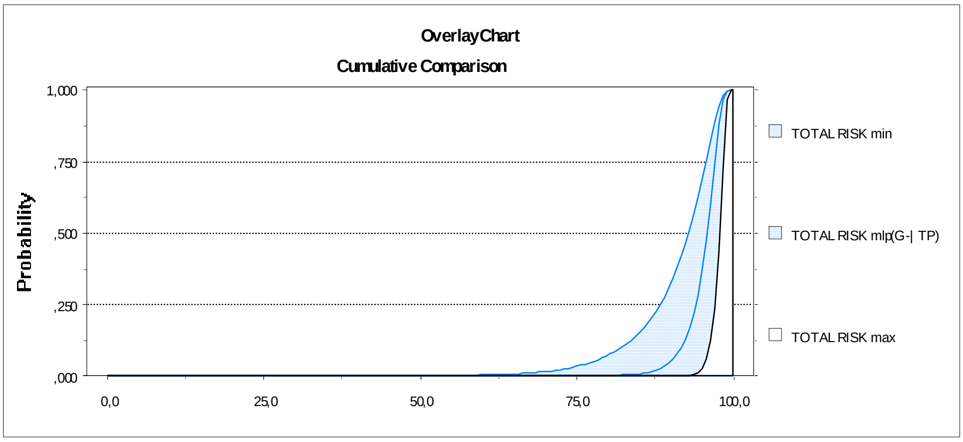


Figure 34. Probabilistic estimation of the Total Eutrophication risk using the Atlantic-N&Central shallow effects assessment scenario. Max and min represents the upper and lower bounds for the estimated risk range (represented by the dotted area). The internal line represents the most likely probability distribution.

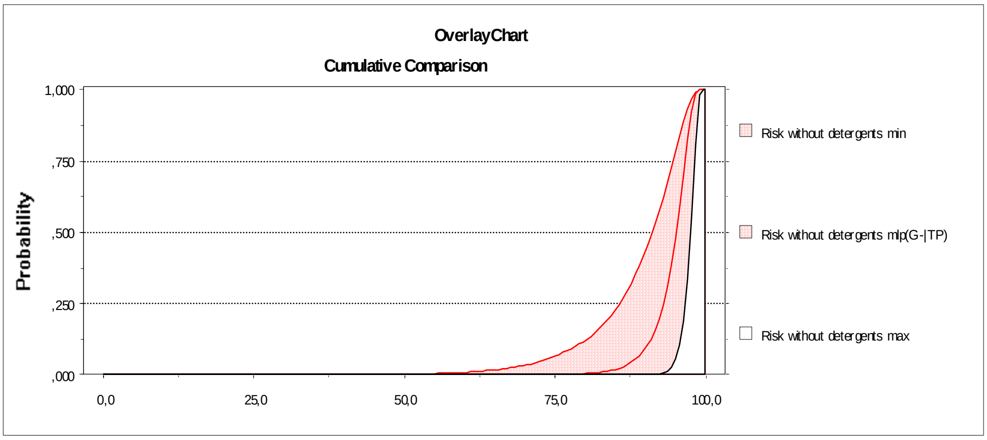


Figure 35. Probabilistic estimation of the Eutrophication risk without P-Detergent contribution using the Atlantic-N&Central shallow effects assessment scenario. Max and min represents the upper and lower bounds for the estimated risk range (represented by the dotted area). The internal line represents the most likely probability distribution.

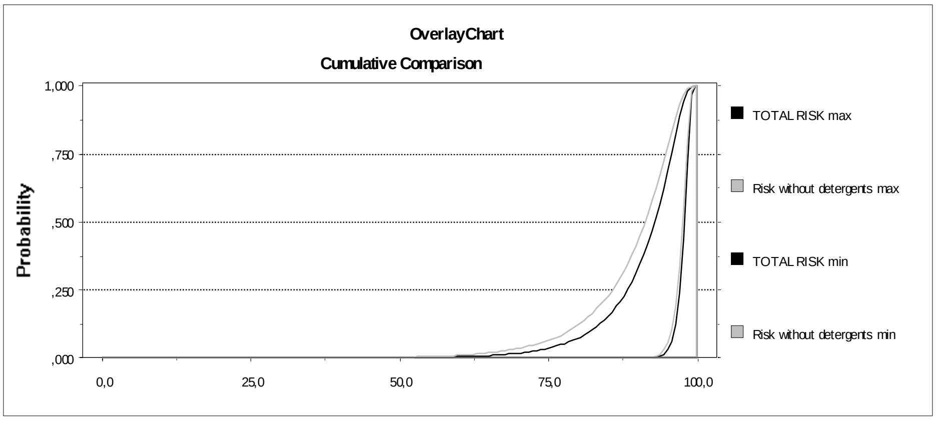


Figure 36. Atlantic-N&Central shallow effects assessment scenario. Comparison between "Total Eutrophication Risk" (black lines) and "Eutrophication Risk without P-Detergent contribution" (grey lines) ranges. Max and min represents the upper and lower bounds respectively.

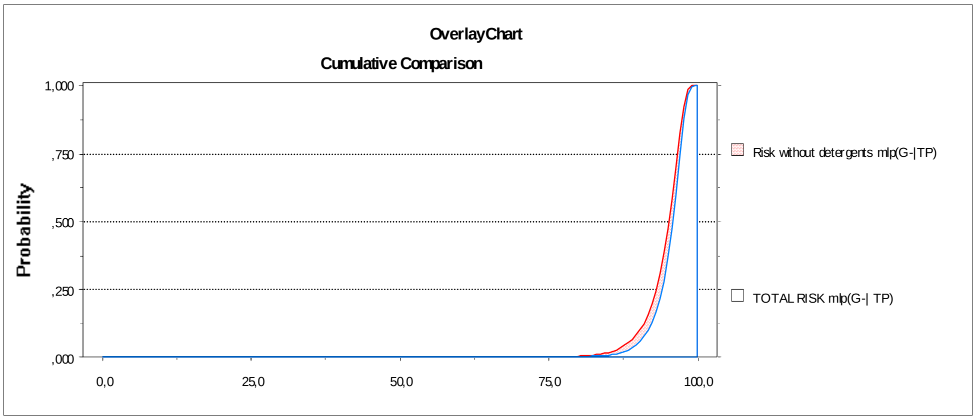


Figure 37. Atlantic-N&Central shallow effects assessment scenario. The dotted area represents the difference between the estimations for the "Total Eutrophication Risk" (blue line) and for the "Eutrophication Risk without P-Detergent contribution" (red line) most likely probability (mlp) distributions.

The sensitivity analysis charts for the former calculations are presented in Figures 38 and 39.

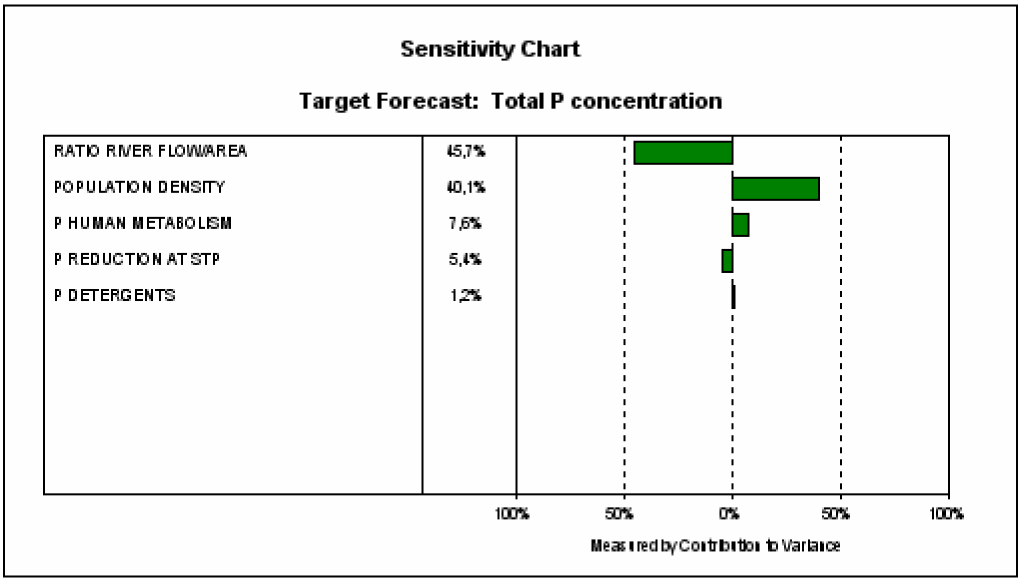


Figure 38. Mediterranean effects assessment scenario. Sensitivity analysis chart for TP concentration.

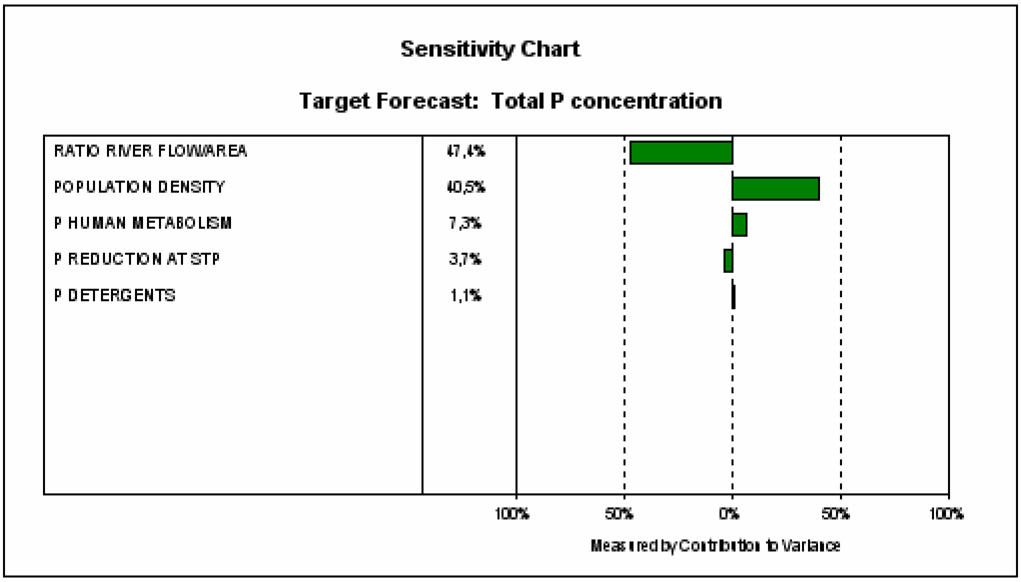


Figure 39. Atlantic-N&Central shallow effects assessment scenario. Sensitivity analysis chart for TP concentration.

The figures represent a pan-European risk assessment scenario, and it must be considered that the risk contribution from P-based detergents offers large differences among different regions and river basins, as demonstrated by the large proportion of the variance associated to the ration between the river flow and the catchment areas, and by the population density. The contribution of P-based detergents represents around 1.1 to 1.2 % of the total variance.

DISCUSSION OF THE RESULTS AND CONCLUSIONS

The results presented in this report offer a new conceptual model for assessing the potential eutrophication risk associated to nutrient emissions and, in particular, to P. The exposure assessment is simple: a generic river basin model based on emission coefficients allowing the estimation of annual averaged TP concentrations based on upstream population density, P removal at the sewage treatment plant, and land uses. The model has been constructed on an excel datasheet, allowing a probabilistic implementation based on Monte Carlo analysis. A simplified exposure model has been developed and validated using Danube river basin data. The comparison of model predictions and measurements for this set of river sub-basins selected from the Danube catchment, indicated that the model offers acceptable predictions.

It should be considered that the model is not a GIS based model, but a generic model offering an estimation for the annual average concentration. The spatial and temporal differences are not included in the model estimations; and obviously, the interpretation of these data must consider the characteristics of the proposed model. Due to differences in land use, population density and hydrology, different TP concentrations, and therefore different likelihoods for effects must be expected for different areas within the river basin. For example, for a single river basin, the TP concentration, would be different for stagnant waters located immediately upstream and immediately downstream of a large city; simply as the result in the point versus diffuse contributions. It should be noted that the point contribution of a one million inhabitants city is equivalent to the diffuse contribution of about half a million hectares of arable land. Therefore, good agricultural practices may produce better results for sensitive areas located upstream main cities while specific wastewater treatment may be better for downstream sensitive areas. Measures for mitigating P losses from agricultural land at the river basin scale level have been reviewed elsewhere (Djodjic et al., 2002; Ulen and Jakobsson, 2005). The high variability in the contribution of direct (STP) and indirect (diffuse) P sources to the overall load observed among river basins can also be identified within a catchment area; for example, Bowes et al. (2005) estimates that the proportion of P from direct STP emissions ranges from less than 10% to more than 90% for different areas of the River Avon basin.

Similarly, the effect assessment has also been developed as a generic assessment for the most sensitive areas within the river basin. The protection of these sensitive areas is assumed to be essential for the overall protection of the river ecosystem. Following the principles of the European protocols developed for assessing the risk of industrial chemicals (ECB, 2003; SSC, 2003) the risk is established for the actual emission levels and the historical pollution is only considered regarding the monitoring programmes. In this model, the risk for the sensitive river areas (lakes, reservoirs, meadow zones, estuaries), is based on the TP concentration of the inflow water, historic loads resulting in a higher P level within the system (e.g. in the sediments) are not considered in this assessment. The assessment of estuaries was a discussion point during the Experts Workshop. The Experts considered that the selected classes cover the most sensitive ecosystem types. Estuaries are expected to be less sensitive, and consequently covered by the assessment. In addition, the exposure is estimated for the inflow concentration using worst case assumptions. As a consequence, no specific assessment for estuaries is required.

The role of other nutrients and particularly nitrogen (N) is covered in the effect assessment as the approach is based on real field conditions. In fact, part of the variability observed for similar TP concentrations is the consequence of variations in concentrations of N and/or other nutrients. As the loads of different nutrients, particularly P and N, are expected to be associated, the role of this association should be considered (see Figure 40).

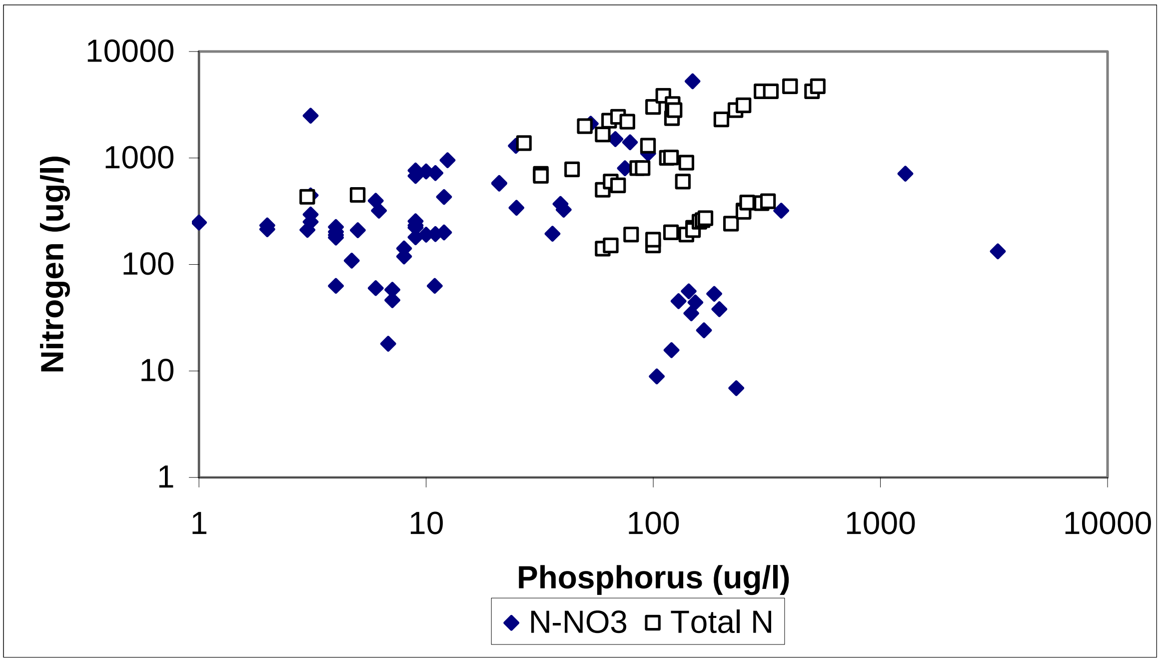


Figure 40. Relationship between P and N in the water bodies selected for the effect assessment.

As expected, there is an obvious tendency for higher total nitrogen and nitrate-nitrogen ($N-NO_3$) concentrations at higher P levels, but the variability in measured N values for a selected P level covers several orders of magnitude.

The proposed conceptual model and its methodological application can be used for very different purposes, from generic assessment of Pan-European measures to comparative assessment of potential management options and analysis of alternative future scenarios. For the broader assessment, the methodology, through the quantification of the expected reduction in risk, could be clearly suited as a tool for cost/benefit assessment.

The assessment can also be targeted for specific ecoregions where the overall risk is known or expected to be higher than the average. Then, the effect assessment should be based on specific data for the addressed eco-region&type-classes, while the simplified exposure model seems to be useful for the entire European continent provided that the river basin characteristics used in the input model may be appropriate for that area.

For specific river-basin assessments the simplified exposure model is not adequate. It should be highly recommended to identify the location of sensitive (stagnant) water bodies and conduct individual assessments for the expected exposure of each sensitive water body. Therefore the exposure part should be replaced by published catchment-specific assessments or by GIS-based models. The assessment of specific river basins should consider the spatial and temporal variability and the delay in ecosystem responses. The methodology developed for the effect assessment part is in principle perfectly applicable to specific river-basin assessments, and can also be extrapolated to other parts of the world. However, the characteristics of the sensitive water bodies within the river basin or area should be considered in order to establish if the ecoregions&type-classes selected for this study are appropriate or if a site-specific ecoregions&type class is required.

The exposure model has been implemented using Monte Carlo analysis for covering the variability and uncertainty. As the model has been developed using an Excel datasheet, the probabilistic implementation for one and two dimensions Monte Carlo Analysis can be easily obtained from commercially available software tools such as Crystal Ball. When assessing specific river-basins and sensitive areas, it should be considered that intentionally, this conceptual model has been designed for predicting changes in risk profiles associated to risk management options but without considering historic pollution. As already mentioned, it is well known that historical nutrient levels constitute a key element for actual responses in stagnant waters. Biotic and abiotic compartments may represent significant nutrient reservoirs, and, therefore, a risk management plan will require some time until the lake or reservoir nutrient concentrations really reflect actual P inputs instead of historical loads.

Obviously, the results obtained from the application of this high tier risk model are complex and require proper explanations in terms of the expected risk and the associated uncertainty. These aspects should be included in the risk communication strategy. For the generic assessment, the evaluation provided by the model should be considered as the equivalent to the comprehensive risk assessments conducted for individual substances, such as those performed for priority and new chemicals in the EU (ECB, 2003). Those models offer a comprehensive assessment of the risks associated to actual production/emission values of the assessed substance; without further consideration of historical emissions or synergistic effects with other substances. The capability and limitations of these assessments have been described in the opinions of the relevant EU scientific committees, CSTEE and SCHER, and in the reports on harmonization of risk assessment procedures adopted by the European Scientific Steering Committee (SSC, 2000; 2003). Similar applicability and limitations are expected for the proposed model, and therefore neither historical data nor synergistic contributions from several nutrients are addressed in this study. Following this rationale, the quantitative estimations of expected changes in the likelihood for effects should be considered as an alternative to the added risk approach, which is applied when "natural" background concentrations are expected for the substance, e.g. when addressing metals, other elements, or compounds which are widely distributed in the environment. As demonstrated in this study, the added risk approach is not suitable for nutrients as the additional risk is directly related to the initial background concentration, and the same increase (either absolute or as percentage) in nutrient loads/concentration may result either in quite significant risk changes or no changes at all. In fact the use of the added risk approach for toxic chemicals has also been questioned (CSTEE, 2004).

The risk communication exercise has confirmed that the results of these risk estimations should be presented in a proper way for avoiding misunderstandings. The preferences and requirements identified in the expert consultation indicate that the risk characterization should present as much information as possible including the information on the uncertainty, even if the overall amount of information requires the use of complex approaches.

An additional element for the risk communication strategy is associated to the perception of the magnitude of the risk. The use of relative percentages has been recommended by some authors (e.g. Windhorst et al., 2004; Kannen et al., 2004).

The examples presented for the specific estimations offer a quantitative estimation of the relative contribution of different sources of P, obviously including P-based detergents.

A summary of the results is presented in Table 12.

Table 12. Results obtained for the different generic scenarios. The table shows the detergent contribution in percentage to the total P load in the catchment (considering the removal of P at the sewage treatment plant for the estimation of loads from point sources); the estimated annual average total P concentration; the employed effect assessment class; and the difference between the total risk and the risk without P-based detergents. *(This difference is presented for the upper bound, the lower bound and the most likely probability (mlp) estimated for the assumption that 33% of water bodies in the area are in less than good status).*

Scenario	Detergent contribution	TP conc.	Ecoregion&type Class	Difference between total risk and risk without detergents		
	%	µg/l		Upper bound 1-p(TP|G+)	Lower bound P(TP|G-)	mlp(G-|TP)
1a	13.1	465	Mediterranean	1.6	4.5	3.7
1b	13.1	465	At-N&C shallow	0.2	1.2	0.5
1c	26	546	Mediterranean	3.4	8.1	7.6
1d	26	546	At-N&C shallow	0.4	2.3	1
2a	13.1	232	Mediterranean	1.6	4.7	4.4
2b	13.1	232	At-N&C shallow	0.4	2.8	1.1
2c	26	273	Mediterranean	3.4	10.3	9.3
2d	26	273	At-N&C shallow	0.8	5.4	2
3a	8	255	Mediterranean	0.9	2.8	2.5
3b	8	255	At-N&C shallow	0.2	1.4	0.6
3c	16.8	282	Mediterranean	2	6.3	5.5
3d	16.8	282	At-N&C shallow	0.5	2.9	1.1
4a	9.6	212	Mediterranean	1.1	3.3	3.2
4b	9.6	212	At-N&C shallow	0.4	2.1	0.8
4c	19.8	239	Mediterranean	2.5	7.4	6.9
4d	19.8	239	At-N&C shallow	0.7	4.4	1.6

5a	9.9	154	Mediterranean	1.1	3	3.2
5b	9.9	154	At-N&C shallow	0.4	3.3	1.4
5c	20.4	174	Mediterranean	2.5	6.8	7.2
5d	20.4	174	At-N&C shallow	0.8	6.7	2.7

The median and the arithmetic mean values for these scenarios are presented in Table 13.

Table 13. Median and arithmetic mean values obtained for the different generic scenarios.

Parameter	Detergent contribution	TP conc.	Difference between total risk and risk without detergents		
	%	µg/l	Upper bound 1-p(TP|G+)	Lower bound P(TP|G-)	mlp(G-|TP)
All scenarios					
Median	15	247	0.85	3.85	2.6
Arith mean	16	283	1.24	4.48	3.31
Mediterranean scenarios					
Median	15	247	1.80	5.50	4.95
Arith mean	16	283	2.01	5.72	5.35
Atlantic-N&Central shallow scenarios					
Median	15	247	0.40	2.85	1.10
Arith mean	16	283	0.48	3.25	1.28

In addition, the Monte Carlo analysis offers a pan-European estimation. It must be noted that the large proportion of the variance is associated to the population density and to the river flow versus catchment area ratio, confirming large regional variations.

The results obtained for the generic scenarios and for the pan-European probabilistic estimation are quite consistent. The difference between the total risk and the risk without P-based detergents estimated from the graphics is typically around 2-8% based on the Mediterranean effect assessment and around 0.4-2% based on the Atlantic-N&Central shallow effect assessment.

As expected, due to the complexity of the eutrophication phenomena, the results are extremely variable by region as a function of water regimen, land use, population density, removal at the sewage treatment plant, and obviously, the eco-region&class typology. It should be noted that the availability of validated data on the emission of P from detergents on a country-by-country basis would allow more specific estimations for some European areas.

To conclude, the conceptual model and its mathematical implementation offered in this report represent an innovative way for addressing the environmental risk of P emissions; which, as indicated by the CSTEE (2003), should be related to its potential contribution to anthropogenic eutrophication instead of typical toxicity measurements. The conceptual model presented here has similar flexibility, reliability and limitations than the "generic comprehensive risk assessments" which constitute the basis of the European chemicals policy (ECB, 2003; EU White Paper), and which in fact are also applied in other developed countries.

The very broad water quality monitoring programme scheduled under the implementation of the WFD, would allow the calibration (e.g. more precise distributions for 1-p(TP | G+) and p(TP | G-) and proper estimations for mlp(G-)) as well as the validation of this model. In the medium term, the methodology is particularly suited as a tool for predicting the expected achievement of alternative risk management and risk mitigation measures through comparative risk assessment processes.

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ANNEXES

APPENDIX: VALIDATED EFFECT DATA BASE (ELECTRONIC FORM)
ANNEX I: SUMMARY TABLE FOR EFFECTS DATASET

ANNEX I: SUMMARY TABLE FOR EFFECTS DATASET

Water body = name (and year of measured effects). TP conc. = reported Total Phosphorus annual average concentration (µg P/l). Rationale = main considerations for the classification decision; DE: direct effects; IE: indirect effects. LTG Status = Less than Good status indicating lack of fulfilment of study criteria (yes= non-good status(G-); no= good status(G+)). Level = Severity of effects (7 categories, see page 35). Reference = literature reference of reported data.

WATER BODY	TP conc.	ECOTYPE	RATIONALE	LTG STATUS	LEVEL	REFERENCE
Bidighinzu Reservoir (1978)	143	Med	DE: excessive presence of algae in the epilimnion IE: hypolimnic deoxygenation; problems of potabilization; P release from the sediment	y (G-)	2	Luglie et al. 2001
Bidighinzu Reservoir (1988)	386	Med	DE: excessive presence of algae in the epilimnion IE: hypolimnic deoxygenation; problems of potabilization; P release from the sediment	y (G-)	2	Luglie et al. 2001
Bidighinzu Reservoir (1994)	167	Med	DE: excessive presence of algae in the epilimnion IE: hypolimnic deoxygenation; problems of potabilization; P release from the sediment	y (G-)	2	Luglie et al. 2001
Bidighinzu Reservoir (1997)	305	Med	DE: excessive presence of algae in the epilimnion IE: hypolimnic deoxygenation; problems of potabilization; P release from the sediment	y (G-)	2	Luglie et al. 2001
Artuìc 1996	9	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Scuro delle Malghette 1996	10	At-S	DE: no; typical species of high mountain lakes IE: no	N (G+)	-3	Tolotti 2001
Tre Laghi 1996	6	At-S	DE: no; typical species of high mountain lakes IE: no	N (G+)	-3	Tolotti 2001
Ritorto 1996	4	At-D	DE: no; typical species of high mountain lakes IE: no	N (G+)	-3	Tolotti 2001
Lambin 1996	4	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Serodoli 1996	4	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Serodoli Medio 1996	8	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Gelato 1996	4	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Nambrone 1996	6	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Nero di Cornisello 1996	4	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
S. Giuliano 1996	8	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Garzoné 1996	9	At-D	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Mandrone 1996	2	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Rotondo 1996	2	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Ghiacciato 1996	3	At-S	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Scuro del Mandrone 1996	1	At-D	DE: no; typical species of high mountain lakes IE: no	n (G+)	-3	Tolotti 2001
Gossenköllesee lake 1997	2,7	At-D	DE: no IE: no	n (G+)	-3	Wille et al. 1999
Jöri Lake III - 1996	36	At-D	DE: no IE: no	n (G+)	-3	Hinder et al. 1999
Jöri Lake III - 1997	9	At-D	DE: no IE: no	n (G+)	-3	Hinder et al. 1999
Lake Iseo (Sebino) (1998)	11	At-D	DE: occasional summer blooms of cyanobacteria; domination by Chlorophyceae in summer IE: no	n (G+)	-1	Salmaso et al. 2003
Lake Iseo (Sebino)	21	At-D	DE: occasional summer blooms of cyanobacteria; domination by	n (G+)	-1	Salmaso et al. 2003

(1999)			Chlorophyceae in summer IE: no			
Lake Iseo (Sebino) (2000)	21	At-D	DE: occasional summer blooms of cyanobacteria; domination by Chlorophyceae in summer IE: no	n (G+)	-1	Salmaso et al. 2003
Lake Garda (Benaco) (1998)	9	At-D	DE: shift in species composition, pollution tolerant species common; increase biomass IE: no	y (G-)	1	Salmaso et al. 2003
Lake Garda (Benaco) (1999)	12	At-D	DE: shift in species composition, pollution tolerant species common; increase biomass IE: no	y (G-)	1	Salmaso et al. 2003
Lake Garda (Benaco) (2000)	11	At-D	DE: shift in species composition, pollution tolerant species common; increase biomass IE: no	y (G-)	1	Salmaso et al. 2003
Lake Maggiore (Verbano) (1997)	9	At-D	DE: recovering its structure; increase of biodiversity, decrease of average community cell size and reduction of biovolume phytoplankton. IE: no	y (G-)	1	Salmaso et al. 2003
Lake Maggiore (Verbano) (1998)	9	At-D	DE: recovering its structure; increase of biodiversity, decrease of average community cell size and reduction of biovolume phytoplankton. IE: no	y (G-)	1	Salmaso et al. 2003
Lake Maggiore (Verbano) (1999)	10	At-D	DE: recovering its structure; increase of biodiversity, decrease of average community cell size and reduction of biovolume phytoplankton. IE: no	y (G-)	1	Salmaso et al. 2003
Lake Lugano (1998)	12	At-D	DE: regular presence of pollution tolerant species; domination by Chlorophyceae in summer	y (G-)	2	Salmaso et al. 2003
Lake Lugano (1999)	25	At-D	DE: regular presence of pollution tolerant species; domination by Chlorophyceae in summer	y (G-)	2	Salmaso et al. 2003
Lake Lugano (2000)	39	At-D	DE: regular presence of pollution tolerant species; domination by Chlorophyceae in summer	y (G-)	2	Salmaso et al. 2003
Mere Mere 1990	79	At-D	DE: seasonal cyanophyte blooms but well developed littoral macrophytes, modest Chl-a concentrations IE: no	n (G+)	-2	Moss et al. 1997
Mere Mere 1991	53	At-D	DE: seasonal cyanophyte blooms but well developed littoral macrophytes, modest Chl-a concentrations IE: no	n (G+)	-2	Moss et al. 1997
Mere Mere 1992	68	At-D	DE: seasonal cyanophyte blooms but well developed littoral macrophytes, modest Chl-a concentrations IE: no	n (G+)	-2	Moss et al. 1997
Mere Mere 1993	95	At-D	DE: seasonal cyanophyte blooms but well developed littoral macrophytes, modest Chl-a concentrations IE: no	n (G+)	-2	Moss et al. 1997
Mere Mere 1994	75	At-D	DE: seasonal cyanophyte blooms but well developed littoral macrophytes, modest Chl-a concentrations IE: no	n (G+)	-2	Moss et al. 1997
Little Mere 1990	2690	At-S	DE: phytoplankton increase controlled by zooplankt. Grazing; zooplankt. Pollution tolerant species dominant IE: Low oxygen concentrations; fish very scarce; submerged plant populations not present;	y (G-)	3	Moss et al. 1997
Little Mere 1991	1550	At-S	DE: phytoplankton increase controlled by zooplankt. Grazing IE: fish very scarce; submerged plant populations not present;	y (G-)	2	Moss et al. 1997
Little Mere 1992	620	At-S	DE: Development of submerged plant population; zooplankt. Pollution sensitive species dominant IE: Recolonisation of fish	y (G-)	1	Moss et al. 1997
Little Mere 1993	325	At-S	DE: Development of submerged plant population; zooplankt. Pollution sensitive species dominant IE: Recolonisation of fish	y (G-)	1	Moss et al. 1997
Little Mere 1994	240	At-S	DE: submerged plant population dominated the entire bottom; zooplankt. Pollution sensitive species dominant IE: Recolonisation of fish	n (G+)	-1	Moss et al. 1997
Rostherne Mere	370	At-D	DE: cyanophyte blooms common in summer; IE: no	n (G+)	-1	Moss et al. 1997

1990						
Rostherne Mere 1991	440	At-D	DE: cyanophyte blooms common in summer; IE: no	n (G+)	-1	Moss et al. 1997
Rostherne Mere 1992	640	At-D	DE: No systematic changes in the zooplankton community only minor changes in the phytoplankton community IE: no	n (G+)	-1	Moss et al. 1997
Rostherne Mere 1993	390	At-D	DE: No systematic changes in the zooplankton community only minor changes in the phytoplankton community IE: no	n (G+)	-2	Moss et al. 1997
Rostherne Mere 1994	295	At-D	DE: No systematic changes in the zooplankton community only minor changes in the phytoplankton community IE: no	n (G+)	-2	Moss et al. 1997
Elterwater lake - Inner Basin - September 1994	288	At-D	DE: phyto taxa common of enriched waters dominated IE: deoxygenation in deep layers; sediments full of P	y (G-)	2	Zinger-Gize et al. 1999
Elterwater lake - Inner Basin - July 1995	145	At-D	DE: phyto tolerant species dominated but more number of species IE: deoxygenation in deep layers; sediments full of P	y (G-)	2	Zinger-Gize et al. 1999
Elterwater lake - Middle Basin - September 1994	63	At-D	DE: cyanophyte species appeared IE: Deoxygenation in the hypolimnion	y (G-)	1	Zinger-Gize et al. 1999
Elterwater lake - Middle Basin - July 1995	31,4	At-D	DE: cyanophyte species dominated IE: Deoxygenation in the hypolimnion	y (G-)	2	Zinger-Gize et al. 1999
Elterwater lake - Outer Basin - September 1994	33	At-D	DE: no IE: Slight decrease in dissolved oxygen levels	n (G+)	-1	Zinger-Gize et al. 1999
Elterwater lake - Outer Basin - July 1995	18,3	At-D	DE: slight changes in phyto composition IE: Slight decrease in dissolved oxygen levels	n (G+)	-1	Zinger-Gize et al. 1999
Lough Conn - 1976	16	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1977	19	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1978	20	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1979	21,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1982	25	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1983	14	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1984	16,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1985	13,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999

Lough Conn - 1986	14	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1987	10	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1988	16	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1989	13,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1990	17,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1991	14,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1992	15,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1993	16	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1994	21	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Conn - 1995	18,5	At-S	DE: Cyanobacterial blooms following wet weather events. IE: sediments w. P; blooms affecting the spawning of other fish species.	y (G-)	1	McGarrigle & Champ 1999
Lough Mask - 1976	11	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1977	19,5	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1978	13	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1979	23	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1981	11	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1982	20	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1983	9	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1984	12,5	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1985	7	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1986	25	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1987	7	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask -	5,5	At-S	DE: no IE: no	n (G+)	-3	McGarrigle &

1988						Champ 1999
Lough Mask - 1990	13	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1991	11	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1992	13	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1993	14,5	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1994	15	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Lough Mask - 1995	13	At-S	DE: no IE: no	n (G+)	-3	McGarrigle & Champ 1999
Tiefer See - 1994	27	At-D	DE: new presence of cyanobacteria IE: high internal P-load; decrease oxygen levels; low transparency for macrophytes	y (G-)	1	Nixdorf & Deneke 1997
Springsee - 1994	50	At-D	DE: cyanobacteria dominated the community IE: high internal P-load; decrease oxygen levels; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Grober Glubigsee - 1994	70	At-D	DE: cyanobacteria abundant IE: high internal P-load; decrease oxygen levels; low transparency for macrophytes	y (G-)	1	Nixdorf & Deneke 1997
Kleiner Glubigsee - 1994	64	At-S	DE: cyanobacteria dominated the community IE: high internal P-load; decrease oxygen levels; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Scharmützelsee - 1994	60	At-D	DE: cyanobacteria dominated the community IE: high internal P-load; decrease oxygen levels; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Storkower See (South) - 1994	77	At-S	DE: cyanobacteria dominated the community IE: high internal P-load; decrease oxygen levels; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Storkower See (North) - 1994	121	At-S	DE: cyanobacteria abundant IE: high internal P-load; anoxia in deep layers; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Wolziger See - 1994	122	At-S	DE: cyanobacteria dominated the community IE: high internal P-load; anoxia in deep layers; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Langer See - 1994	124	At-S	DE: cyanobacteria dominated the community IE: high internal P-load; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Lebbiner See - 1994	111	At-S	DE: cyanobacteria dominated the community IE: high internal P-load; low transparency for macrophytes	y (G-)	2	Nixdorf & Deneke 1997
Las Tablas de Daimiel - Gigüela river - 1996	500	Med	DE: slight reduction macrophyte cover IE: P internal loading; sediments w organic matter	y (G-)	1	Sanchez-Carrillo & Alvarez-Cobelas 2001
Las Tablas de Daimiel - Gigüela river - 1997	530	Med	DE: summer phyto bloom; slight reduction macrophyte cover IE: P internal loading; sediments w organic matter	y (G-)	1	Sanchez-Carrillo & Alvarez-Cobelas 2001
Las Tablas de Daimiel - Gigüela river - 1998	330	Med	DE: frequent phyto blooms; high Chla levels; slight reduction macrophyte cover IE: P internal loading; sediments w organic matter	y (G-)	2	Sanchez-Carrillo & Alvarez-Cobelas 2001
Las Tablas de	400	Med	DE: slight reduction macrophyte cover IE: sediments w organic matter	n (G+)	-1	Sanchez-Carrillo &

Daimiel - Molemocho - 1996						Alvarez-Cobelas 2001
Las Tablas de Daimiel - Molemocho - 1997	250	Med	DE: occasional phyto blooms; moderate reduction macrophyte cover IE: sediments w organic matter	y (G-)	2	Sanchez-Carrillo & Alvarez-Cobelas 2001
Las Tablas de Daimiel - Molemocho - 1998	230	Med	DE: frecuent phyto blooms; major reduction macrophyte cover IE: sediments w organic matter	y (G-)	3	Sanchez-Carrillo & Alvarez-Cobelas 2001
Las Tablas de Daimiel - Puente Navarro - 1996	300	Med	DE: slight reduction macrophyte cover IE: sediments w organic matter	n (G+)	-1	Sanchez-Carrillo & Alvarez-Cobelas 2001
Las Tablas de Daimiel - Puente Navarro - 1997	100	Med	DE: moderate reduction macrophyte cover IE: sediments w organic matter	y (G-)	1	Sanchez-Carrillo & Alvarez-Cobelas 2001
Las Tablas de Daimiel - Puente Navarro - 1998	200	Med	DE: frecuent phyto blooms; major reduction macrophyte cover IE: sediments w organic matter	y (G-)	2	Sanchez-Carrillo & Alvarez-Cobelas 2001
Albufera de Valencia - Frente a Port de Silla - 1985	3,1	Med	DE: very high Chl-a levels; low transparency IE: no	y (G-)	3	Soria et al. 1987
Albufera de Valencia - Flotó de Llebeig - 1985	365,8	Med	DE: high Chl-a levels IE: no	y (G-)	3	Soria et al. 1987
Albufera de Valencia - Zona Central - 1985	3,1	Med	DE: very high Chl-a levels; low transparency IE: no	y (G-)	3	Soria et al. 1987
Albufera de Valencia - Frente a Carrera de Saler - 1985	40,3	Med	DE: very high Chl-a levels; low transparency IE: no	y (G-)	3	Soria et al. 1987
Albufera de Valencia - Gola del Pujol - 1985	6,2	Med	DE: very high Chl-a levels; low transparency IE: no	y (G-)	3	Soria et al. 1987
Albufera de Valencia - Llebeig de L´Antina- 1985	3,1	Med	DE: very high Chl-a levels; low transparency IE: no	y (G-)	3	Soria et al. 1987
Albufera de Valencia - Frente a L´Overa - 1985	3,1	Med	DE: high Chl-a levels IE: no	y (G-)	3	Soria et al. 1987
Foxcote reservoir - 1982	80	At-S	DE: high algal biomass; increase in benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species typical of eutrophied water; high P internal loading	y (G-)	3	Daldorph 1999
Foxcote reservoir -	80	At-S	DE: high algal biomass; increase in benthic filamentous algae;	y (G-)	3	Daldorph 1999

1983			macrophyte species typical of eutrophied waters IE: zooplankton species typical of eutrophied water; high P internal loading			
Foxcote reservoir - 1984	60	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species typical of eutrophied water; high P internal loading	y (G-)	2	Daldorph 1999
Foxcote reservoir - 1985	80	At-S	DE: beds of benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species typical of eutrophied water; high P internal loading	y (G-)	2	Daldorph 1999
Foxcote reservoir - 1986	80	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species changing again through more pollution sensitive species; high P internal loading	y (G-)	2	Daldorph 1999
Foxcote reservoir - 1987	300	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species recovering; high P internal loading	y (G-)	1	Daldorph 1999
Foxcote reservoir - 1988	100	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species changing again through more pollution sensitive species; high P internal loading	y (G-)	1	Daldorph 1999
Foxcote reservoir - 1989	80	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species changing again through more pollution sensitive species; high P internal loading	y (G-)	1	Daldorph 1999
Foxcote reservoir - 1990	70	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters IE: zooplankton species changing again through more pollution sensitive species; high P internal loading	y (G-)	1	Daldorph 1999
Foxcote reservoir - 1991	60	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters declined and sensitive species Elodea became dominant IE: zooplankton species recovering; high P internal loading	y (G-)	1	Daldorph 1999
Foxcote reservoir - 1992	60	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters declined and sensitive species Elodea became dominant IE: zooplankton species recovering; high P internal loading	y (G-)	1	Daldorph 1999
Foxcote reservoir - 1993	60	At-S	DE: cyanophyte bloom; increase in benthic filamentous algae; macrophyte species typical of eutrophied waters declined and sensitive species Elodea became dominant IE: zooplankton species recovering; high P internal loading	y (G-)	1	Daldorph 1999
Foxcote reservoir - 1994	60	At-S	DE: increase in benthic filamentous algae; macrophyte species typical of eutrophied waters declined and sensitive species Elodea became dominant IE: zooplankton species recovering; high P internal loading	y (G-)	1	Daldorph 1999
Loch Leven - 1985	63	At-S	DE: algal biomass increase; decline in submerged macrophytic vegetation; decreases in higher aquatic plant IE: decrease invertebrate species diversity.	y (G-)	1	Bailey-Watts & Kirika 1999
Loch Leven - 1995	79	At-S	DE: cyanophyte domination w occasional blooms; algal biomass increase; decline in submerged macrophytic vegetation; decreases in higher aquatic plant IE: decrease invertebrate species diversity.	y (G-)	2	Bailey-Watts & Kirika 1999
Lake Chozas -	12,5	Med	DE: no IE: no	n (G+)	-3	Rodriguez et al.

1994						2003
Lake Chozas - 1995	29	Med	DE: no IE: no	n (G+)	-3	Rodriguez et al. 2003
Lake Chozas - 1996	29	Med	DE: high algal biomass;	n (G+)	-1	Rodriguez et al. 2003
Lake Chozas - 1998	100	Med	DE: high algal biomass; no submerged vegetation could be found	y (G-)	3	Rodriguez et al. 2003
Lake Chozas - 1999	323	Med	DE: high algal biomass; no submerged vegetation could be found	y (G-)	3	Rodriguez et al. 2003
Lake Chozas - 2000	160	Med	DE: high algal biomass; no submerged vegetation could be found	y (G-)	3	Rodriguez et al. 2003
Lake Vaeng - 1986	140	At-S	DE: high algal biomass; low submerged macrophytes IE: low zoopl biomass; Removal of 50% plankti-benthivorous fish biomass; transparency very low	y (G-)	3	Jeppesen et al. 1999
Lake Vaeng - 1987	120	At-S	DE: low submerged macrophytes IE: low zoopl biomass; Removal of 50% plankti-benthivorous fish biomass; transparency recovering	y (G-)	2	Jeppesen et al. 1999
Lake Vaeng - 1988	95	At-S	DE: low submerged macrophytes IE: low zoopl biomass; Removal of 50% plankti-benthivorous fish biomass; transparency recovering	y (G-)	2	Jeppesen et al. 1999
Lake Vaeng - 1989	70	At-S	DE: low submerged macrophytes IE: low zoopl biomass; piscivorous fish dominated; transparency recovering	y (G-)	2	Jeppesen et al. 1999
Lake Vaeng - 1990	65	At-S	DE: submerged macrophytes disappeared IE: low zoopl biomass; piscivorous fish dominated; transparency decreasing	y (G-)	2	Jeppesen et al. 1999
Lake Vaeng - 1991	135	At-S	DE: submerged macrophytes disappeared IE: low zoopl biomass; piscivorous fish dominated; transparency decreasing	y (G-)	2	Jeppesen et al. 1999
Lake Vaeng - 1992	115	At-S	DE: submerged macrophytes reappeared IE: piscivorous fish dominated; transparency increased	y (G-)	1	Jeppesen et al. 1999
Lake Vaeng - 1993	90	At-S	DE: submerged macrophytes colonizing IE: no	y (G-)	1	Jeppesen et al. 1999
Lake Vaeng - 1994	85	At-S	DE: submerged macrophytes better covered IE: no	n (G+)	-1	Jeppesen et al. 1999
Lake Vaeng - 1995	60	At-S	DE: still recovering macrophytes IE: no	n (G+)	-2	Jeppesen et al. 1999
Okoto - Seven Rila Lakes - 2001	2	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Okoto - Seven Rila Lakes - 2000	7,1	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Okoto - Seven Rila Lakes - 1996	66	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Okoto - Seven Rila Lakes - 1995	22	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Bubreka - Seven Rila Lakes - 2001	4	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Bubreka - Seven	14,7	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004

Rila Lakes - 2000						
Bubreka - Seven Rila Lakes - 1996	41	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Bubreka - Seven Rila Lakes - 1995	31	At-D	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Sulzata - Seven Rila Lakes - 2001	8	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Sulzata - Seven Rila Lakes - 2000	17,6	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Sulzata - Seven Rila Lakes - 1996	28	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Sulzata - Seven Rila Lakes - 1995	30	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Bliznaka - Seven Rila Lakes - 2001	4	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Bliznaka - Seven Rila Lakes - 2000	7,1	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Bliznaka - Seven Rila Lakes - 1996	19	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Bliznaka - Seven Rila Lakes - 1995	33	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Alekovo - Mousala Lakes - 2000	4,7	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Ledeno - Mousala Lakes - 2000	5	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Karakashevo - Mousala Lakes - 2000	10,9	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Dolno Marichino - Maritsa Lakes – 2000	9,1	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Gorno Marichino - Maritsa Lakes - 2000	6,8	At-S	DE: no IE: zooplankton impairment recovering	n (G+)	-1	Kalchev et al. 2004
Milchsee (Lago di Latte) - 1998	3	At-S	DE: Chl-a values are sometimes very high and more typical of mesotrophic conditions; IE: no	n (G+)	-2	Tait & Thaler 2000
Langsee (Lago Lungo) - 1998	5	At-D	DE: Chl-a values are sometimes very high and more typical of mesotrophic conditions; IE: occasional anoxia in deep layers	n (G+)	-1	Tait & Thaler 2000
Alte Donau - 1987	35,1	At-S	DE: no IE: no	n (G+)	-2	Donabaum et al. 1999
Alte Donau - 1988	66,1	At-S	DE: increasing phyto biomass	n (G+)	-1	Donabaum et al. 1999
Alte Donau - 1989	110	At-S	DE: increasing phyto biomass	n (G+)	-1	Donabaum et al.

						1999
Alte Donau - 1990	42,4	At-S	DE: increasing phyto biomass	n (G+)	-1	Donabaum et al. 1999
Alte Donau - 1991	47,1	At-S	DE: increasing phyto biomass	n (G+)	-1	Donabaum et al. 1999
Alte Donau - 1992	41,4	At-S	DE: increase phyto biomass; cyanobacteria appeared; remarkable decline of macrophytes IE: transparency low; turbid state	y (G-)	1	Donabaum et al. 1999
Alte Donau - 1993	54,2	At-S	DE: high algal biomass; shift in species composition; cyanobacteria abundant; remarkable decline of macrophytes IE: low transparency;	y (G-)	2	Donabaum et al. 1999
Alte Donau - 1994	70	At-S	DE: high algal biomass; shift in species composition; cyanobacteria abundant; remarkable decline of macrophytes IE: low transparency; Loss of characteristic species and poor diversity of macroinvertebrates; internal loading.	y (G-)	3	Donabaum et al. 1999
Alte Donau - 1995	27,3	At-S	DE: high algal biomass; shift in species composition; cyanobacteria abundant; remarkable decline of macrophytes IE: low transparency; Loss of characteristic species and poor diversity of macroinvertebrates; internal loading.	y (G-)	3	Donabaum et al. 1999
Cambroneras-Spring 1994	180	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Campillo-Spring 1994	220	Med	DE: high algal biomass; Cyanophyceae dominated IE: no	y (G-)	1	Arauzo et al. 1996
Camping-Spring 1994	40	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Capricho-Spring 1994	10	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Castillo-Spring 1994	40	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Lago B-Spring 1994	45	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Madres 1-Spring 1994	60	Med	DE: no IE: no	n (G+)	-2	Arauzo et al. 1996
Madres 2-Spring 1994	180	Med	DE: cyanophyceae dominated sometimes	y (G-)	1	Arauzo et al. 1996
Madres 3-Spring 1994	25	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Madres 4-Spring 1994	80	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Niño-Spring 1994	50	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Steeley-Spring 1994	30	Med	DE: nutrient tolerant algal species IE: no	n (G+)	-1	Arauzo et al. 1996
Villafranca-Spring 1994	30	Med	DE: no IE: no	n (G+)	-2	Arauzo et al. 1996
Barton Broad 1983	130	At-S	DE: ver high algal biomass; submerged macrophytes not re-established	y (G-)	3	Lau & Lane 2002

			IE: water turbid			
Barton Broad 1984	164	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1985	93	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1986	158	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1987	116	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1988	122	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1989	152	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1990	180	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1991	198	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1992	183	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Barton Broad 1993	150	At-S	DE: ver high algal biomass; submerged macrophytes not re-established IE: water turbid	y (G-)	3	Lau & Lane 2002
Laguna de Manjavacas 1990/91	880	Med	DE: algal bloom; Chl-a very high in summer and shift in phyto species composition IE: organic matter in sediments; substitution of certain zoobenthic species; hypoxia	y (G-)	2	Garcia-Ferrer et al. 2003
Laguna de Manjavacas 1997	617	Med	DE: Chl-a high in summer and shift in phyto species composition IE: organic matter in sediments; substitution of certain zoobenthic species; hypoxia	y (G-)	2	Garcia-Ferrer et al. 2003
Laguna del Pueblo 1990/91	1922	Med	DE: very high Chla; algal blooms; IE: anoxia in summer	y (G-)	3	Garcia-Ferrer et al. 2003
Laguna del Pueblo 1997	1311	Med	DE: very high Chla; algal blooms; IE: anoxia in summer	y (G-)	3	Garcia-Ferrer et al. 2003
Lake Wolderwijd - 1975	320	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1976	220	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1977	250	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1978	260	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997

Lake Wolderwijd - 1979	250	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1980	260	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1981	300	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1982	160	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1983	170	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1984	165	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1985	100	At-S	DE: high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1986	140	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1987	100	At-S	DE: high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1988	150	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1989	150	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation; shift in species composition thorugh more autoctonous species IE: impaired invertebrates communities; low transparency	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1990	120	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation; shift in species composition thorugh more autoctonous species IE: impaired invertebrates communities; low transparency; fish biomanipulation	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd - 1991	60	At-S	DE: high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation; shift in species composition thorugh more autoctonous species IE: impaired invertebrates communities; fish biomanipulation	y (G-)	3	Meijer & Hosper 1997
Lake Wolderwijd -	65	At-S	DE: high Chla; blooms and domination of cyanobacteria; poorly developed	y (G-)	3	Meijer & Hosper

1992			submerged vegetation; shift in species composition thorugh more autoctonous species IE: recovering invertebrates communities; fish biomanipulation			1997
Lake Wolderwijd - 1993	80	At-S	DE: very high Chla; blooms and domination of cyanobacteria; poorly developed submerged vegetation; shift in species composition thorugh more autoctonous species IE: recovering invertebrates communities; low transparency; fish biomanipulation	y (G-)	3	Meijer & Hosper 1997
Serra Serrada reservoir - 2000	57	Med	DE: cyanobacteria dominated occasionally; phyto small speciesIE: organic matter in sediments; internal loading; anoxia in deep layers	y (G-)	1	Geraldes & Boavida 2003
Serra Serrada reservoir - 2001	78	Med	DE: cyanobacteria dominated occasionally; phyto small speciesIE: organic matter in sediments; internal loading; anoxia in deep layers	y (G-)	1	Geraldes & Boavida 2003
Azibo reservoir - 2000	61	Med	DE:occasional blooms; cyanobacteria dominated occasionally; phyto small species IE: organic matter in sediments; internal loading; anoxia in deep layers	y (G-)	1	Geraldes & Boavida 2003
Azibo reservoir - 2001	69	Med	DE:occasional blooms; cyanobacteria dominated occasionally; phyto small species IE: organic matter in sediments; internal loading; anoxia in deep layers	y (G-)	1	Geraldes & Boavida 2003
Gonzalez-Lacasa reservoir 2000	24	Med	DE: no IE: anoxia in bottom layers	n	-2	C. H. Ebro 2000
Escales reservoir 2002	21	Med	DE: low phyto diversity IE: no	n	-2	C. H. Ebro 2000
Eugui reservoir 2000	8	Med	DE: IE: low oxygen at bottom	n	-2	C. H. Ebro 2000
Ullivarri reservoir 2000	22	Med	DE: IE: low oxygen at bottom; zoobenthos low abundance	n	-1	C. H. Ebro 2000
Urrunaga reservoir 2000	7,5	Med	DE: IE: low oxygen at bottom; zoobenthos low abundance	n	-1	C. H. Ebro 2000
Vadiello reservoir 2000	7	Med	DE: no IE: low oxygen at bottom in some areas	n	-2	C. H. Ebro 2000
Oliana reservoir 2001	24,5	Med	DE: cyanophytes, foam, local blooms, low transparency IE: anoxia, zooplankton low abundance and tolerant species; methane bubbles	y (G-)	2	C. H. Ebro 2000
Barasona reservoir 2001	50	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
Pineta reservoir 2001	5	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
El Grado reservoir 2001	66	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
Sotonera reservoir 2001	46	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
Yesa reservoir 2001	21	Med	DE: IE: low oxygen at bottom; zoobenthos low abundance	n	0	C. H. Ebro 2000
Ebro reservoir 2001	35	Med	DE: high Chl-a, blooms, cyanophytes dominate IE: no	n	0	C. H. Ebro 2000

Mansilla reservoir 2001	10	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
Maidevera reservoir 2001	19	Med	DE: no IE: anoxia in bottom layers	n	-2	C. H. Ebro 2000
La Tranquera reservoir 2001	13,5	Med	DE: high density of phyto, cyanophytes, blooms IE: anoxia hypolimnion	y (G-)	1	C. H. Ebro 2000
Las Torcas reservoir 2001	18	Med	DE: high density phyto, low transparency IE: no	n	-1	C. H. Ebro 2000
Cueva Foradada reservoir 2001	28	Med	DE: high density of phyto, some cyanophytes, some blooms IE: anoxia hypolimnion	y (G-)	0	C. H. Ebro 2000
Santolea reservoir 2001	4	Med	DE: no IE: anoxia hypolimnion	n	-2	C. H. Ebro 2000
Calanda reservoir 2001	13	Med	DE: no IE: anoxia hypolimnion	n	-2	C. H. Ebro 2000
Caspe reservoir 2001	10	Med	DE: high Chl-a, blooms, cyanophytes dominate IE: hypolimnetic anoxia, low zooplankton	y (G-)	1	C. H. Ebro 2000
Talarn reservoir 2002	83	Med	DE: no IE: anoxia in bottom layers	n	-2	C. H. Ebro 2000
Camarasa reservoir 2002	17,5	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
San Lorenzo Mongay reservoir 2002	26,5	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
Mequinenza reservoir 2002	329	Med	DE: high Chl-a, blooms, cyanophytes IE: hypolimnetic anoxia, low zooplankton	y (G-)	1	C. H. Ebro 2000
Ribarroja reservoir 2002	106	Med	DE: high Chl-a, blooms IE: hypolimnetic anoxia	y (G-)	0	C. H. Ebro 2000
De la Penya reservoir 2002	29	Med	DE: high Chl-a IE: low transparency	n	-2	C. H. Ebro 2000
El Val reservoir 2002	452	Med	DE: no IE: anoxia, P release, SH2, NH4	y (G-)	1	C. H. Ebro 2000
Estanca de Alcañiz 2002	29,5	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
Alloz reservoir 2002	17,6	Med	DE: no IE: no	n	-2	C. H. Ebro 2000
Sobron reservoir 2002	23	Med	DE: eutrophic species IE: anoxia	n	-1	C. H. Ebro 2000
A. Flumendosa reservoir 1992	23	Med	DE: no IE: no	n	-2	Marchetti et al. 1992
Gusana reservoir 1992	18	Med	DE: no IE: no	n	-2	Marchetti et al. 1992
M. Flumendosa reservoir 1992	10	Med	DE: no IE: no	n	-2	Marchetti et al. 1992

Mulargia reservoir 1992	20	Med	DE: cyanophytes IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Pattada reservoir 1992	60	Med	DE: cyanophytes IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Simbirizzi reservoir 1992	100	Med	DE: cyanophytes and chlorophytes; high Chl-a IE: no	y (G-)	2	Marchetti et al. 1992
Cuga reservoir 1992	60	Med	DE: cyanophytes IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Cixerri reservoir 1992	100	Med	DE: cyanophytes; high Chl-a IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Liscia reservoir 1992	90	Med	DE: cyanophytes IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Coghinas reservoir 1992	100	Med	DE: cyanophytes IE: hypolimnetic hypoxia	y (G-)	1	Marchetti et al. 1992
M. Roccadoria reservoir 1992	110	Med	DE: cyanophytes IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Omodeo reservoir 1992	140	Med	DE: cyanophytes IE: hypolimnetic hypoxia	y (G-)	1	Marchetti et al. 1992
Bunnari alto reservoir 1992	220	Med	DE: cyanophytes and chlorophytes IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Bidighinzu reservoir 1992	400	Med	DE: cyanophytes; high Chl-a IE: hypolimnetic anoxia	y (G-)	2	Marchetti et al. 1992
Ancipa reservoir 1992	9,7	Med	DE: no IE: no	n	-2	Marchetti et al. 1992
Nicoletti reservoir 1992	35	Med	DE: no IE: hypoxia	n	-2	Marchetti et al. 1992
Olivo reservoir 1992	33	Med	DE: no IE: anoxia	n	-1	Marchetti et al. 1992
Pozzillo reservoir 1992	50	Med	DE: cyanophytes co-dominated, medium Chl-a IE: no	n	0	Marchetti et al. 1992
Rubino reservoir 1992	29	Med	DE: cyanophytes IE: no data	n	0	Marchetti et al. 1992
Piano del Leone reservoir 1992	47	Med	DE: medium chl-a IE: no	n	-2	Marchetti et al. 1992
Poma reservoir 1992	51	Med	DE: chlorophytes IE: hypoxia	y (G-)	0	Marchetti et al. 1992
Garcia reservoir 1992	51	Med	DE: no IE: no	n	-2	Marchetti et al. 1992
Cimia reservoir 1992	54	Med	DE: chlorophytes co-dominant IE: anoxia	y (G-)	0	Marchetti et al. 1992
Trinita reservoir 1992	83	Med	DE: cyanophytes, high Chl-a IE: no	y (G-)	1	Marchetti et al. 1992
Piano degli	47	Med	DE: high Chl-a IE: anoxia	n	-1	Marchetti et al. 1992

Albanesi reservoir 1992						
Santa Rosalia reservoir 1992	56	Med	DE: chlorophytes co-dominant IE: anoxia	y (G-)	0	Marchetti et al. 1992
Fanaco reservoir 1992	54	Med	DE: no IE: anoxia	n	-1	Marchetti et al. 1992
Vasca Ogliastro reservoir 1992	107	Med	DE: no IE: hypoxia	n	-2	Marchetti et al. 1992
Guadalami reservoir 1992	39	Med	DE: no IE: anoxia	n	-1	Marchetti et al. 1992
Ogliastro reservoir 1992	41	Med	DE: chlorophytes IE: no	n	-1	Marchetti et al. 1992
Castello reservoir 1992	109	Med	DE: high Chl-a IE: anoxia	n	0	Marchetti et al. 1992
Prizzi reservoir 1992	53	Med	DE: no IE: no	n	-2	Marchetti et al. 1992
Dirillo reservoir 1992	61	Med	DE: medium-high Chla, chlorophytes IE: anoxia	y (G-)	1	Marchetti et al. 1992
Scanzano reservoir 1992	62	Med	DE: high Chl-a IE: anoxia	n	-1	Marchetti et al. 1992
Villarosa reservoir 1992	64	Med	DE: high Chl-a, cyanophytes and chlorophytes IE: anoxia	y (G-)	2	Marchetti et al. 1992
Gorgo reservoir 1992	81	Med	DE: cyanophytes, very high Chl-a IE: ND	y (G-)	2	Marchetti et al. 1992
San Giovanni reservoir 1992	81	Med	DE: cyanophytes, very high IE: anoxia	y (G-)	2	Marchetti et al. 1992
Arancio reservoir 1992	166	Med	DE: cyanophytes, very high IE: anoxia	y (G-)	3	Marchetti et al. 1992
Gammauta reservoir 1992	182	Med	DE: high Chl-a, cyanophytes IE: ND	y (G-)	3	Marchetti et al. 1992
Disueri reservoir 1992	1094	Med	DE: very high Chl-a IE: ND	y (G-)	3	Marchetti et al. 1992