STARTPAGE

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PART B

"CREAM"

Mechanistic Effect Models for Ecological Risk Assessment of Chemicals

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1. LIST OF PARTICIPANTS

Table 1. Participants of the CREAM project.

	Industrial partners only: **Level of involvement**			**Legal Entity**	**Department**	**Person-in-charge**
	1	**2**	**3**			
Network Participants						
1. UFZ				Helmholtz Centre for Environmental Research, Germany	Ecological Modelling, System Ecotoxicology	Volker Grimm (Coordinator)
2. RUC				Roskilde University, Denmark	Environmental, Social and Spatial Change	Valery Forbes
3. WU				Wageningen University, The Netherlands	Aquatic Ecology and Water Quality Management Group	Paul J. Van den Brink
4. RWTH				RWTH Aachen University, Germany	Institute of Environmental Research	Hans Toni Ratte
5. EAWAG				Swiss Federal Institute of Aquatic Science and Technology	Environmental Toxicology	Roman Ashauer
6. SYN	X			Syngenta Ltd., UK	Product Safety	Pernille Thorbek
7. IME				Fraunhofer Gesellschaft, Germany	Fraunhofer Institute for Molecular Biology and Applied Ecology	Udo Hommen
8. UREAD				Reading University, UK	Quantitative Biology and Applied Statistics	Richard Sibly
9. INRA				National Institute of Agronomic Research, France	Ecotoxicology and Quality of Aquatic Environments	Virginie Ducrot
10. VU				Vrije Universiteit Amsterdam, The Netherlands	Theoretical Biology	Bas Kooijman
11. UYORK				University of York, UK	Environment Department	Alistair Boxall
12. UAJG				Jagiellonian University, Poland	Ecotoxicology and Stress Ecology Group	Ryszard Laskowski
13. NERI				National Environmental Research Institute, University of Aarhus, Denmark	Department of Arctic Environment	Jacob Nabe-Nielsen
Associated Partners						
1. RifCon		X		Rifcon GmbH, Germany		Magnus Wang
2. gaiac		X		Research Institute Gaiac, Germany		Monika Hammers-Wirtz
3. Bayer		X		Bayer CropScience		Dieter Schäfer

4. BASF		X		BASF	Crop Protection	Peter Dohmen
5. UBA				Federal Environmental Agency, Germany	Plant Protection Products	Jörn Wogram
6. KEMI				Swedish Chemical Agency	Pesticides and Biotechnical products	Gunilla Ericson
7. PSD				Pesticides Safety Directorate, UK		Melissa Reed
8. CTGB				Board for the Authorisation of Plant Protection Products and Biocides		Peter van Vliet
9. INIA				Instituto Nacional de Investigación y Tecnologia Agraria y Alimentaria, Spain	Departamento de Medio Ambiente	José Tarazona

Further regulatory authorities expressed interest in participating as associated partners, but could not provide letters of commitment at this stage, i.e. AFSSA (France), EPA (Denmark) and EFSA (EU).

2. PROJECT OVERVIEW AND OBJECTIVES

There is widespread concern for how the production and use of chemicals may affect the environment, yet food production and the benefits of chemical products are vital for the functioning of European societies. In order to ensure sustainable use, chemicals are subject to regulation, such as EU directive 91/414, REACH and the Water Framework Directive, and extensive risk assessments are required before the use of a chemical is approved. For this, however, it is vital to gain a better understanding of how anthropogenic stressors interact with ecosystems - a better understanding than what current regulation allows for because it will lead to more ecologically relevant risk assessments as well as improved risk mitigation strategies and ecosystem management.

Current regulatory data requirements for environmental risk assessments of chemicals focus on the individual organism level, but according to EU directives the protection goal is the population-level. Population-level effects depend not only on exposure and toxicity but also on a suite of important ecological characteristics of the species of concern and the landscape under consideration. It is **virtually impossible** to fully address all these characteristics empirically for all possible organisms and environmental conditions. Mechanistic effect models enable the inclusion of these characteristics and simulate how they modify the impact of toxic effects at the population level. By mechanistic effects models we mean ecological models that explicitly represent key ecological processes such as toxicokinetic models, population models and community models.

So far, however, regulators and industry have to a large extent lacked understanding of what benefits mechanistic models can deliver, and academics have not been consistent in the modelling approaches applied and model descriptions have often been incomplete, which have lead to widespread scepticism about models, preventing a wider use of mechanistic models in risk assessments. There is a pressing need for examples that clearly demonstrate the power of mechanistic effect models for risk assessment, and there is a European-wide need for researchers as well as employees for industry and regulatory authorities that are well-trained in both mechanistic modelling and regulatory risk assessment.

To achieve this, CREAM (Chemical Risk Effects Assessment Model) has two main objectives:

1. Develop a suite of well-tested and validated mechanistic ecological effect models, such as population models and toxicokinetic-toxicodynamic models, for an array of organisms and ecosystems relevant for chemical risk assessments.

2. Provide world class training for the next generation of ecological modellers, emphasizing transparency and rigorous model evaluation as core elements of models for decision support.

These objectives will be achieved by involving all relevant sectors (industry, academia, regulatory authorities) as active partners; by including modelling experts that cover a wide range of organisms, chemicals, ecosystems, and model types; and by formulating guidance regarding **Good Modelling Practice** (GMP). This will ensure that model development and evaluation of all the individual ESR's projects will be scientifically sound and yet coherent and efficient; and provide a **comprehensive and unique network training** in ecological modelling, risk assessment, and complementary skills.

CREAM will deliver: a cohort of ESRs which will have excellent career opportunities in industry and regulatory authorities as well as in academia. They will disseminate the framework and approaches of CREAM to different sectors all over Europe, improve relationships between the different sectors of society within and across European countries, and develop concrete guidance on GMP for ecological risk assessments that has been approved by many of established developers and decision makers from industry, academia, and regulatory authorities from all over Europe.

CREAM is inter-disciplinary and inter-sectoral by its very nature: developing mechanistic models requires collaboration among different disciplines (chemistry, ecotoxicology, biology, ecology, mathematics, computer science, geography, socio-economy), and regulatory risk assessment requires that the three main sectors industry, academia, and regulatory authorities are involved. CREAM's consortium covers all disciplines and sectors relevant for the projects' success. In addition, one postdoc will be hired for studying socio-economic aspects of chemical risk assessment all over Europe.

3. S&T QUALITY

3.1. STATE-OF-THE-ART AND OBJECTIVES

For the current EU regulatory risk assessment of chemicals mandatory data sets consist of individual level toxicity data, while protection goals are set at the population and community levels. For example, for crop protection products the protection goal is that their application "does not have any long-term repercussions for the abundance and diversity of non-target species" (EU Dir 91/414). Population-level effects, however, depend not only on exposure and toxicity but also on life-history characteristics, population structure, density dependence, timing of exposure, and landscape structure. The ecological significance of current risk assessments of chemicals remains unclear.

It is in society's interest to minimize both false negatives and false positives. This means avoiding impairment of ecosystem services, on which human well-being depends, while at the same time ensuring cost-effective food production to feed a growing global population. All this is even more critical since currently environmental conditions are changing at unprecedented rates so that the management of natural resources, biodiversity, and ecosystem functions will become even more important in the near future. This is especially true for agricultural landscapes where the growing population and demands for biofuels put strain on food security that has to be managed carefully in order to avoid adverse environmental impacts

Empirical methods to assess risk at the population or community level are model ecosystems (e.g. aquatic micro- and mesocosm studies), greenhouse and (semi-)field tests. However, recovery of populations cannot always be observed in these systems because of their isolated nature and the short time-span covered. In addition, for vertebrates, testing effects on population dynamics directly is not practicable or ethical. The main limitation of empirical methods is, however, that it remains unclear how representative their results are for the variety of agricultural and other ecosystems present in Europe, i.e. to what extent extrapolation is needed.

Tools are urgently needed that overcome the limitations of laboratory, semi-field and field tests and allow predicting the recovery of populations, extrapolation from standard laboratory toxicity test data to endpoints with ecological relevance, and extrapolation from existing data to larger scales, different exposure patterns or geographic regions. In principle, such a set of tools already

exists: **mechanistic effect models**. These are ecological models that represent key processes at the individual, population or community level. Indeed, ecological modelling has been used to demonstrate how the effects of toxicants interact with life history (Stark & Banks, 1999; Stark et al., 2004), landscape structure (Halley et al., 1996; Topping et al., 2003; Thorbek & Topping, 2005; Topping et al., 2005), differences in sensitivity among life stages (Meng et al., 2006), timing of application (Thompson et al., 2005), density dependence (Forbes et al., 2001; Forbes et al., 2003), endocrine disruption (Brown et al., 2005), and multiple stressors (Koh et al., 1997; Ashauer et al. 2007b). Models are also used to extrapolate from lab and semi-field studies to field situations (Naito et al., 2003; Lopes et al., 2005; Van den Brink et al., 2006) or to predict recovery time (Barnthouse, 2004; Ashauer et al. 2007a; Van den Brink et al., 2007).

There are, however, **two main obstacles** hindering the use of mechanistic effect models in regulatory risk assessments: (1) the lack of a framework for developing these models in a coherent and transparent way, fostering a widespread scepticism about models; (2) the lack of researchers that are well-trained both in ecological modelling and risk assessment. Across Europe, very few regulatory authorities or chemical industries have personnel trained in ecological modelling; and only few academic developers of ecological models are familiar with the regulatory process. To overcoming these two obstacles CREAM's two main objectives are:

1. **Develop a suite of well-tested mechanistic effect models for an array of organisms and systems relevant for chemical risk assessments.** The consortium includes the three main sectors involved (industry, academia, regulators) and will formulate a Good Modelling Practice (GMP) which will be followed and scrutinized in all the individual modelling projects, leading to consistency and transparency across all systems and questions addressed. The project will deliver 1) concrete guidance regarding GMP for ecological risk assessments, 2) a suite of models that clearly demonstrate the power of mechanistic effect models, and 3) a suite of risk assessments that are based on increased realism, ecological relevance and robustness.
2. **Provide world class training for the next generation of ecological modellers, emphasizing transparency and rigorous model evaluation as core elements of models for decision support.** The ESRs will be trained in their individual projects by leading modelling experts. Every project will be co-supervised by at least two full partners (modelling) and at least one associate partner (modelling and/or risk assessment). Network level training will include all relevant aspects of ecological modelling, risk assessment and complementary skills. The project's training will offer excellent career opportunities not only in academia, but also in the other stakeholder groups involved. Excellent modellers are a highly sought-after human resource, also beyond the specific field of chemical risk assessment.

CREAM's focus will be on effects of chemicals on populations. Many of the case studies will focus on pesticides as there are more data available, and the possibility for achieving significant breakthroughs is high, but further chemicals will be included, and the deliverables of the project will be relevant for chemical risk assessment under other chemical directives (biocidal products, veterinary medicines and pharmaceuticals), the Water Framework Directive and REACH. Data for parameterisation and validation will be taken from existing data bases and from newly performed experiments specifically designed for model parameterisation or model testing.

3.2. RESEARCH METHODOLOGIES

A broad spectrum of population models exists. Three major types can be identified in the context of chemical risk assessment: differential and difference equations, matrix models, and individual- or agent-based simulation models (Bartell et al. 2003, Pastorok et al. 2002, 2003). Differential and difference equations are good for exploring general ideas and principles, and they are often used for modelling effects at the individual level, e.g. toxicokinetic-toxicodynamic models (TK/TD) focussing on physiological effects and so-called DEBtox models (Dynamic Energy Budget; Kooijman 2000) which explore the effects of chemicals on reproduction and, in turn, populations. Matrix

models (Caswell 2001) describe population structure and are designed for projections, i.e. extrapolating the consequences of current environmental conditions into the future. Matrix models can, based on limited and easily obtainable data, compare the impact of a certain exposure for species with different life histories (Stark et al. 2004). Individual-based models (IBMs) are very flexible and can include a wide range of factors of importance for population dynamics (Grimm and Railsback 2005, Van den Brink et al. 2007), but their development and testing can be time-consuming. In metapopulation models, networks of local populations are described, which are too small for long-term persistence but linked, via dispersal, to other local populations (Hanski 1999).

CREAM will include all model types mentioned above, and – in contrast to current practice (Grimm et al. 2008) – the choice of model type and structure will follow consistent and logical principles. Guidance on **Good Modelling Practice** (GMP) for chemical risk assessment will be formulated, with the aim of documenting important model design decisions, thereby making them transparent and reproducible. The GMP will be based on five elements:

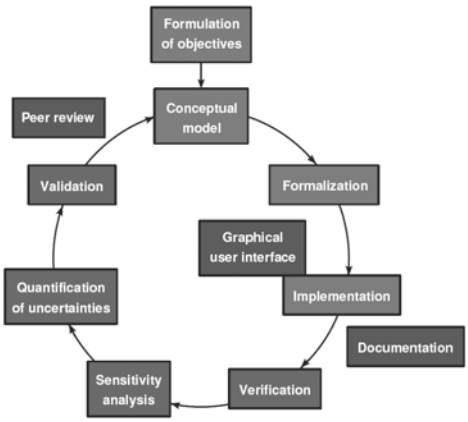

Fig. 1. The modelling cycle for models for decision support and risk assessment. (From Schmolke et al., *unpubl. manuscript*).

1. **Modelling cycle:** Developing models always follows the same sequence of tasks, independent of model type and problem addressed. Modelling means to go through this "modelling cycle", or parts of it, iteratively (Grimm and Railsback 2005). For CREAM, the modelling cycle depicted in Fig. 1 will be used as a framework for all individual projects. The GMP includes checklists for each of these tasks, which will be used for a concise but comprehensive documentation of the entire modelling process. This will support the transparency and rigorousness required for models for decision support.
2. **ODD protocol**: For individual-based models, a general format for model description has already been developed (the Overview, Design concepts, Details protocol; Grimm et al. 2006). For CREAM, this protocol will be extended to include other model types so that all model descriptions follow the same format, e.g. present the model's elements in a certain sequence.
3. **Rigorous model evaluations**: Model evaluation includes four elements, which will be dealt with in a systematic and rigorous way (Fig. 1). (1) Verification: Making sure the model has been implemented correctly and represents the real system sufficiently well according to specific criteria. Verification includes calibration and parameterisation. (2) Sensitivity analysis: Ranking model parameters according to relative influence on model predictions, thereby identifying key parameters that need to be determined more carefully. (3) Uncertainty analysis: Quantifying variation in model output in response to variation in model parameters, thereby providing confidence limits for model predictions. (4) Validation: Testing model predictions that were not used for verification and calibration, with independent data sets. Models cannot be "valid" in an absolute sense, because they are simplified representations of reality. Therefore validation is rather

a means for increasing confidence in the model's capability of capturing key mechanisms of the real system, so that management decisions can be based on model predictions.

4. **Combining different model types**: IBMs can be simplified until they correspond to matrix models; matrix models can be aggregated to differential equation models. Thus, where possible different types of models will be developed for the same project and question. This approach is innovative. It will ensure consistency among model predictions of different model types, it provides a test of more complex models, and it allows clear demonstration of how understanding, predictive power, and required resources change depending on model complexity. ESRs will thus be – in contrast to the training currently available – trained in the full spectrum of model types. This will be ensured by co-supervision of each project by at least two full partners and by the network training.
5. **Peer review**: CREAM will implement and test anonymous peer reviewing of model-based risk assessments. In the final phase of the project, all individual model documentations will be peer-reviewed by other, anonymous CREAM partners that were not involved in developing the model. Peer review will check whether GMP has been followed, i.e. whether the structure and behaviour of the model are well-documented, etc., so that the model-based risk assessments can be evaluated in terms of meeting the requirement for registration. Peer review thus serves, as for scientific publications, quality control and improvement.

3.3. RESEARCH QUESTIONS

Within the frame of the two main research objectives of CREAM (Section 2), CREAM will focus on a suite of specific highly relevant research questions. CREAM provides a unique combination of disciplines, sectors, and excellence to answer these questions at a level that will go far beyond the current state-of-the-art in ecological risk assessment of chemicals:

Recovery: How does population recovery depend on toxicity and ecological factors such as life-history characteristics, species traits, population structure, density dependence, timing of exposure, and landscape structure?

Extrapolation: How can we extrapolate from individual to population, from small scales to larger scales, from species to species, and from certain environmental settings to different ones?

Sensitivity: How does sensitivity at the individual level mechanistically link to impacts on populations, and to what extent can the linkages be extrapolated among species?

Sublethal effects: What is the relative importance of lethal versus sublethal effects for controlling the population- (and community) level impacts of chemicals in the field?

Model complexity: What level of model complexity is needed for different types of risk assessment questions?

Most individual PhD projects will focus on a sub-set of these questions, but for every question CREAM includes the "critical mass" of projects so that synergies can be employed and general answers found.

3.4. WORK PACKAGES

CREAM includes five work packages (WPs; Fig. 2). The first three WPs group individual projects by the type of ecosystem and organisms addressed:

- Work package A: Aquatic Invertebrates
- Work package B: Terrestrial Invertebrates
- Work package C: Vertebrates

The fourth work package organizes the formulation, testing, and refinement of CREAM's core feature, the Good Modelling Practice:

- Work package D: Good Modelling Practice

CREAM will provide unique data sets for a wide range of systems, species, and environmental conditions. These data sets can be used not only in many of CREAM's individual projects but also for future tests and validations of mechanistic effect models.

- Work package E: Validation Data Sets

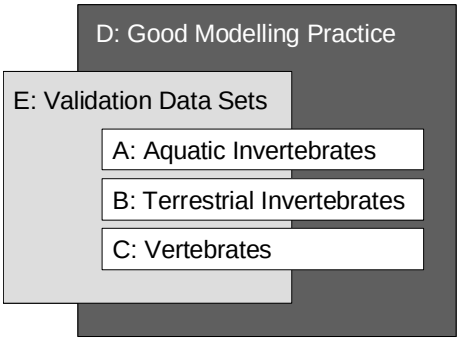

Fig. 2. Schematic overview of CREAM's work packages. WP D applies to all individual projects and includes a socio-economic postdoctoral project (**Risk**, see Table 2). WP E applies to most projects, but also includes data sets from external sources.

Table 2 provides an overview of the 20 PhD and three postdoc projects. For the three **postdoctoral** projects, experienced researchers (ERs) with training in ecological modelling and risk assessment are needed because they will integrate clusters of PhD projects and they will significantly contribute to training. More detailed explanations of their role in CREAM are given in the corresponding project descriptions.

Table 2. Overview of CREAM's work packages and projects, including each project's supervisor (bold) and co-supervisor, research theme, type of work (modelling, empirical, or both), main model type, and the advising associated partner. Some of the projects are closely related to other projects, which is indicated by using the same acronym for these project clusters. Projects with a focus on empirical work (Emp) still include at least 20% modelling work (see Section 4). Postdoctoral projects that require an ER are highlighted.

Project Acronym	**Super-visors**	**RESEARCH THEME**	**Modelling or Empirical**	**Main Model Type**	**Associated Advisor**
WORK PACKAGE A: Aquatic Invertebrates					
Daph-1	**UFZ** IME	Experiments on effects of interspecific competition on population recovery (input for Daph-2)	Emp	IBM	UBA
Daph-2	**UFZ** RWTH	Modelling effects of interspecific competition on population recovery	Mod	IBM	Gaiac
Daph-3	**RWTH** UFZ	Modelling the effects of mode-of-action of the toxicant on population recovery and extinction	Both	IBM	Gaiac
Copepod	**RWTH** IME	Develop, calibrate and test a model for freshwater copepods	Both	IBM	Gaiac
Scales-1	**EAWAG** WU	Determination of toxicity by compound and species characteristics at different scales (input for Scales-3)	Both	TK/TD	Bayer
Scales-2	**UYORK** EAWAG	Influence of time-varying patterns of exposure on chronic and sub-lethal effects (input for Scales-3)	Both	TK/TD	PSD
Scales-3	**WU** UFZ	Population-level effects of pesticide exposure at the small watershed level	Both	IBM Meta	CTGB

Scales-4 postdoc	**WU** UYORK	Extrapolating from local to regional effects using GIS and Population Viability Analysis	Mod	IBM Meta	UBA
DEB-1	**VU** INRA	Food web effects of the limits of individual-level mechanisms like “dilution of effect by growth”	Mod	DiffEq	Bayer
DEB-2	**INRA** VU	Mechanistic modelling for risk assessment of endocrine disrupting pesticides in molluscs	Both	DiffEq	CTGB
WORK PACKAGE B: Terrestrial Invertebrates					
Soil-1	**RUC** UJAG	Impact of spatial heterogeneity in soil contamination on collembolans populations	Both	IBM Meta	INIA
Soil-2	**UJAG** RUC	Disturbance interactions: the combined effects of toxicants and environmental stochasticity on collembolans (input for Soil-3)	Emp	-	KEMI
Soil-3	**UJAG** RUC	Disturbance interactions: modelling environmental and demographic stochasticity for populations exposed to toxicants	Mod	Matrix IBM	INIA
Matrix	**RUC** UREAD	Life-table experiments and elasticity analyses for linking toxicity to ecological risk	Both	Matrix	INIA
WORK PACKAGE C: Vertebrates					
Verteb postdoc	**SYN** UREAD	Applying toxicokinetic modelling to wildlife risk assessment for pesticides	Mod	TK/TD IBM	PSD
Mam-1	**SYN** UREAD	Modelling the importance of exposure patterns, life history traits and toxicokinetics for the risk to populations of small mammals	Mod	IBM	PSD
Mam-2	**UYORK** UFZ	Modelling the effects of soil contaminants on bats	Both	IBM	RifCon
Bird-1	**UREAD** SYN	Modelling the importance of landscape structure and life history traits for the risk to populations of skylarks	Mod	IBM	PSD
Bird-2	**UREAD** SYN	Modelling the importance of landscape structure and life history traits for the risk to populations of wood pigeons	Mod	IBM	RifCon
Bear	**NERI** UFZ	Modelling effects of chemicals on polar bear population dynamics	Mod	IBM Matrix	KEMI
Fish-1	**EAWAG** IME	Predicting toxicity to fish based on in vitro data via a two step model (input for Fish-2)	Both	TK/TD	BASF
Fish-2	**IME** EAWAG	Extrapolating sub-lethal effects on fish to the population level	Mod	Matrix IBM	BASF
WORK PACKAGE D: Good Modelling Practice					
Risk postdoc	**RUC** UFZ	Integrating ecological models in risk assessment and risk management	-	-	UBA

In about half of the projects, new models will be developed; the rest will build on existing models. Since the existing models were not developed according to the guidance for GMP provided by CREAM, these models may need to be reformulated, documented, tested, and often also newly parameterized. This will act to **synchronize projects** working with new and existing models.

In some projects the modelling and empirical work will be carried out by the same ESR. This guarantees that the modelling is carried out with an awareness of how the data are generated and what kind of uncertainty they contain and will ensure that the experimental design is tailored to the modelling needs. Some ESRs will work mainly empirically but nevertheless will obtain full training in ecological modelling. They will be involved in formulating the problem and conceptual model, in

parameterization, testing, validation, and application for risk assessments. They will closely collaborate with the ESRs developing a model for their system; this ESR will also be involved in performing the experiments, so that a true integration of modelling and empirical work is guaranteed.

In the following, the WP's projects are described in more detail, followed by the WP's deliverables and milestones. The leaders of the WPs are indicated as well as 1st and 2nd supervisor and the advising Associated Partner.

WORK PACKAGE A: Aquatic Invertebrates (WP leader: Udo Hommen)

Daph-1: **Experiments on effects of interspecific competition on population recovery**. The Department of System-Ecotoxicology at UFZ has developed a test-system that enables long-term experiments supporting several generations of competing species in small lab systems. This project will explore the effects of competition by insect larvae on population recovery of *Daphnia magna* competing with larvae of *Culex pipiens*. The experiments will directly support the development and testing of corresponding individual-based community models developed together with **Daph-2**. Supervisors: Liess (UFZ), Hommen (IME). Advisor: UBA.

Daph-2: Pattern-oriented modelling of interspecific competition and recovery. Pattern-oriented modelling is a strategy that was formulated at UFZ. Its main element is to try and validate a model simultaneously with a set of multiple patterns observed at different scales and levels of organisation. For laboratory populations of *Daphnia magna*, such patterns are provided by the test-system of **Daph-1** where in addition to population size, age-structure can be monitored continuously. This offers the unique chance to develop well-tested and predictive individual-based models of *Daphnia* populations which can be used to explore population recovery after the application of a toxicant. The aim of this project is to develop testable, predictive models, to use model results for designing new experiments for **Daph-2**, and to provide insights into the effect of interspecific competition on population recovery. Supervisors: Grimm (UFZ), Preuß (RWTH). Advisor: gaiac.

Daph-3: Modelling the effects of toxicant mode-of-action on population recovery and extinction. An existing individual-based model (IdamP) for laboratory populations of *Daphnia magna* will be used to test the relevance of ecological factors on the time to recovery and extinction probability for different modes-of-actions. The modes-of-action will include acute toxicity (e.g. nonylphenol), inhibition of reproduction (e.g. 3,4-Dichloroaniline, Dispersogen A) and male formation (e.g pyriproxyfen). The outcome of the simulation will be tested against laboratory data, which will be collected for different exposure scenarios. The model output will be tested against semi-field data for different pesticides and chemicals with different modes-of-action. Supervisors: Preuß (RWTH), Grimm (UFZ). Advisor: gaiac.

Copepod: **Development of an individual-based copepod model.** This project will develop an individual-based model for cyclopoid copepods. Parameterisation of life-cycle characteristics, such as food consumption, growth and reproduction, will be based on available literature. Effects of a selected pesticide will be measured at the level of the individual. The model will be tested against effects at the population level at laboratory scale as well as against mesocosm data. This model will allow extrapolation of effects from the individual to the population level as well as between different environmental scenarios. Supervisors: Ratte (RWTH), Hommen (IME). Advisor: gaiac.

Scales-1: Determination of toxicity by compound and species characteristics at individual and population levels. This project investigates whether the importance of the different factors determining toxic effects shift when moving from lower levels of biological organisation (individual) towards higher levels (population level). A set of combined models, consisting of a toxicokinetic-toxicodynamic (TK/TD) part and an individual-based population model, will be developed for environmental toxicants with contrasting properties and aquatic invertebrates with contrasting species traits and life-cycles. Project **Scales-3** will use output from this project as building blocks for the metapopulation model. Supervisors: Ashauer (EAWAG), Van den Brink (WU). Advisor: Bayer

Scales-2: Influence of time-varying patterns of exposure on chronic and sub-lethal effects. This project will develop and apply innovative experimental methodologies to investigate how realistic, time-varying patterns of exposure influence chronic and sub-lethal effects on aquatic invertebrates. A TK/TD modelling approach will be adopted that fits to models developed in **Scales-1/3**. Laboratory experiments will consider chemicals with specific modes-of-action (e.g. moulting inhibitors) as well as general narcotic compounds. Endpoints will include reproductive tests (e.g. *Daphnia*), emergence tests (e.g. *Chironomus*) and feeding inhibition (*Gammarus*). Experiments will generate model parameters that can then be related back to chemical properties to generalise the experimental findings. Supervisors: Brown (UYORK), Ashauer (EAWAG). Advisor: PSD.

Scales-3: Population-level effects of pesticide exposure at the small watershed level. A set of individual-based metapopulation models will be developed that can describe the effects of pesticide exposure to a range of macro-invertebrate species at the small watershed level. Individual-level effects will use building blocks of the projects **Scales-1/2**. A range of small and simple landscape scenarios will represent contrasting situations with varying potential for recovery of affected populations. The fully parameterised set of IBM models can be used to investigate species and compound-specific driving factors of toxic effects at different levels of biological organisation and allows the calculation of recovery times and recovery potential at different scales. A central part of this project will be the gathering of unique validation data sets. Supervisors: Van den Brink (WU), Grimm (UFZ). Advisor: CTGB.

Scales-4 (POSTDOC): Extrapolating from local to regional effects using GIS and Population Viability Analysis. This project will build on and integrate the projects **Scales-1/2/3**, i.e. the individual-based and TK/TD models from projects will be used as building blocks for a metapopulation model. Therefore, this project requires an ER with experience in ecological modelling at different scales. The ER will be hired in the second year of the project and will help the ESRs of **Scales-1/2/3** in developing appropriate interfaces of their models to models covering larger scales. The project will focus on developing methodologies for extrapolating effects on populations at the local scale to the regional, watershed level. Supervisors: Van den Brink (WU), Brown (UYORK). Advisor: UBA.

DEB-1: Food web effects of the limits of individual-level mechanisms like “dilution of effect by growth”. The primary aim of the proposed project is to use Dynamic Energy Budget (DEB) theory to work out population- and ecosystem-level consequences for the combination of body size scaling relationships and Quantitative Structure Activity Relationships including both transient and long-term behaviour. The project will focus on generic small-bodied aquatic organisms and address two questions: what is the importance of the phenomenon of "dilution by growth": can small-bodied organisms keep the internal concentration of slowly entering compounds low by growing fast? The second focus is the relationship between No Effect Concentrations (NECs) for individuals and a variety of quantifiers for the performance of food webs. Supervisors: Kooijman (VU), Ducrot (INRA). Advisor: Bayer.

DEB-2: Mechanistic modelling for risk assessment of endocrine disrupting pesticides in molluscs. This project aims at developing an innovative mechanistic modelling approach, including test methods and data analysis tools, to extrapolate effects of endocrine disrupting pesticides (EDPs) on populations from individual indices as quantified through life-cycle tests on *Lymnaea stagnalis*, i.e. species for which OECD testing guidelines for EDCs are currently in development. Life-cycle test data obtained in the laboratory will be used to develop mechanistic models of effect based on DEB theory, in agreement with good modelling practice. Outputs of the DEB models will be compared with TK/TD models and used to assess population-level effects. The findings will contribute to developing standard test methods for EDCs in molluscs and will provide a generic modelling framework that can be applied to other species, including vertebrates, to evaluate population effects of EDCs. Supervisors: Ducrot (INRA), Kooijman (VU). Advisor: CTGB.

Deliverables of WP A:

1. Ten successfully defended PhD theses.
2. Per fellow project three manuscripts submitted/published to/in international journals.
3. Articles providing overview and synthesis of the answers of the WP to CREAM's research questions
4. Documentation on Good Modelling Practice (GMP) for each project.
5. An after-project career development plan for every fellow.

Milestones of WP A:

1. Recruitment of fellows finished (month 4).
2. Formulation of working hypotheses and work plan for each project (month 6).
3. Personal career development plans for each ESR including complementary skills checklist (month 12, 24, 36).
4. Submission of first manuscript (month 20) and draft documentation of GMP.
5. Completion of deliverables (month 48).

WORK PACKAGE B: Terrestrial Invertebrates (WP leader: Valery Forbes)

Soil-1: Impact of spatial heterogeneity in soil contamination on collembolan populations. This project will use a combination of metapopulation modelling and individual-based modelling to predict the impacts of spatial heterogeneity in soil contaminant levels for the population dynamics of the collembolan, *Folsomia candida*. The models will be developed following the principles of Good Modelling Practice, and thereby used to 'field-test' and fine tune the principles. The model predictions will be subsequently tested in mesocosm studies of intact populations of *F. candida* and the implications of the results for ecological risk assessment explored. Supervisors: Forbes (RUC), Laskowski (UJAG). Advisor: INIA.

Soil-2: Disturbance interactions: the combined effects of toxicants and environmental stochasticity on collembolans (input for Soil-3). In this project we will perform experiments in which populations of two springtail species are exposed simultaneously to elevated metal concentrations in soil and environmental stochasticity (i.e., temperature) of different magnitude and frequency. The species to be used represent two contrasting reproduction strategies: parthenogenesis (*Folsomia candida*) and sexual reproduction (*Sinella curviseta*), allowing a comparison of effects on otherwise similar species, differing mainly in their reproductive strategies. Both basic population parameters and extinction probabilities will be calculated. This project will deliver data for the project **Soil-3**. Supervisors: Kramarz (UJAG), Forbes (RUC). Advisor: KEMI.

Soil-3: Disturbance interactions: modelling environmental and demographic stochasticity for populations exposed to toxicants. This project aims at using a range of different stochastic models, including matrix models, to find the best mechanistic description of the phenomena actually observed in empirical studies. The empirical data sets generated in **Soil-2** will be used for testing the models, and model outputs will be employed for developing appropriate experimental designs. This "feedback loop" between models and experiments will allow for developing reliable ecotoxicological tests, which can be used in ecological risk assessment. Supervisors: Laskowski (UJAG), Sibly (UREAD). Advisor: INIA.

Matrix: Life-table experiments and elasticity analyses for linking toxicity to ecological risk. In this project we will perform life-table response experiments on selected invertebrate species and integrate the results in matrix population models, from which we can perform elasticity analyses of different population-level endpoints. We will validate the elasticity predictions (which estimate the relative changes in population dynamics resulting from relative changes in individual life-history traits) by manipulations of intact populations, in which we selectively harvest different age/size classes to simulate toxicant impacts. A range of invertebrate species, with varying life histories (and hence elasticity patterns) will be investigated. The results will contribute to improving the selection and interpretation of test endpoints to be used in risk assessment. Supervisors: Forbes (RUC), Sibly (UREAD). Advisor: INIA.

Deliverables of WP B:

1. Four successfully defended PhD theses.
2. Per fellow project three manuscripts submitted/published to/in international journals.
3. Articles providing overview and synthesis of the answers of the WP to CREAM's research questions
4. Documentation on Good Modelling Practice (GMP) for each project.
5. An after-project career development plan for every fellow.

Milestones of WP B:

1. Recruitment of fellows finished (month 4).
2. Formulation of working hypotheses and work plan for each project (month 6).
3. Personal career development plans for each ESR including complementary skills checklist (month 12, 24, 36).
4. Submission of first manuscript (month 20) and draft documentation of GMP.
5. Completion of deliverables (month 48).

WORK PACKAGE C: Vertebrates (WP leader: Pernille Thorbek)

Verteb (POSTDOC): Applying toxicokinetic modelling to wildlife risk assessment for pesticides. The host of this project, Syngenta (SYN), has in contrast to all other full partners currently only one person (P. Thorbek) that can supervise ESR. SYN plays, however, a central role in CREAM: it is the only full partner from industry and will host several co-supervised ESRs and interns; it is involved in three PhD projects; it will be actively involved in CREAM's implementation (see Section 5). Thus, additional staff is needed to fulfil Syngenta's role in CREAM, in particular in the first two years, which cover the ESR's initial training. This postdoctoral project aims at making individual-level effect models usable for wildlife risk assessment, i.e. birds and mammals. The project supports all other ESR projects focusing on individual-level models with regard to the extrapolation and ecological relevance of their findings. The project will explore the mechanisms that drive pesticide risk to birds and mammals by taking account of the temporal aspect of the interaction between exposure, depuration and toxicology. Special emphasis will be given to finding methods for parameterisation that can reduce the need for animal testing or give less severe endpoints. Supervisors: Thorbek (SYN), Sibly (UREAD). Advisor: PSD.

Mam-1: **Modelling the importance of exposure patterns, life history traits and toxicokinetics for the risk to populations of small mammals**. In this project, an individual-based model will be constructed for a small mammal (field vole and/or wood mouse). The model will take into account factors such as life history (e.g. breeding pattern and dispersal), landscape structure and spatio-temporal variation in exposure. The model will integrate the toxicokinetic models constructed in the project Verteb. The research questions are: (a) what impact do sublethal effects such as reduced fecundity have at the population level, (b) a sensitivity analysis will be used to explore whether spatiotemporal aspects of exposure, life history or the feeding pattern and toxicokinetic aspects have the greatest contribution to risk. Supervisors: Thorbek (SYN), Sibly (UREAD). Advisor: PSD.

Mam-2: Modelling the effects of soil contaminants on bats. In this project, a modelling framework will be developed for predicting the effects of soil contaminants (heavy metals) on individual bat species. Controlled experiments will explore the uptake of the test chemicals from soil into insects and insect contaminant uptake models will be developed. Alongside these studies, experiments will investigate the bioaccessibility of the study contaminants from insects into predatory species using i*n vitro* bioaccessibility studies that mimic the chemistry of the bat gut. Read across approaches for extrapolating from standard mammalian toxicity species to wildlife will be developed. The resulting individual-level model will be combined with an individual-based landscape-level population model. Supervisors: Boxall (UYORK), Grimm (UFZ). Advisor:RifCon.

Bird-1: Modelling the importance of landscape structure and life history traits for the risk to populations of skylarks. This project will address the following questions: (1) what is the mini-

mum level of model complexity needed to get a realistic simulation of skylark population dynamics; (2) is realism affected by detailed landscape structure? An individual-based model (IBM) of the skylark will be developed and deployed in a Northern European landscape. Existing data will be used to parameterize the model using pattern-oriented modelling. The performance of the model will be systematically compared with simpler matrix models and with a more complex ALMaSS model developed by Dr C.J. Topping of the Danish National Environmental Research Institute. The IBM will finally be used to investigate the population effects of a pesticide that are difficult to assess using existing tools, i.e. recovery and sublethal effects. Supervisors: Sibly (UREAD), Thorbek (SYN). Advisor: PSD.

Bird-2: Modelling the effects of chemicals on wood pigeons. This project is similar in concept to **Bird-1** but differs in approach and focus. The woodpigeon is a key component of Northern European landscapes but differs markedly in its diet (herbivorous vs. graminaceae seeds and leaves) and nesting (trees vs. ground) from the skylark, and it does not migrate. While there is an immense scientific literature on its behaviour and ecology it has never been modelled. Following a review of the relevant literature an IBM will be developed and comparisons made with the skylark model to determine the effect of diet, breeding and migratory strategies on how birds are affected by pesticides. These comparisons will be used for considering the important but difficult question of extrapolation between species. Supervisors: Sibly (UREAD), Thorbek (SYN). Advisor: RifCon.

Bear: Modelling effects of chemicals on polar bear population dynamics. This project will develop individual-based and matrix models for studying population-level effects of varying food availability and chemical concentrations on polar bear population dynamics in three geographically separated bear populations. A major focus of the project will be to evaluate what level of model complexity is needed in order to reproduce sufficiently accurate population level patterns. This will be achieved by building a hierarchy of models of gradually increasing complexity, starting with a simple non-spatial model. Supervisors: Nabe-Nielsen (NERI), Grimm (UFZ). Advisor: KEMI.

Fish-1: Predicting toxicity to fish based on in vitro data via a two step model. In this project a toxicokinetic-toxicodynamic (TK/TD) model for fish will be parameterised based on in-vitro data. Physico-chemical properties of the compound, artificial membrane permeability assays and in-vitro biotransformation studies with cellular fractions from fish liver can be used to obtain toxicokinetic parameters whereas the toxicodynamic parameters will be obtained from fish cell line toxicity studies. A set of existing toxicity data (from IME) will be used to obtain a quantitative relationship between toxicity on fish cells predicted by the model and effects on the level of whole organisms. If the link to effects on the level of organisms can be established this modelling approach can greatly reduce the need for animal testing to predict toxicity. Supervisors: Schirmer (EAWAG), Hommen (IME). Advisor: BASF.

Fish-2: Extrapolating sublethal effects on fish to the population level. This project will develop models that extrapolate sublethal effects in standard toxicity tests to the population level for fish species with different life-cycle types. The data from **Fish-1** on alternative test methods (e.g. cell line tests) will also be used. Life-cycle data for European fish species will be taken from the literature. Patterns in these data will be used to validate the models. The project will lead to a more realistic assessment of chemical effects on fish populations of temperate regions and also to a decreased use of animal testing. Supervisors: Hommen (IME), Ashauer (EAWAG). Advisor: BASF.

Deliverables of WP C:

1. Seven successfully defended PhD theses.
2. Per fellow project three manuscripts submitted/published to/in international journals.
3. Articles providing overview and synthesis of the answers of the WP to CREAM's research questions
4. Documentation on Good Modelling Practice (GMP) for each project.
5. An after-project career development plan for every fellow.

Milestones of WP C:

1. Recruitment of fellows finished (month 4).
2. Formulation of working hypotheses and work plan for each project (month 6).
3. Personal career development plans for each ESR including complementary skills checklist (month 12, 24, 36).
4. Submission of first manuscript (month 20) and draft documentation of GMP.
5. Completion of deliverables (month 48).

WORK PACKAGE D: Good Modelling Practice (WP leader: Volker Grimm)

This WP will setup, train, test, and refine the Good Modelling Practice, which is the core approach of CREAM (described in detail in Section 3.2 Research Methodologies). All projects of CREAM have to use this GMP and contribute to its evaluation and improvement. The WP includes one specific postdoctoral project that prepares the European-wide dissemination of the GMP.

Risk (POSTDOC): Integrating ecological models in risk assessment and risk management. This project will systematically analyse the ways in which risk assessors and risk managers in different EU countries assess ecological risks in actual practice and, on this basis, identify where and how mechanistic models can play an important role. The project thus requires an ER who has a background in ecological modelling and risk assessment and is able to deal with socio-economic aspects of risk assessments of chemicals. The ER will start in the first year of CREAM. The project is important for the success of the other ESR's projects because it helps to understand different mindsets prevailing in different sectors. The ER will help ESRs to design their projects and present their results in a way that is easily accessible and usable by representatives of the other sectors (industry, regulatory authorities) in a large number of European countries. The study will identify the most important challenges and obstacles (e.g., scientific, economic, psychological) that limit the use of mechanistic effect models in risk assessment. Areas of high priority, i.e. where the application of mechanistic models is likely to lead to the greatest improvements in risk assessment and management, will be identified. The findings will contribute to developing, and disseminating guidance on Good Modelling Practice for pesticide risk assessment. Supervision: Calow (RUC), Thorbek (SYN). Advisor: UBA.

Deliverables of WP D:

1. Guidance document for Good Modelling Practice (GMP) for ecological risk assessment of chemicals, delivered as a report and in scientific publications.
2. Web site (maintained by UFZ, mirrored by partners) introducing into, explaining, and demonstrating GMP.
3. Course material for 1 to 3 days training courses introducing into GMP.

Milestones of WP D:

1. A draft guidance document for GMP, provided on the project's web site (month 4).
2. An updated version of the guidance document (month 24).
3. Final versions of guidance document, web site, and course materials (month 48).

WORK PACKAGE E: Validation Data Sets (WP leader: Paul J. Van den Brink)

Unique community and ecosystem level validation field data sets will be collected using microcosms and mesocosms. For invertebrates outdoor mesocosms will be used using the unique facilities of Wageningen University, The Netherlands. The facilities in Wageningen consist of experimental ditches of 60 m by 3.5 m which can be interlinked, if needed. They constitute an ideal experimental tool to study the influence of migration, life-cycle characteristics and density dependence of populations and of the structure of the aquatic ecosystem and spatial structure of the water ways on the response of aquatic lentic invertebrates to chemical stress. The pond mesocosms available at the gaiac in Aachen, Germany will be used to gather planktonic validation data sets. Soil validation sets for springtails like *F. candida* and other soil invertebrates will be collected using

terrestrial mesocosms and lab facilities at RUC. In order to parameterise the uptake of chemicals by bats, the University of York will perform experiments studying the bioaccessibility of the study contaminants from insects into predatory species, mimicking the chemistry of the bat gut. EAWAG and IME will perform toxicity tests with fish cells to study the TK/TD of chemicals in fish and how sublethal effects propagate to the population level. UFZ and RWTH will compile *Daphnia* data sets.

Deliverables of WP E:

1. A database containing validation data sets that can be used to validate future models

Milestones of WP D:

1. Specification of data(base) format for validation data sets (month 6).
2. Compilation of mid-term data sets (month 24).
3. Completion of deliverable (month 48).

3.5. THE ROLE OF ASSOCIATED PARTNERS

In the field of chemical risk assessment, an international society exists (**SETAC**, Society of Environmental Toxicology and Chemistry) that actively aims at integrating the knowledge and interests of the three main sectors involved: industry, academia, and regulators. All full and associated partners of CREAM are active SETAC members, including the current **president of SETAC Europe** (Paul Van den Brink, WU), the organizers of the first European SETAC workshop on ecological modelling for pesticide risk assessment (**LEMTOX**, Leipzig, Sept 2007), and members of the steering committee of **SETAC Advisory Group** MEMoRisk (Mechanistic Modelling for Ecological Risk Assessment of Chemicals), which is currently being established. Thus, all CREAM partners, both full and associated, are actively involved in all relevant interdisciplinary and inter-sectoral aspects of chemical risk assessments, and most have been involved in SETAC activities over the last two years that have aimed at fostering a wider and more efficient use of mechanistic effect models for chemical risk assessment.

The regulatory authorities involved (PSD, UK; KEMI, Sweden; CTGB, Netherlands; UBA , Germany; INIA, Spain) have expressed strong interest in providing risk assessment training from the regulatory perspective as well as being trained in mechanistic modelling for risk assessment. Their participation in the project ensures that the end users of the models, the risk assessors, are involved in formulating the GMP, i.e. the very criteria that will be used by risk assessors to assess the quality of model-based risk assessments.

All associated partners will be involved in advising individual PhD projects so that they can contribute their expertise in specific projects that are directly relevant for regulatory risk assessments. All full and associated partners will not only teach, but also learn in this project. Involvement of the associated partners is thus a decisive means for disseminating the concepts, approaches, and results of CREAM at the European level. (For the role of associated partners from industry, see Section 5.3).

4. TRAINING

A **concerted effort is urgently needed** for training of researchers in the field of ecological modelling for decision support in general and for mechanistic effect models in particular. Comprehensive training in ecological modelling is only offered in a few places in Europe, but then usually is focussed on academic, and not applied, problems. Mechanistic models are essential for ecological applications and risk assessments, but qualified researchers that have learned to design, evaluate and apply models in a systematic way are rare. The number of job announcements for PhD students and postdocs with modelling expertise is increasing, both in academia and in environmental management (e.g., conservation biology, fisheries management, regulatory risk assessment). Therefore, CREAM is designed to provide world class training for the next generation of ecological modellers, emphasizing transparency and rigorous model evaluation as core elements of models for decision support.

4.1. ESR TRAINING AT THREE LEVELS

ESR **training** in CREAM operates at **three levels**: individual project, local training, and CREAM network. **Skills** that are **complementary** to disciplinary skills, i.e. time and project management, communication, IPR, ethics, grant writing, CV writing, interviews, obtaining postdoc positions, networking, commercial exploitation of results, research policy, entrepreneurship, etc., will be taught also at these three levels.

At the **level of Individual Projects**, for every PhD and postdoc project two full partners will supervise the project and at least one associated partner will advise the project from the perspective of industry, SME, or regulatory authorities by commenting on regular short progress reports, by meeting with the ESR/ER during training courses, workshops and project meetings. Co-supervision by full partners includes hosting the ESR for in total at least three months during the project. Associated partners will offer internships. Non-university hosts will make sure that the PhD project is registered at a partner university (for example, UFZ: Potsdam University, Germany). For every ESR a **personal career development plan** will be formulated and updated once a year by the ESR, the supervisors and the advisor. Overall career options of the ESRs include: universities and other research centres, industry, consulting firms, regulatory authorities, and self-employment. The ESRs are not restricted to the field of chemical risk assessment; areas such as conservation biology, fisheries management and epidemiology will also offer employment opportunities. Most instruments to implement these options are included in CREAM's network training: courses, workshops, conferences, and internships. Specific instruments needed for an ESR's specific interests, or identified as particularly useful by the supervisors, can be chosen, e.g. courses not covered by CREAM or internships at firms or institutions not involved in CREAM. Particular emphasis will be put on **complementary skills** by including a checklist in the career development plan that lists where and when training in the different skills will be obtained.

At the **level of Local Training Programs:** more and more universities in Europe establish special training programs for graduate students. It will be ensured that the ESRs can participate in these programs. Table 3 gives an overview of local graduate programs or schools of CREAM partners. For hosts without such training programs, ESRs will be able to participate in training programs at a partner university, i.e. either the university where the ESR graduates, or at co-supervisor's host. These programs usually include training in **complementary skills**; if not, it will be ensured in the ESR's career development plan, where and when this training can be obtained, for example at one of the partner institutions. Local training will also include (depending on the hosting institution) participation at lectures and seminars outside the direct scope of the ESR project and working in non-university environments (e.g. industry, working according to Good Laboratory Practice).

Table 3. Local training programs or graduate schools offered by the host institutions or their local partners.

Host	PhD-Program	Description
UFZ	Helmholtz Interdisciplinary GRADuate School for Environmental Research (HIGRADE)	HIGRADE is a graduate school for doctoral candidates/PhD students at the Helmholtz Centre for Environmental Research - UFZ and their partner universities (Leipzig, Dresden, Halle, Jena, Freiberg, Kassel)
RUC	Graduate School of Environmental Stress Studies (GESS)	GESS is Denmark's international graduate school for stress ecology. GESS is led by an interdisciplinary team of scientists from a number of Danish institutions. An important goal of the graduate school is to contribute to improving the scientific basis for environmental risk assessment and management.
WU	The Netherlands Research School for Socio-Economic and Natural Sciences of the Environment (SENSE)	SENSE is a network for integrated environmental research and multidisciplinary PhD training, involving institutes from eight universities and UNESCO-IHE (Delft) and provides a multidisciplinary research program aimed at high quality understanding of environmental problems and advanced training of PhD stu-

		dents.
RWTH	Post-gradual training course offering “Certified Ecotoxicologist” by SETAC GLB and GDCh	3 of the 10 modules are organised at the RTWH ('Statistics', 'Ecological chemistry', 'Aquatic Ecotoxicology') and RWTH is involved also in the modules 'Molecular Mechanisms' and 'Landscape Ecology'
EAWAG	ETH-EAWAG graduate training courses, e.g. in ecology, ecotoxicology, contaminant fate and effects.	Theoretical and practical training in ecology and ecotoxicology, contaminant fate and effect modelling. Complementary skills, research methods, career planning, networking.
UREAD	School of Biological Sciences PhD Program	Training in transferable skills and in research methods (statistical methods; maintenance of lab books; intellectual property considerations etc) including MSc modules where appropriate.
VU	Dynamic Energy Budget (DEB) tele-course (2009)	The tele-course consists of a plenary program of five weeks (part-time) on basic DEB theory (Feb/Mar 2009) followed by an a set of parallel programs of five weeks (part-time), one of them dealing with ecotoxicology (Sept/Oct 2009).
UYORK	Graduate training programs	Graduate training programs across a wide range of environmental disciplines including ecotoxicology, environmental chemistry and risk assessment. Compulsory, credit-based training in transferable skills, research methods (advanced statistics, publishing, public speaking etc), and future career skills (introductory management skills, media training etc).

At the **Network Level** training mainly consists of a series of events (see **work plan** in Annex I) plus the CREAM **homepage** that contains status reports of each project, a Wiki site covering all approaches and methods used, and a user forum for discussion, that also serves as a repository of methods, certain skills, and events. Network-level training will start, during the **recruitment phase** (4 months), with a workshop that will detail CREAM’s research and training program (W: workshop; C: course):

W1. GMP Workshop. Month 3; 4 days. All full and associated partners will discuss and agree on draft guidance for Good Modelling Practice (GMP). Research program and network training will be detailed. Organisation: Van den Brink (WU). Location: Wageningen, Netherlands

After the recruitment phase, CREAM will provide a series of introductory courses and workshops for installing the network, for initial training and for coordinating the individual projects. The workshop and course program in this **initial start-up phase** is intensive but necessary so that all ESRs initially obtain the same comprehensive training in modelling, risk assessment, and the scope and framework of CREAM (i.e., Good Modelling Practice)

All training courses will be designed for **40 participants**; vacant positions will be open to associated partners (first priority) and the public (second priority). Workshops W1 and W2 will be for CREAM members only. The events in the **initial start-up phase** are:

W2. CREAM Start-up. Month 6; 5 days. Introductory lectures about risk assessment and ecological modelling will be given. The needs and concerns of the three sectors involved (industry, academia, regulators) will be discussed and summarized. Associated partners will introduce themselves and explain the training they offer and their capacity. The research questions and (tentative) approaches of all individual projects will be briefly presented by the ESRs. The guidance for GMP that was formulated at W1 will be presented and discussed. All partners will contribute to presentations and lectures. Organisation: Forbes (RUC). Location: Roskilde, Denmark. Participants: 60.

C1. Ecological Modelling. Month 8; 8 days. This course will consist of lectures and computer exercises. General principles of ecological modelling will be introduced, i.e. all tasks of the “model-

ling cycle" (Fig. 1). Specific modules will cover differential equation models, matrix models, and individual/agent-based models. These model types will be introduced in general and exemplified using models that have been developed for chemical risk assessment. Specific requirements for developing models for decision support will be emphasized, and CREAM's Good Modelling Practice explained, demonstrated, and trained in exercises. The course will build on the "Winter School in Ecological Modelling" provided by UFZ since 2000. Organisation: Grimm (UFZ). Location: Leipzig, Germany.

C2. Techniques. Month 10; 5 days. This course is about specific skills that are important for all ESRs of the project. **Database management** for storing and retrieving experimental data and model output. **Statistical methods** for analyzing data generated by experiments and models, for parameterizing, testing, calibrating and validating models, and for performing sensitivity and uncertainty analyses. **Software engineering techniques** for writing robust, effective, and flexible code. **Geographic Information Systems (GIS)** for linking models to real landscapes. Organisation: Sibly and Boxall (UREAD and UYORK). Location: Reading, UK.

C3. Ecotoxicology and Ecological Risk Assessment. Month 14; 4 days. This course will provide the background information on chemical risk assessment in Europe. It will cover the different legal frameworks for different types of chemicals (e.g. Dir 91/414, REACH) the standard and higher tier tests to measure effects on non-target species, the models to estimate fate and exposure and the concepts to assess the risks. Presentations will be given by people from academia, industry and regulators. Organisation Hommen (IME). Location. Schmallenberg, Germany.

After this initial start-up phase, a course will be given on complementary skills. Scientific training in this **mid phase** includes internships and exchange of PhD students. Every PhD student should stay for at least **three months** in one or more of the full partner institutions and give presentations at the projects' mid-term workshop and at international workshops and conferences.

C4. Complementary Skills. Month 18; 5 days. This course will be provided by Roskilde University, where it has been offered for 3 years. Topics covered include: making oral presentations, preparing a CV, writing grant proposals, writing for scientific journals, writing science for a non-scientific audience, and poster presentations. Organisation: Forbes (RUC). Location: Roskilde, Denmark.

W3. Open Mid-term Workshop. Month 24; 4 days. This workshop will be open for up to 80 participants. Thus, approximately 20 people from outside the CREAM consortium can attend, e.g. representatives from regulatory agencies in Europe, chemical companies, and consultants. Keynote presentations by project members and invited scientists will be given on different aspects of the CREAM background. The results of the individual projects will be presented by the ESRs. Organisation: Laskowski (UJAG). Location: Krakow, Poland. Participants: 80.

In the **final phase** of CREAM, a course on career development and options will be given and a wrap-up conference organized.

C5. Career Development. Month 36; 2 days. Researchers who had been trained in ecological modelling and made careers in academia, industry, authorities, or consulting firms will be invited to report their experience and give practical advice. Organisation: Ratte and Van den Brink (RWTH and WU). Location: Aachen, Germany.

W4. Open Conference: "Mechanistic Effect Models for Ecological Risk Assessment of Chemicals". Month 46; 4 days. In this conference, the final deliverables of the work packages will be presented and discussed. This includes presentation on individual projects and presentations on more generic findings, e.g. GMP and answers to CREAM's research questions. The conference will be open to submitted contributions that refer to the research topics of CREAM. The conference will be announced via the SETAC websites and will be open to the same sector as **W3** plus the press. Fund-

ing is required for CREAM members only (ca. 60). Organisation: Grimm, Thorbek (UFZ and SYN). Location: Leipzig, Germany. Participants: 120.

CREAM will **disseminate** its results and overall approach (GMP) to the community by offering, from the second project year on, **"Short Courses" at the annual SETAC meetings** in Europe, North America, and Germany. These courses are a well established part of the SETAC meetings. ESRs will be invited to contribute, which offers them training in teaching and provides opportunities to get into contact to potential future employers. In addition, ESRs will be encouraged to submit posters and presentations to SETAC and other relevant meetings and to publish their work in peer-reviewed journals.

4.2. ROLE AND CONTRIBUTION OF PARTNERS TO THE TRAINING PROGRAM

The **skill requirements** are defined by all sectors involved in chemical risk assessment and, in turn, CREAM (industry, academia, regulators). Therefore the skill requirements will be discussed and determined finally in the start-up workshop of the CREAM partners (**W1**). The ESRs are hosted by the **network partners**, mostly universities or research centres. The one full **industry partner** is particularly active by hosting one PhD project and one early-stage postdoc who will support internships and student exchanges with the other partners. All network partners will co-supervise at least one other ESR and will organise and contribute to the CREAM workshops and training courses. All **associated partners** are industry, SME, or a regulatory agency. They will give lectures at the courses and workshops, will advise the individual PhD projects, and offer internships. Thus, the associated partners will guarantee that all aspects of the usability of ecological models in the risk assessment are considered. Hence, the ESRs will become familiar with different perspectives, views and needs from industry and regulators.

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4.3. EARLY STAGE AND EXPERIENCED RESEARCHERS TO BE RECRUITED

In total twenty ESRs and three ERs as well as three visiting scientist will be recruited to CREAM. While the ESRs will work on projects appropriate to get a PhD, i.e. developing models for specific questions, the ERs will work on more integrated questions which require more experience and which can be answered within two years. The ERs play an important role in integrating ESR projects (see description of work packages and ER projects in Section 3).

Three visiting scientists will be invited for short-term visits (1-2 months). These scientists are outstanding experts in specific aspects of ecological models: **Prof. Donald L. DeAngelis**, University of Miami and USGS, is a world-leading expert in ecological modelling, including mechanistic modelling for decision support. He will visit UFZ and other partners. **Prof. John D. Stark**, Washington State University, is an expert on the use of matrix models for risk assessment. He will visit RUC, SYN, and other partners. DeAngelis and Stark will give direct insight on the ecological modelling activities in the USA and will disseminate objectives and results of the CREAM project there. **Dr. Chris Topping,** University of Aarhus, Denmark**,** has developed ALMASS, a spatially explicit model framework for individual-based models of different animal species in a Danish agricultural landscape. Chris Topping will visit UREAD to share his experience on the detailed modelling of birds and mammals.

	Early-stage and experienced researchers to be financed by the grant agreement			
Network Team	Early-stage researchers (ESRs) (person-months) (A)	Experienced researchers (ERs) (person-months) (B)	Visiting Scientists (VS) (person-months) (C)	Total (A+B+C)
UFZ	72		1 (DeAngelis)	73

RUC	72	24		96
WU	36	24		60
RWTH	72			72
EAWAG	72			72
SYN	36	24	1 (Stark)	61
IME	36			36
UREAD	72		2 (Topping)	74
INRA	36			36
VU	36			36
UYORK	72			72
UJAG	72			72
NERI	36			36

5. IMPLEMENTATION

5.1. CAPACITY OF THE HOSTS INSTITUTIONS

The full partners of CREAM comprise eight universities, four research centres (UFZ, EAWAG, IME, INRA) and one industry partner (SYN). All these partners have excellent capacities in terms of personnel, research facilities, ESR training, and management of joint research projects:

UFZ: The **Helmholtz Centre for Environmental Research - UFZ**, Germany, was established in 1991 as the first and only centre in the Helmholtz Association of National Research Centres (HGF) to be exclusively devoted to environmental research in a great variety of fields. It currently employs around 900 people. UFZ is a world-wide recognised centre of expertise in the remediation and re-naturation of contaminated landscapes, as well as the preservation of natural landscapes. UFZ has the capacity, resources and experience to coordinate this project. Since its foundation UFZ has participated in 116 EU-projects, co-ordinating 43 of them. Within the Fifth Framework Program UFZ has launched 22 projects co-ordinating 7 of them. In Framework six UFZ is or was involved in 48 projects co-ordinating three Integrated Projects, two STREPs, two ESTs, one RTN, one SFC, and five TOKs. At present UFZ is in grant agreement negotiations for eight Cooperative Projects within FP 7, four of them are coordinated by UFZ. **PD Dr. Volker Grimm** is a senior scientist at the Department of Ecological Modelling and affiliated to the University of Potsdam. He is a world-leading expert in ecological modelling and has recently published the first monograph on individual-based modelling and a general protocol for describing individual-based models. **PD Dr. Matthias Liess** is a leading expert in ecotoxicological effect assessment of complex ecological systems. He has published more than 80 peer reviewed papers, books and book chapters and is well ranked in the ISI list of highly cited scientists. He is affiliated to UFZ as Head of Department and as lecturer to the Technical University of Braunschweig, Germany.

- Grimm V, Railsback SF (2005) *Individual-based Modeling and Ecology*. Princeton University Press, Princeton, N.J., 428 pp.
- Grimm V, Revilla E, Berger U, Jeltsch F, Mooij WM, Railsback SF, Thulke H-H, Weiner J, Wiegand T, DeAngelis DL (2005) Pattern-oriented modeling of agent-based complex systems: lessons from ecology. *Science* 310: 987-991.
- Liess M, Pieters B, Duquesne S (2006) Long-term signal of population disturbance after pulse exposure to an insecticide - rapid recovery of abundance, persistent alteration of structure. *Environmental Toxicology and Chemistry* 25: 1326-1331.

RUC: Roskilde University. Roskilde University is a state university, founded in 1972, with the objective of providing research and education at the highest level in the fields of natural science, social science and the humanities. The university has a student enrolment of approximately 9300 students and employs about 900 academic and administrative/technical staff. The Ecotoxicology

Unit is part of the Environmental Dynamics Research Group under the Department of Environmental, Social and Spatial Change (ENSPAC). **Prof. Valery E. Forbes** is Head of Department, professor of Aquatic Ecology and Ecotoxicology and director of the Centre for Integrated Population Ecology (CIPE). She has published over 140 articles and two books on these topics. **Prof. Peter Calow** is professor of Environment and Economics, has published over 260 articles and books, and has extensive consulting experience with industry and government.

- Forbes VE, Calow P, Sibly RM. (in press). The extrapolation problem and how population modeling can help. *Environ Toxicol Chem.* (available online).
- Palmqvist A, Forbes VE (2008) Demographic effects of the polycyclic aromatic hydrocarbon, fluoranthene, on two sibling species of the polychaete Capitella capitata. In: *Demographic Toxicity: Methods in Ecological Risk Assessment*, HR Akçakaya, JD Stark, TS Bridges (eds), Oxford University Press, Oxford, UK, pp. 200-212.
- Forbes VE, Calow P (2002) Population growth rate as a basis for ecological risk assessment of toxic chemicals. *Phil Trans Roy Soc Series B* 357: 1299-1306.

WU: Wageningen University - Aquatic Ecology and Water Quality Management Group. The research of the Aquatic Ecology and Water Quality Management group focuses on the physical, chemical and biological processes occurring predominantly in freshwater ecosystems. The research approach is quantitative with a strong emphasis on state-of-the-art statistical and modelling techniques. **Prof. Paul J. Van den Brink** works at the research institute Alterra and at Wageningen University, both belonging to the Wageningen University and Research centre. Since 1994, he has published over 85 peer reviewed papers, for two of which he won an international prize. He is presently president of SETAC Europe and editor of the journal: 'Environmental Toxicology and Chemistry'.

- Van den Brink PJ, Verboom J, Baveco JM, Heimbach F (2007) An individual-based approach to model spatial population dynamics of invertebrates in aquatic ecosystems after pesticide contamination. *Environ. Toxicol. Chem.* 26: 2226-2236.
- Van den Brink PJ (2006) Response to recent criticism on aquatic (semi-) field studies experiments: opportunities for new developments in ecological risk assessment of pesticides. Letter to the editor. *Integrated Environmental Assessment and Management* 2: 202-203.
- Van den Brink P., Brown CD, Dubus IG (2006) Using the expert model PERPEST to translate measured and predicted pesticide exposure data into ecological risks. *Ecological Modelling* 191: 106-117.

RWTH: Institute for Environmental Research - RWTH Aachen is the largest German University institute addressing ecotoxicology and consists of three professorships, 1 junior professorship (starting 2008), 1 Humboldt stipendiate, 3 senior scientists, 4 Post-Docs and 30 PhD students. One main research area of the institute is modelling and simulation of effects of stressors on organism, population and ecosystem levels. The institute has experience in Marie-Curie Actions (AQUABASE project). **Prof. Hans Toni Ratte** leads the workgroup of aquatic ecotoxicology. He is a leading expert in ecotoxicology and statistics and involved in EU expert groups (EFSA, OECD, DIN). **Dr. Thomas G. Preuß** is a postdoc in aquatic ecotoxicology working on effect modelling. He is an expert in modelling and ecotoxicology and chair of the SETAC advisory group MEMoRisk (with U. Hommen, IME).

- Preuss TG, Hammers-Wirtz M, Hommen, U, Rubach MN, Ratte HT (2008) An individual-based population model of *Daphnia magna* for analysis and extrapolation of population dynamics under laboratory conditions. *Ecological Modelling* (in press).
- Ratte HT, Lennartz F, Roß-Nickoll M (2005) Ecosystem dynamics and stability - are the effects of pesticides acceptable? In: *Effects of pesticides in the field - EPIF*, Liess et al. (eds.) SETAC - Press, 88-90.
- Ratte HT. 1996: Statistical implications of end-point selection and inspection interval in the *Daphnia* reproduction test - a simulation study. *Environ. Toxicol. Chem.* 15, 1831-1843.

EAWAG: The Swiss **Federal Institute** of **Aquatic Science and Technology** is an internationally linked aquatic research institute of the **ETH** (Federal Institutes of Technology) domain. EAWAG employs about 350 scientists, engineers and technicians in the fields of environmental chemistry, microbiology, toxicology, engineering, limnology, and systems sciences. The Department of Environmental Toxicology (UTox) studies adverse effects of pollutants on aquatic organisms and eco-

systems. **Dr. Roman Ashauer** develops toxicokinetic-toxicodynamic models. His research consists of mathematical modelling and ecotoxicological experiments with a focus on application in chemical risk assessment. **Prof. Kristin Schirmer** develops vertebrate cellular models, particularly of fish, to study the toxicity of environmental contaminants. She is involved in several international research projects and is a member of the SETAC Animal Alternatives Advisory Group.

- Ashauer R, Boxall ABA, Brown CD (2007c) Modelling combined effects of pulsed exposure to carbaryl and chlorpyrifos on Gammarus pulex. *Environmental Science and Technology* 41: 5535-5541.
- Ashauer R, Boxall ABA, Brown CD (2007a) New ecotoxicological model to simulate survival of aquatic invertebrates after exposure to fluctuating and sequential pulses of pesticides. *Environmental Science and Technology* 41: 1480-1486.
- Schirmer, K. (2006). Proposal to improve vertebrate cell cultures to establish them as substitutes for the regulatory testing of chemicals and effluents using fish. *Toxicology* 224, 163-183.

SYN: Syngenta[1] is a world-leading agri-business committed to sustainable agriculture through innovative research and technology. Jealott's Hill, established in 1927, is a centre of excellence for discovery and bio-performance research and is a key site for environmental sciences. It is Syngenta's largest research site, employing over 800 scientists and support staff. It is also Syngenta's global centre for environmental sciences and works to ensure that products are tested for safety in the environment. Syngenta pioneered the use of ecological models in regulatory risk assessments and funds extensive research in the areas of ecotoxicology, ecology and environmental sciences. **Dr. Pernille Thorbek** is an ecological modeller and has developed ecological models used for regulatory submissions and research purposes. She initiated the organisation of the LEMTOX workshop on Ecological Modelling and is currently industry supervisor for three PhD students and three postdocs in the area of ecological modelling.

- Geoffrey Caron-Lormier, Roger W. Humphry, David A. Bohan, Cathy Hawes and Pernille Thorbek (2008). Asynchronous and synchronous updating in individual-based models. *Ecological Modelling* 212 (3-4): 522-527
- Thorbek. P. & Topping, C.J. (2005) The influence of landscape diversity and heterogeneity on spatial dynamics of agrobiont linyphiid spiders: an individual-based model. *BioControl* 50:1-33.
- Thorbek, P. & Bilde, T. (2004) Reduced numbers of arthropod generalist predators after crop management. *Journal of Applied Ecology* 41: 526-538.

IME: Fraunhofer Institute for Molecular Biology and Applied Ecology. The Fraunhofer-Gesellschaft undertakes applied research in more than 80 research units, including 56 Fraunhofer Institutes in Germany. The Fraunhofer IME conducts research in the field of applied life sciences from a molecular level to entire ecosystems. At Schmallenberg the main focus is on chemical risk assessment including experimental analysis of fate and effects as well as modelling. **Dr. Udo Hommen** is senior scientist in the department of ecotoxicology. Research topics include aquatic model ecosystem studies, statistics and modelling. Together with Thomas Preuß (RWTH) he is chair of the new SETAC Europe Advisory Group on Mechanistic Effect Models (MEMoRisk).

- Munns WR Jr, Hoffmann A, Hommen U, Gervais J, Nakamaru M, Sibley R, Topping C. (2008) Modelling approaches to population-level risk assessment. In: Barnthouse, L.W.; Mary Sorensen, M. (eds.): Population level ecological risk assessment. SETAC, Pensacola, Florida, p. 179-210
- Schäfers C, Hommen U, Dembinski M, Gonzalez-Valero JF (2006) Aquatic macroinvertebrates in the Altes Land, an intensely used orchard region in Germany. Correlation between community structure and potential for pesticide exposure. Environ Tox Chem 25: 3275-3288
- Schäfers C, Teigeler M, Wenzel A, Maack G, Fenske M, Segner H (2006) Concentration- and time-dependent effects of the synthetic estrogen, 17-ethynylestradiol, on reproductive capabilities of the zebrafish, Danio rerio. Journal of Toxicology and Environmental Health, Part A, 70: 768-779.

UREAD: Reading University is ranked as one of the UK's ten most research-intensive universities and as one of the top 200 universities in the world. Established in 1926 it is particularly known for its work in the sciences relating to agriculture. The School of Biological Sciences is one of the larger such Schools in the UK and offers the benefits of a modern multi-disciplinary approach to pro-

[1] Syngenta's involvement is subject to agreement of contract and senior management approval.

jects supported by considerable recent investment in the field. The school has particular strengths in quantitative biology. **Prof. Richard M. Sibly** has been Professor since 1992 and is a member of the Quantitative Biology and Applied Statistics section. He has worked widely within ecology and current themes include population risk assessment of both vertebrates and invertebrates. He has published over 170 articles and four books on these topics and has been awarded the Scientific Medal of the London Zoological Society.

- Forbes VE, Calow P, Sibly RM (in press). The extrapolation problem and how population modeling can help. *Environ Toxicol Chem*. (available online).
- Sibly RM, Barker D, Denham MC, Hone J, Pagel M (2005) On the regulation of populations of Mammals, Birds, Fish and Insects. *Science* 309: 607-610.
- Sibly RM, Akçakaya HR, Topping CJ, O'Connor RJ (2005) Population-level assessment of risks of pesticides to birds and mammals in the UK. *Ecotoxicology* 14: 863-876.

INRA: Ranked the number one agricultural institute in Europe (number two in the world), the **French National Institute for Agronomic Research** carries out mission-oriented research for better food and nutrition, preservation of the environment and competitive, sustainable agricultural practices. Research aims at quantifying and modelling the impacts of both human production systems and global changes on the functions and dynamics of ecosystems. **Dr. Virginie Ducrot** has been researcher at INRA since 2006. Involved in risk assessment of freshwater invertebrates, she focuses on the study of pesticides-induced changes in individual performances for fitness related traits, and their consequences for population dynamics.

- Sourisseau S, Bassères A, Perié F, Caquet Th (2008) Calibration, validation and sensitivity analysis of an ecosystem model applied to artificial streams. *Water Res*. 42: 1167-1181.
- Coutellec M-A, Caquet Th, Lagadic L (2008) *Lymnaea stagnalis*: the effects of experimental demographic reduction on population dynamics In *Demographic Toxicity*, Oxford University press, 275p
- Ducrot V, Péry ARR, Mons R, Queau H, Charles S, Garric J (2007) Dynamic energy budgets as a basis to model population-level effects of zinc-spiked sediments in the Gastropod *Valvata piscinalis. Environ. Toxicol. Chem.* 26:1774-1783.

VU: The **Department of Theoretical Biology** of the **Vrije Universiteit** (VU-TB) in Amsterdam specializes on the development and application of Dynamic Energy Budget (DEB) theory. The department is involved in some large European projects on effects of chemicals in the environment (MODELKEY, NOMIRACLE) and has a long tradition of mechanistic effect modelling. The OECD document No 54 of “Series on Testing Assessment” (Magaud, H. (Ed.): Current approaches in the statistical analysis of ecotoxicity data: A guidance to application) OECD, and the ISO version (ISO TC 147/SC 5/WG 10/N0390) include biology-based methods that were developed in the department VU-TB. **Prof. Bas Kooijman**, professor in applied theoretical biology, is head of the department VU-TB since 1985. He started his work on mechanistic modelling of effects of chemical compounds on organisms in 1977 and has had intensive interactions with chemical industries and governmental bodies. He has written over 200 papers and 3 books.

- Jager T, Heugens EHW, Kooijman SALM (2006) Making sense of ecotoxicological test results: towards process-based models. *Ecotoxicology* 15: 305-314
- Jager T, Reinecke SA, Reinecke AJ (2006) Using process-based modelling to analyse earthworm life cycles. *Soil Biology & Biochemistry* 38: 1-6
- Kooijman SALM (2000) *Dynamic Energy and Mass Budgets in Biological Systems*. Cambridge University Press.

UYORK: The **University of York** is one of the leading research and teaching institutions in the UK. The project would involve the EcoChemistry Group (a collaborative venture between UYORK and the Defra Central Science Laboratory) in the Environment Department at the University that are world leaders in the area of environmental chemistry, ecotoxicology and environmental risk assessment. Modelling and experimental-based research projects focus on uptake and effects in terrestrial and aquatic systems and risks at the local and landscape scale. Recent and ongoing projects include: ERAPHARM, KNAPPE, HAIR and ERAVMIS. **Dr. Alistair Boxall** is an environmental chemist with an international reputation in the area of emerging contaminants in the environment. He sits on the UK Veterinary Products Committee and the UK Advisory Committee on Hazardous

Substances. **Prof. Colin Brown** is chair of Environmental Science. His research has a strong policy-based focus and contributes to the introduction of regulatory approaches to minimising environmental contamination by pesticides. He is a member of the Advisory Committee on Pesticides and chairs the DG-Sanco FOCUS Work Group on Landscape and Mitigation Factors in Ecological Risk Assessment.

- Boxall ABA, Sherratt T, Pudner V, Pope l (2007) A Screening Level Model for Assessing the impacts of veterinary medicines on dung organisms. *Environmental Science and Technology* 41: 1480-1486.
- Boxall ABA, Johnson P, Smith EJ, Sinclair CJ, Stutt E, Levy L (2006) Uptake of veterinary medicines from soils into plants. *Journal of Agricultural and Food Chemistry* 54: 2288-2297.
- Brown CD, Holmes C, Williams R, Beulke S, van Beinum W, Pemberton E, Wells C (2007) How does crop type influence risk from pesticides to the aquatic environment? *Environmental Toxicology and Chemistry* 26:1818-1826

UJAG: Jagellionian University. Founded in 1364, the Jagiellonian University is one of oldest European universities and the most prestigious one in Poland, housing almost 4000 scientists and 30000 students. The project will be performed in the **Institute of Environmental Sciences**, a leading research and educational institution in its field and a European Community Centre of Excellence. The research of the institute includes ecotoxicology and stress ecology. There are 44 academic staff working at the Institute, and approximately 50 PhD students participate actively in research and teaching every year. The Institute is well equipped in modern analytical instruments, including walk-in climatic chambers with regulated temperature, humidity and light-dark regime. **Prof. Ryszard Laskowski** is head of the Ecotoxicology and Stress Ecology Group. He has co-edited a book on the role of demography in ecotoxicology.

- Bednarska AJ, Laskowski R (2008) Effects of nickel and temperature on the ground beetle *Pterostichus oblongopunctatus* (Coleoptera : Carabidae). *Ecotoxicology* 17: 189-198.
- Kramarz PE, de Vaufleurey A, Zygmunt PMS, Verdun C (2007) Increased response to cadmium and Bt maize toxicity in the snail Helix aspersa infected by the nematode *Phasmarhabditis hermaphrodita*. *Environmental Toxicology and Chemistry* 26: 73–79.
- Kammenga J, Laskowski R (eds.) (2000) *Demography in Ecotoxicology*. John Wiley and Sons, 297 pp.

NERI: The **Department of Arctic Environment** at the **National Environmental Research Institute** (Aarhus University) is responsible for Arctic environmental research activities with focus on Greenland. The department has extensive expertise on population biology and modelling. It plays an active role in the International Polar Year as the international coordinator of the IPY project “BearHealth” and retains some of the most extensive Arctic sample time series, including the longest and most substantive series so far (Hg in polar bear hair over 150 years and PFCs in polar bear tissues for 22 years). **Dr. Jacob Nabe-Nielsen** is a scientist at NERI. He is an expert on the effects of spatiotemporal variation in resource availability on population dynamics. He has extensive knowledge of pattern-oriented individual-based modelling and has worked on a variety of models during his research in the Centre for Integrated Population Ecology (CIPE).

- Nabe-Nielsen J, Sibly R, Topping CJ, Forchhammer MC, Sudharsan K (2007) Effects of landscape complexity in agent-based population models. In: Bunce RGH, Jongman RHG, Hojas L, Weel S (eds.): *25 Years of Landscape Ecology: Scientific Principles in Practice*. Proceedings of the 7th IALE World Congress 8-12 July Wageningen, The Netherlands. - IALE Publication series 4: 329-330.
- Nabe-Nielsen J (2004) Demography of Machaerium cuspidatum, a shade-tolerant neotropical liana. *Journal of Tropical Ecology* 20: 505-516.
- Dietz R, Riget FF, Sonne C, Letcher RJ, Backus S, Born EW, Kirkegaard M, Muir DCG (2007) Age and seasonal variability of polybrominated diphenyl ethers in free-ranging East Greenland polar bears *Ursus maritimus. Environmental Pollution* 146: 166-173.

5.2. WORK PLAN

A graphical representation of the work plan is included in the Annex I.

5.3. INDUSTRY INVOLVEMENT

Industry involvement is decisive for the success of CREAM with regard to both the main scientific and training objectives. Therefore, the consortium includes one big agro-chemical company (**Syn-**

genta Ltd., UK) as full partner, which plays a **central role** by hosting one ESR project and co-supervising two further ESR projects, and by hosting one ER who will support local training, internships, and integration of projects within WP C (see Section 3). This industry partner in fact initiated the LEMTOX workshop on ecological modelling for pesticide risk assessment (Leipzig, September 2007), which directly lead to setting up the consortium for CREAM. **Two further agrochemical companies** (Bayer, BASF) have expressed strong interest in using mechanistic effect models for registrations in the future (see attached letters of commitment). As associated partners they will contribute to teaching risk assessment from the industry perspective and they will provide internships so that ESRs understand the potential role of mechanistic models for regulatory risk assessment; most importantly, during these internships ESRs will learn about career options in industry. The consortium also includes, as associated partners, **two SME** (small-to-medium enterprises; RifCon and gaiac), which develop ecological risk assessments for both chemical industry and regulators. Such consulting firms are another career option of CREAM's ESRs. Moreover, CREAM includes as associated and active partners **regulatory authorities** from five European countries (see letters of commitment). This ensures that risk assessment developed within CREAM is tailored to the needs of the regulatory process in different countries and at the EU level.

5.4. COMPLEMENTARITIES AND SYNERGIES AMONG PARTNERS

One of the main obstacles for a wider and more efficient use of mechanistic effect models for chemical risk assessment is that currently most modellers are specialized on using only one type of model, e.g. matrix model or individual-based model. Without a training network, local training would perpetuate this situation. The CREAM network is sufficiently large and covers the full range of model types and enough species relevant for chemical risk assessment to provide training that meets the needs of Good Modelling Practice (GMP) for risk assessment (Table 4). In order for the GMP to work in practice, the different perspectives and considerations of the sectors involved, i.e. academia, industry, and regulatory authorities, need to be represented and taken into account. As CREAM has members from all the main sectors and also has representatives from many countries in Europe, it offers a unique opportunity to develop scientifically sound and yet practical guidance on how mechanistic models should be applied to decision support in ecosystem management. Collaboration of these three sectors is already established in SETAC (Society of Environmental Toxicology and Chemistry), and all CREAM participants are active SETAC members, including the current president of SETAC Europe (Paul Van den Brink, WU).

Collaboration in CREAM is implemented by co-supervision of every fellow project by two partners with complementary skills. Every fellow will spend at least three months in the institution of the co-supervising partner (second column in Table 4). Additionally, every fellow project is advised by one associated partner from industry or regulatory authorities. Furthermore, associated partners offer internships and they will contribute to the training courses.

Close collaboration is also fostered by the Good Modelling Practice described in Section 3: model developments, peer review of models and risk assessments, which will be implemented in CREAM, and will ensure that partners that were not directly involved in a project become involved and thereby informed. Finally, CREAM's regular meetings (workshops, courses) and the homepage (including Wiki site and a user forum) will provide a network of expertise that provides unique synergies, leading to scientific results and training at a level that is far beyond the capacity of any local training program.

Table 4. CREAM's expertise in model types and modelling systems and organisms. Model types: Matrix: matrix models; Meta: metapopulation models; IBM: individual-based models; DEB: DEBtox models; TK/TD: toxikokinetic/toxikodynamic models; Diff Eq: differential or difference equations; Ecosystem: community and ecosystem models. **Systems/organisms**: Ter: terrestrial systems, S: soil organisms, Aq: aquatic systems, B: birds; M: mammals, F: fish.

	Matrix	**Meta**	**IBM**	**DEB**	**TK/TD**	**Diff Eq**	**Ecosystem**
UFZ		Ter^{M}	$Ter^{B,M}$ /Aq			Ter	Ter

RUC	Aq	Aq	Aq/Ter				
WU		Aq	Aq		Aq		Aq
RWTH		Aq	Aq/Ter		Aq		Aq/Ter
EAWAG					Aq^{F}	Aq	Aq
SYN			$Ter^{B,M,T}/Aq^{F}$		$Ter^{B,M}$	Aq	Aq
IME			$Aq^{F, M}$			Aq	Aq
RU	Aq/Ter		Aq/Ter			Aq/Ter	
INRA	Aq			Aq			Aq
VU				Aq/Ter			
UYORK	Ter				Aq		
UJAG	Ter^{S}						
NERI		$Ter^{B,M}$	$Ter^{B,M}$				

5.5. MANAGEMENT OF THE NETWORK

The CREAM network will include different levels of decision-making from operational management and central organisation needs. The partners will sign a Consortium Agreement (CA) in-line with the **DESCA** model for Collaborative Projects (www.DESCA-FP7.eu) regulating decision making. The management structure will consist of the following Consortium Bodies:

1. The **Supervisory Board** as the decision-making and executive body of the ITN,
2. The **Coordinator** for communication between the Consortium partners and the EC,
3. The **Associated Partner group** consult the coordinator and supervisory board with respect to applied science and development of research directions.

The **Supervisory Board (SB) chaired by the Coordinator** is the highest decision-making body in the Consortium. The SB will be composed of all participants (see participant list in B1) and chaired by the Coordinator. The SB takes decisions on all main issues, including content, finances and intellectual properties. The SB will be responsible for the overall strategic and scientific management and for practical supervision of the ESRs/ERs in their field of expertise, especially the science-related and training aspects. Ordinary meetings will take place once a year (see work plan in Annex I) or at any time upon written request of any member of the SB. The SB will monitor and coordinate the efficient implementation of the ITN by initiating, coordinating, organising and monitoring the work packages and training events thereby supporting the Coordinator in his tasks. The SB will regularly evaluate progress of the work packages by means of progress reports, which the ESRs have to provide. **The Supervisory Board will be responsible for adjusting the individual ESR's work plans in cases of delay and disruptions, e.g. delayed recruitment, ESR leaving the network, etc.** The SB is responsible for crisis management within the ITN, if e.g. problems arise among the ESRs or between ESRs and their supervisors.

CREAM will be coordinated by the Helmholtz Centre for Environmental Research – UFZ. Dr Volker Grimm will be the **Coordinator (CO)** in charge of the overall supervision and management of CREAM. The CO will also be responsible for communication with EC and execution of all tasks assigned in Grant Agreement and the CA including collecting, reviewing and submitting information on the progress, including financial statements and related certifications. The CO chairs SB meetings and prepares agenda and minutes and monitors the implementation of decisions taken. The CO will manage exchange of information and documents between partners via mail/e-mail and the projects homepage on the Internet, maintained by the UFZ. To guarantee a well organised project an **administrative project manager will be employed**. The project manager will assist the Coordinator in all tasks described above and the partners in the organisation of workshops and training events.

Additionally, the management structure of the CREAM ITN comprises an **Associated Partner Group (APG) consisting of** partners from **industry or governmental authorities** (see associated partner list in B1). The APG will advise the ESRs and provide feedback on projects, especially on work that considers economic, jurisdictional and social aspects. The APG thereby provides an external view on the research. Members of the APG will all provide internships for ESRs at their institution.

For **Financial Management**, the UFZ runs a professional office for the co-ordination and management of international projects within the framework of scientific and technical co-operation. The Coordinator will be further supported by the financial department at the Helmholtz Centre for Environmental Research (UFZ). The contact person for all matter of administration is Annette Schmidt who is responsible for all the general EC-related issues at the UFZ. The management and distribution of the grants to the partners will be done according to the EC's regulations. All EC contribution provided for the Categories A, B, C, and D will be exclusively spent to cover the activities carried out by the ESRs and ERs. The amount available in Category E will mainly be used for the organisation of the training events and the participation expenses of the supervisors as well as the representatives of the Associated Partners. All partners who are not involved in the organisation of a workshop or a course (SYN, INRA, VU, NERI) undertake to pay the associated partner's travel and subsistence costs. The salary of the administrative project manager will be covered by Category G. Thus, the main part of the network's management budget will be allocated to the coordination institution UFZ.

5.6. DISSEMINATION OF RESULTS

Dissemination will be executed according to the Consortium Agreement. The European Commission will be informed about results of the research training projects by annual scientific reports delivered by each of the fellows to the responsible supervisors and assembled by the coordinator. The final report for the Commission will include all research results. The reports will also be delivered to all partners via a network internal internet portal hosted by UFZ with a special forum for each fellow to facilitate the exchange of scientific knowledge and of personal impressions at the single research institutes.

The CREAM ITN activities will be published on the **homepage** of the training network, which will be updated regularly. Fellows and supervisors will have full access and will present results to inform collaborators on a protected web page. The CREAM homepage will also have an open part that gives access to information for the public. The protected web pages will guarantee effective day to day communication for members of the consortium. This will include (1) a Wiki site about ecological modelling, chemical risk assessment, specific statistical methods, and complementary skills that will develop during the project to a web repository of the accumulated knowledge; (2) a user forum where fellows can post questions and discuss upcoming issues of interest. The results of fellows will be presented at regular workshops (see work plan in Annex).

Research results will be published in international peer-reviewed journals as well as on national and international conferences where each fellow will get the opportunity to participate and present the latest results. A main deliverable of CREAM, the guidance document for Good Modelling Practice, will be published as a report, made freely available on the Internet, and referred to in all publications originating from CREAM. Fellows will be encouraged to give talks at international conferences about the CREAM ITN network, thereby strengthening their presentation skills. Concepts developed within the individual research themes will be made available for different stakeholders/sectors in the fields of chemical risk assessment, which are organized in the SETAC (Society of Environmental Toxicology and Chemistry) and comprises academia, industry, and regulators. SETAC journals, conferences, and report will be **important fora for disseminating** CREAM's results. In particular, the GMP and more specific uses of mechanistic modelling for chemical risk assessment will be presented at the **"Short Courses", which are a well established part of the annual SETAC meetings** in Europe and North America).

After termination of the CREAM ITN, research results will be further disseminated via partners from industry and regulatory authorities. Several partners intend to incorporate CREAM's scientific developments directly into their portfolio.

5.7. INTELLECTUAL PROPERTY

Research results of the CREAM ITN will be published only after an initial review of its potential for patenting and commercial exploitation by the inventors and the project management. For this purpose, industrial property and technology transfer guidelines will be agreed by all partners prior to project launch in a Consortium Agreement (CA). This will cover internal rules of exploiting research results, concepts and technologies and of the publication policy and the CA will also include a description of industrial property and technology transfer guidelines.

The industrial partners will have co-ownership and an option to obtain an exclusive licence on the results, which were produced with their significant collaboration, as well as a non-exclusive option to obtain a license on other results of the group. The UFZ hold a Patent and Technology Transfer Unit which will consult the consortium on all matters of intellectual property protection of inventions, results, materials and know-how if appropriate. The intellectual properties will be managed according to international good practise giving advantage to the inventors.

5.8. RECRUITMENT STRATEGY FOR EARLY STAGE RESEARCHERS (ESR)

Our recruitment scheme will strictly follow the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (COM (2005) 576 of 11/3/2005) will guarantee worldwide access and a fair and competitive selection of fellows by the Supervisory Board and the host institutions. Advertisements will be published via a variety of internet recruitment databases of international leading scientific journals and scientific organisations, in particular SETAC (Society of Environmental Toxicology and Chemistry) and ecological societies. In addition, advertisements will be made on several internet portals including those of the CREAM project, the EC - Cordis server and the homepages of the partner institutions, and several European networks, such as the Researchers Mobility Portal of the EC or the PEER network to guarantee a wide-spread distribution and to improve public access the advertisement of fellowships. In addition open positions will be promoted on conferences and via E-mail lists of our national and international collaborators

The candidates will apply for a specific project and the **Supervisory Board and the host institution** will select the candidates (i) based on their scientific background and potential as indicated by their experience and respective master or diploma thesis, (ii) the expected benefit of scientific exchange between the trainees' home countries and institutions and the hosts, and (iii) in accordance to gender equality and minority rights. CREAM aims at a participation of at least 50% women in the network, according to the Commission's recommendation of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (COM (2005) 576 of 11/3/2005) to overcome extraordinary persistence of gender inequalities in the field of science, research and development which has been identified to hinder scientific excellence within Europe. The participating institutions encourage female scientists providing institutional services, like child care to ensure equal opportunities for female scientists in participating in the project. The UFZ as a member of the Helmholtz Association is committed for encouraging women's participation in research and to guarantee equal opportunities. Two of five WP leaders of CREAM are female and will make sure that gender issues are taken into account while recruiting fellows.

6. IMPACT

6.1. IMPROVEMENT OF THE CAREER PROSPECTS OF THE FELLOWS

Many areas of **ecosystem management** are making increased use of ecological models for decision support, e.g.: ecological risk assessments of chemicals, conservation, integrated crop management, agronomy, fisheries, forestry and epidemiology. However comprehensive training in ecological

modelling is only offered in a few places in Europe and qualified researchers that have learned to design, evaluate and apply models in a systematic way are rare in all sectors. Moreover, most modellers are trained in academia with little exposure to how their science is applied to decision making in industry and government, which makes the mobility of both knowledge and people between sectors challenging. CREAM by its very nature is interdisciplinary and inter-sectoral and will contribute significantly to improving this situation by offering early stage scientists the multidisciplinary and inter-sectoral training in modelling for environmental sciences within internationally recognised research institutions in Europe. The research training is characterized by (i) an individual scientifically ambitious research project well interconnected with other fellows and disciplines, (ii) close collaboration with a partner institution working in similar or complementing research field. Furthermore, (iii) the well structured PhD curriculum offers internships from weeks to months in industry and regulatory authorities and (iv) complementary in (soft) skills essential for ESRs is provided. The training program provides close collaboration with SMEs, larger companies, consultants and/or governmental authorities dealing with ecological risk assessments of chemicals, either via a co-supervision or training internships. This elaborated training package will consequently have a major impact on the careers and improves the fellows' competitive prospects in the field of academics, government or industry.

Experts from selected European institutions with a long-standing expertise in modelling applied to environmental sciences guarantee exposure of the fellows to state-of-the-art scientific knowledge ranging from basic to applied research. The CREAM ITN combines the challenging task of excellent training with original and innovative research. The ESRs will be trained to handle ambitious scientific research projects in the emerging field of mechanistic effects modelling by being embedded in an **interdisciplinary working environment**. The individual working program foresees spending at least three months at a partner institution to improve methodological repertoire and to gain international experience. In parallel the fellows will be trained in transferable skills such as communication, project management, presentation techniques, writing proposals and acquisition of funding, among others urgently needed for careers in academia, industry or government.

The Supervisory Board of CREAM combines experts from academia, regulatory authorities and industry and will guarantee a professional supervision directing the fellows research from fundamental to very applied issues. CREAM will therefore give the ESRs unique opportunities not only to receive comprehensive training in modelling but also to get hands on experience of how models are applied to real world problems in other sectors of society. **In summary, the training program will provide excellent career prospects to the fellows and will promote a new generation of young modelling experts to the European Union** continuing their careers in academia, government or industry.

Also in academia, models are receiving increased attention. Recently, awards in the field of ecological risk assessment have been given mainly to modelling projects (e.g. CEFIC LRI Innovative Science Award 2005 and 2007 (Van den Brink and Ashauer, respectively); ECETOC Science Award, in the category 'Environmental Fate and Effects' (Van den Brink); SETAC-GLB Young Scientist award 2006 (Preuß). Moreover, the number of job announcements for PhD students and postdocs with expertise in modelling projects are increasing in academia and industry.

6.2. BENEFITS FOR THE INSTITUTIONS INVOLVED AND ESTABLISHMENT OF LONG TERM COLLABORATIONS

At present, development of mechanistic effects models for risk assessment of chemicals mainly takes place in academia, where several groups are active. However, so far there has only been limited collaboration between these academics groups so CREAM provides much needed opportunities for exchange of expertise and formation of long term collaborations. Industry and regulatory authorities across Europe are very interested exploring the potential of mechanistic effects modelling for improving ecological risk assessment of chemicals and **mitigation strategies** for improvement of ecosystem functioning. However, these sectors currently lack expertise in modelling so CREAM

will offer excellent opportunities for these sectors of society to get a better understanding of where modelling can help and how to assess models. In return, these partners will give the academic partners a better understanding of how their science contributes to risk assessments and management.

6.3. BENEFITS AT THE LEVEL OF EUROPEAN RESEARCH

CREAM will lead to outstanding relationships and competence in the field of ecological risk assessment and mechanistic effect modelling at the European level. Both, industry and regulatory authorities have a strong interest in modelling approaches, preferably even standard models for the different species and systems involved that are harmonized at the European level. Developing and establishing such standards, including the formulation of EU directives, will require a time frame of 5-10 years. CREAM would be the first, decisive step in this process and lead to long-term multilateral collaborations. It is assumed that CREAM will be a platform for networking of all partners leading to further projects on a European level that are funded by both industry and governments. The CREAM consortium consists mainly of partners from central and north Europe, since mechanistic modelling as a tool in ecotoxicology and ecology so far is under discussion almost exclusively in this region. Therefore, some efforts will be conducted to recruit PhD candidates from south and east Europe. This will result in a broader distribution of these techniques within Europe. Since mechanistic modelling can contribute not only to regulatory risk assessments but also to research, this will improve European research for ecology and ecotoxicology.

6.4. BENEFITS OF TRAINING EVENTS OPEN TO EXTERNAL PARTICIPANTS

Mechanistic effects models are being used in many areas of ecosystem management, but there is no clear agreement on which criteria a model needs to fulfil in order to be fit for purpose. Furthermore, often model users in industry and government have insufficient knowledge about models to assess whether they are scientifically sound. By opening the raining events to external partners, academics will learn what criteria models used for decision support should meet, and stakeholders from industry and government will learn what techniques are available and how to assess models.

6.5. ROLE OF VISITING SCIENTISTS

Interest in the potential of mechanistic effects models to improve risk assessments of chemicals and ecosystem management has also been growing outside Europe. John Stark and Don DeAngelis are both world leading experts in their respective areas. **In the US**, John Stark has pioneered the use of matrix models for use in risk assessments of crop protection products and Don DeAngelis has pioneered the use of individual-based models to improve ecosystem management. Thus, their visits will give CREAM access to cutting edge expertise as well as giving a global perspective to CREAM. Chris Topping has made extensive use of agent-based models to explore landscape level impacts of man’s activities on wildlife populations. His visit will therefore give CREAM access to much needed expertise on the interaction between landscape structure and life histories.

7. ETHICAL ISSUES

ETHICAL ISSUES TABLE

	YES	PAGE
Informed Consent		
• Does the proposal involve children?	NO	
• Does the proposal involve patients or persons not able to give consent?	NO	
• Does the proposal involve adult healthy volunteers?	NO	
• Does the proposal involve Human Genetic Material?	NO	
• Does the proposal involve Human biological samples?	NO	
• Does the proposal involve Human data collection?	NO	
Research on Human embryo/foetus		
• Does the proposal involve Human Embryos?	NO	
• Does the proposal involve Human Foetal Tissue / Cells?	NO	
• Does the proposal involve Human Embryonic Stem Cells?	NO	
Privacy		
• Does the proposal involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)	NO	
• Does the proposal involve tracking the location or observation of people?	NO	
Research on Animals		
• Does the proposal involve research on animals?	NO	
• Are those animals transgenic small laboratory animals?	NO	
• Are those animals transgenic farm animals?	NO	
• Are those animals cloned farm animals?	NO	
• Are those animals non-human primates?	NO	
Research Involving Developing Countries		
• Use of local resources (genetic, animal, plant etc)	NO	
• Impact on a local community	NO	
Dual Use and potential for terrorist abuse		
• Research having direct military application	NO	
• Research having the potential for terrorist abuse	NO	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL		YES

ENDPAGE

PEOPLE
MARIE CURIE ACTIONS

Marie Curie Initial Training Networks (ITN)
Call: **FP7-PEOPLE-ITN-2008**

PART B

"CREAM"

Annex I – Work plan of the CREAM ITN

Months from project start	0-6			7-12			13-18			19-24			25-30			31-36			37-42			43-48		
	2009			**2010**						**2011**						**2012**						**2013**		
Training and Education																								
Recruitment																								
W2 CREAM start-up																								
C1 Ecological Modelling																								
C2 Techniques																								
C3 Ecotoxicology and Risk Assessment																								
C4 Complimentary Skills																								
W3 Open Mid-term Workshop																								
C5 Career Development																								
W4 Open CREAM conference																								
Project Management																								
W1 Good Modelling Practice Workshop																								
Reports to the Commission																								
Supervisory board meetings																								
Work Packages																								
WP A Aquatic Invertebrates																								
WP B Terrestrial Invertebrates																								
WP C Vertebrates																								
WP D Good Modelling Practice																								
WP E Validation Data Sets																								

Milestones

WP A – C

1. Recruitment of fellows finished (4).
2. Formulation of working hypotheses and work plan for each project (6).
3. Personal career development plans for each ESR including complementary skills checklist (12, 24, 36).
4. Submission of first manuscript and draft documentation of GMP (20).
5. Completion of deliverables (48).

WP D

1. A draft guidance document for GMP, provided on the project's web site (4).
2. An updated version of the guidance document (24).
3. Final versions of guidance document, web site, and course materials (48).

WP E

1. Specification of data(base) format for validation data sets (6).
2. Compilation of mid-term data sets (24).
3. Completion of deliverable (48).

Deliverables (month 48)

WP A – C

1. Successfully defended PhD theses.
2. Per fellow project three manuscripts submitted to international journals.
3. Articles providing overview and synthesis
4. Documentation on Good Modelling Practice (GMP) for each project.
5. An after-project career development plan for every fellow.

WP D

1. Guidance document for Good Modelling Practice (GMP) for ecological risk assessment of chemicals, delivered as a report and in scientific publications
2. Web site introducing into, explaining, and demonstrating GMP.
3. Course material for 1 to 3 days training courses introducing into GMP.

WP E

1. Database containing validation data sets that can be used to validate future models

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