

Overview Article

Decline of fish catch in Switzerland

Project Fishnet: A balance between analysis and synthesis

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Abstract. Fish catch, especially of brown trout, has decreased by about 50% over the last 15 years in many Swiss rivers and streams. In addition, the health status of brown trout has been reported to be impaired in many streams. In order to evaluate the causes of these phenomena, the project “Fishnet” was launched in 1998. We present an overview of the concepts and approaches of this interdisciplinary nationwide project, our experience to date of identifying problems and filling data gaps, and the first results from selected sub-projects.

Fishnet has a planned duration of 5 years and aims to (i) document the decline in catch, abundance and impaired health status of fish populations in selected rivers, (ii) elucidate the causes of these problems, and (iii) develop measures to improve the situation. To achieve these aims, a wide variety of research projects are being undertaken. In addition to co-ordinating existing projects, Fishnet initiates and launches new projects that investigate these issues. Monitoring projects are being conducted over a geographically broad area to investigate selected aspects

of the decline (e. g. the incidence and prevalence of diseases). Other studies aim at detailing the relationships between suspected causes and observed effects. Twelve hypotheses were initially formulated to identify probable causes. These include reproductive failure, fish health, habitat degradation, reduced quality of habitat, and climatic changes (such as increased water temperature and shifts in the seasonal occurrence of floods). Results of initial studies point to the differential impact of factors, depending on the specific geographic region, the fish species and other factors. For example, most of the hypothesized causes are currently found in the Swiss midlands.

By integrating the results and conclusions of existing and new sub-projects, solutions for the complex problem of fish decline and impaired health will be proposed. Practical measures to address the problem will be developed and disseminated to the public and policy groups. The various stakeholders will also be involved during the whole project. Financial and other forms of support are provided by these different parties.

Key words. Teleostei; brown trout; reproduction; habitat; fish health; concept.

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Purpose

Every scientist and every policy maker may one day be confronted with a situation in which a problem is evolving, and yet something must be done. But what and by whom? Who should be involved and who will pay? How, when, and in what form should the results be communicated? Can appropriate measures be proposed? How and when is it feasible to evaluate the success of the solution? We describe here the example of a project, Fishnet, that explores the problem of fish decline in Swiss rivers. The purpose of this communication is not to present the scientific findings or the practical achievements of the project, but to introduce the strategy and approaches with which Fishnet addresses the problem. It is not strictly or exclusively a scientific problem, but one that also includes practical, social and political issues. Therefore, Fishnet involves several disciplines and can be addressed as an interdisciplinary project.

In this overview we

- present this interdisciplinary project involving parties with different, sometimes opposed, interests,
- draw attention to the challenges and difficulties associated with such a task, and
- propose an approach to a problem of both scientific and social dimensions by scientific means.

Background

Several indications over recent years have suggested that fish populations in many Swiss rivers and streams have experienced serious declines. Corresponding data are primarily based on the yearly records of catches by anglers, which indicate a decrease of up to 50% since the 1980s (Friedl, 1999). The situation was analysed in detail and revealed a decline in 20 of 26 cantons (political units in Switzerland; (Fig. 1)), especially in the most densely populated areas, the midlands and the north-west of Switzerland (Fig. 2), where an accumulation of anthropogenic influences are present (urban agglomerations, traffic, intensive agriculture, etc.). Direct correlation between decreasing angler catch and abundance of fish is not possible since angler data are restricted to certain age classes (>2 +/3 +, depending on species and legal size) and species. Of the fish species most commonly caught by fishermen, brown trout (*Salmo trutta fario*), grayling (*Thymallus thymallus*), and nase (*Chondrostoma nasus*) are most affected (Frick et al., 1998). Nevertheless, for some rivers (especially slow-running stretches and riverine reservoirs), data for cyprinids are also available and also show a constant decline (Friedl, 1999). Additionally, a decrease in fish yields in some lakes has been reported (Müller, 1997). This may be due, at least in part, to the

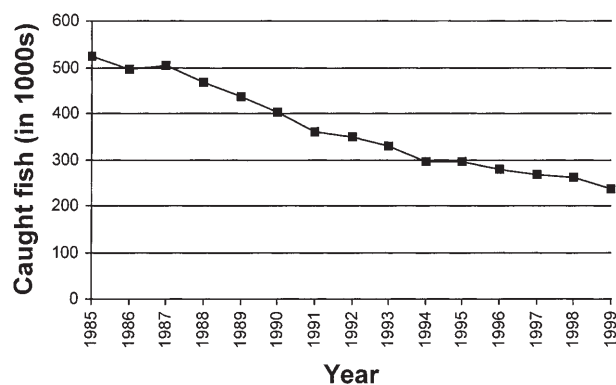


Figure 1. Catches of brown trout in Swiss river systems (Statistics from 20 cantons, data: SAEFL angling catch statistics; Friedl, 1999).

reduction in phosphate load in the Swiss waterways (ban of phosphate from laundry detergents since 1986) and in consequence, a lowered primary production and fish biomass in lakes. However, the threshold concentrations limiting primary production in running waters are rarely reached (Uehlinger et al., 1997). Therefore, the decrease of fish yields in lakes is more amenable to assessment and is not the focus of the present project.

In parallel with the indications of decreasing fish catches, monitoring since the 1980s has produced evidence of an impaired health status of wild fish. In a number of Swiss streams, brown trout with both macroscopic visible lesions and histopathological tissue alterations have been observed (Rüfenacht and Spörri, 1988; Pedrolì et al., 1991; Fishing statistics, canton Bern, unpublished; Schneeberger, 1995; Bernet et al., 2000; Schmidt-Posthaus et al., 2001; Wahli et al., 1998). Studies of the morphology, hydrobiology, habitat quality, and physico-chemical status of streams (Elber et al., 1993) indicated a degradation of habitat structure, including a loss of breeding substrates. To date, however, these studies have not been able to unambiguously identify the causes of the impaired health status and decreased abundance of fish populations in Swiss rivers.

In January 1998, representatives of all cantonal fisheries administrations, of the Swiss federal administration, and of several research institutions, met to discuss the observed problems in Swiss fish populations. Public seminars, organised by the cantonal fishery administration of Bern at this time, proved unexpectedly popular, reflected in large attendance and substantial press activity. As a result of the increased awareness by the scientific and administrative representatives, as well as the general public, a request was sent to the Swiss Agency for the Environment, Forests and Landscape (SAEFL) and the Swiss Federal Institute for Environmental Science and Technology (EAWAG) to establish a nationwide network. The name of the network, "Fischnetz" ("Netzwerk Fischrückgang Schweiz", "réseau suisse poissons en diminu-

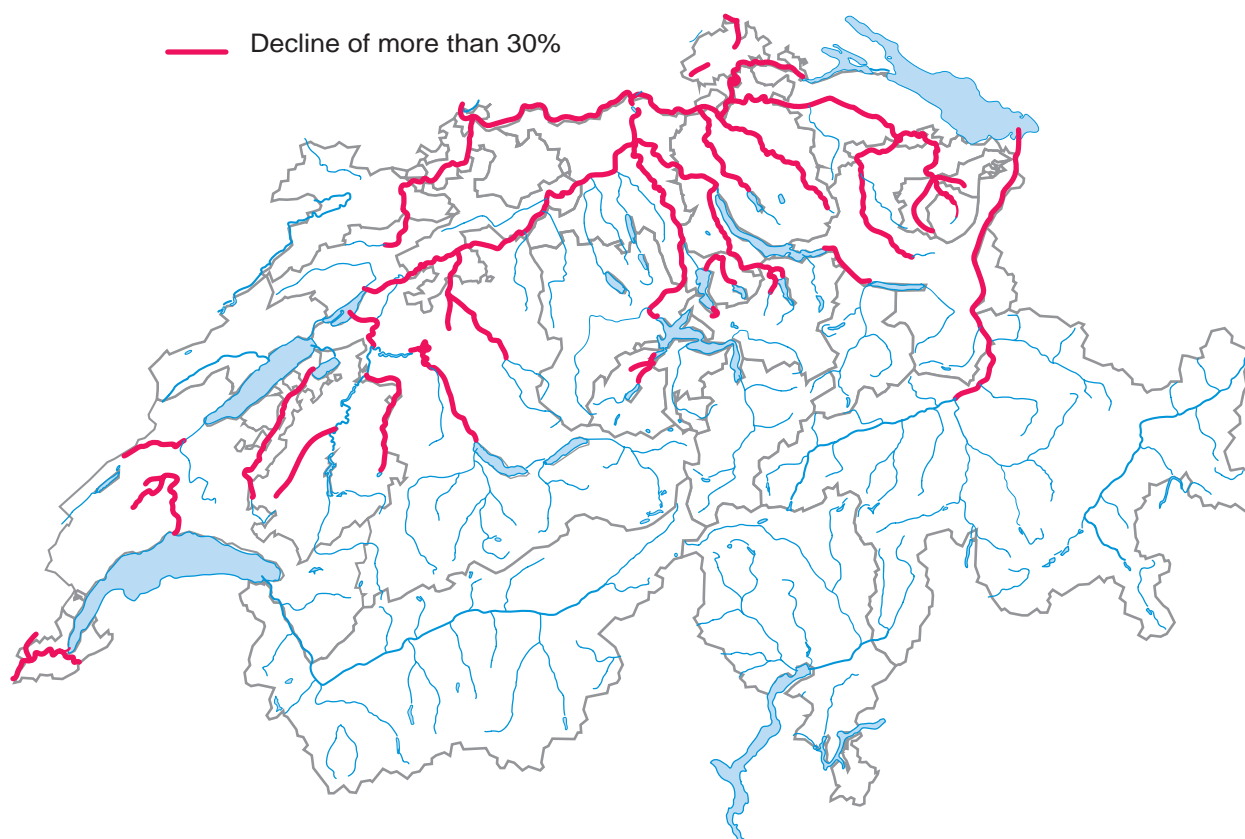


Figure 2. Map of Swiss river systems with decline in fish catch of more than 30% in the last 10 years (information provided by fishery agencies). Reproduced with the permission (1.1.2002) of the Swiss Federal Topography Office.

tion”), or Fishnet, reflects the integrative and communicative nature of this interdisciplinary approach. Integration and communication is achieved through: (a) the collection of available but scattered data on the hydrological and contamination status of Swiss rivers and on the status of fish catches, fish health, and fish populations, (b) improved communication and linking of individual research activities in various Swiss universities, research institutions and cantonal and private organisations, and (c) the initiation of new research activities wherever significant gaps in information are identified and projects that collect, evaluate, and synthesise existing data.

Organisation of Fishnet

Fishnet was started as a joint project of SAEFL and EAWAG. However, to meet complex challenges, such as those addressed by the project Fishnet, co-operation between different parties of society and academia is necessary (Hollaender et al., 2001; Fig. 3). Therefore, all 26 cantons of Switzerland, the chemical industry (SGCI: Swiss Association of Chemical Industry), research institutions, and the Swiss Fisheries Association (SFV) have joined and support the project in various ways (financial,

personal and networking activities). The formal and financial commitment of all interested parties is essential to ensure the implementation of such a project, particularly as the background and goals of these parties are diverse. The project must also bridge the gap between the various stakeholders, including fishermen, anglers, fishery and water authorities, industry, agriculture, researchers, nature protection groups and policy-makers. For example, the chemical industry is often accused of causing water pollution and thereby being solely responsible for the observed effects on biota. However, this can be difficult to establish and requires robust and objective scientific data. Perhaps through compromise and co-operation facilitated by the project Fishnet, reasonable avoidance measures based on the precautionary principle can be developed.

Approximately 240,000 persons (equivalent to 6% of the Swiss population between 15 and 74 years of age) practise angling at least once a year. Thus this hobby is a socially and economically important activity (Schwärzel Klingenstein et al., 1999). The Swiss fishing association (SFV) has 40,000 angling members, and considers the improvement of Swiss waters and the protection of its fish as among its prime concerns. 80’000 anglers have an angling licence, they each spend an average of 2,400

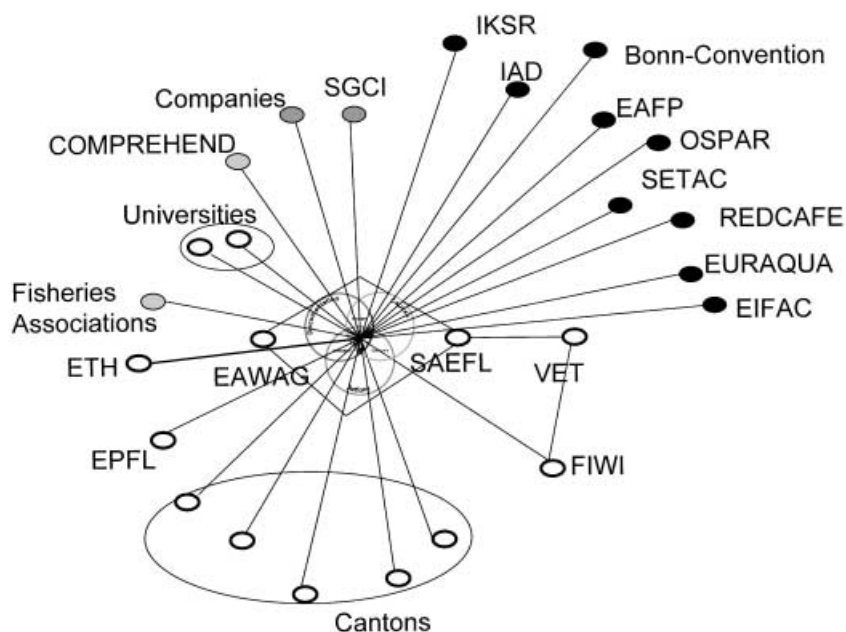


Figure 3. Network of actors; national and international contacts in Fishnet. **Bonn-Convention:** Pan-European management plan on cormorant; **COMPRESHEND:** Community Programme of Research on Endocrine Disrupters and Environmental Hormones; **EAFP:** European Association of Fish Pathologists; **EAWAG:** Swiss Federal Institute for Environmental Science and Technology; **EIFAC:** European Inland Fisheries Advisory Commission; **EPFL:** Swiss Federal Institute of Technology Lausanne; **ETH:** Swiss Federal Institute of Technology Zurich; **EURAQUA:** Network of European Freshwater Research Organisations; **FIWI:** Centre for Fish and Wildlife Health, University of Bern; **IAD:** International Association for Danube Research; **IKSR:** International Commission for the Protection of the River Rhine; **OSPAR:** Convention for the Protection of the Marine Environment of the North East Atlantic; **REDCAFE:** REDuction of conflicts between Cormorants And Fisheries in Europe (EU project); **SAEFL:** Swiss Agency for the Environment, Forests and Landscape; **SETAC:** Society of Environmental Toxicology and Chemistry; **SGCI:** Swiss Society of Chemical Industries; **VET:** Federal Veterinary Office.

EURO per year on his/her hobby, and in total these anglers spend more than 147.8 million EURO per year on inland fishing (Schwärzel Klingenstein et al., 1999). Some areas rely on angling as an important part of local tourism. Furthermore, significant funds are received by the administration for angling licences.

Fish are accepted as reliable and important bioindicators of environmental status – as demonstrated by the title of the technical review “Let the fish speak” edited by the EurAqua Network (van de Kraats, 1997). By this measure, the quality of many aquatic ecosystems in Switzerland is impaired, indicated by the decreasing number of fish species that are not yet threatened (12 of the original 54 native species; OECD, 1998). Accordingly, non governmental organisations (NGOs) and authorities active in water and environment protection aim at protecting and maintaining ecologically sound aquatic ecosystems. Finally, as a bioindicator, fish also provide information on health risks to which the human population may be exposed. Many Swiss inhabitants obtain their drinking water from water filtered through the river bank – including, for example, 400,000 people in the canton of Bern (U. Ochsenbein, oral communication). Therefore, Fishnet also indirectly addresses questions of relevance to human health, for example when pathogens or chemicals are

detected in fish and the risk of a transfer of these compounds via drinking water to humans has to be considered.

Collaboration between the different partners involved in Fishnet is in part fixed structurally, but is also complemented by numerous formal (expert hearings, round tables, workshops) and informal activities such as discussions and exchange of information. A strategic committee confirms the aims, monitors the success, and is responsible for the implementation of the relevant political measures. This committee is composed of senior members of the civil service and further representatives of administration, fisheries, the chemical industry, and science. A project management team is responsible for detailed planning, implementation and delivery of objectives, the identification of research gaps, and the initiation of corresponding scientific studies. It is also responsible for the communication and interpretation of the results. This team consists of nine scientific experts and representatives from the chemical industry, administration and the Swiss Fisheries Association. The members contribute knowledge and experience from a number of disciplines, including fish biology, fisheries, ecology, chemistry and ecotoxicology.

Sub-projects lie at the heart of the practical work of the Fishnet project. These projects are typically com-

prised of field studies aimed at generating new data on the hypotheses (see below) of Fishnet, filling important gaps in our knowledge, and evaluating the success of any practical corrective measure. To focus on the questions of highest priority and to guarantee an efficient procedure for networking at optimised costs, sub-projects are reviewed by experts and are advised by a member of the project management team with expertise in the relevant area. These sub-project advisors are also responsible for information flow, the exchange of results and methodological knowledge.

In addition to networking between the sub-projects, contacts with other national and international institutions exist and are exploited for knowledge transfer (Fig. 3). The limited duration of the project, in conjunction with the complexity of the problem, necessitates an iterative process. This entails the initiation of projects in parallel and their continuous evaluation and integration of the results, thus allowing for continuous modification and further development of activities.

Objectives and questions

The objectives of Fishnet are:

- 1 a) to collect, synthesise and critically evaluate the existing data on fish catches, population abundance, and health status of fish in Swiss rivers collected over the last 20–30 years,
- 1 b) to develop a basis for standardised field monitoring of fish abundance and health,
- 1 c) to design a monitoring scheme for future investigations based on the abundance and health of fish (monitoring of success),
- 2) to extend such investigations as described in (1) in order to identify the most important causes of the

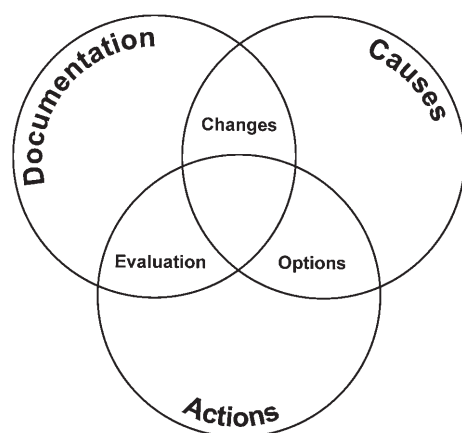


Figure 4. Aims of Fishnet (from Burkhardt-Holm, 2001).

present situation and consider the relative impact, to develop and propose options for remediation, to provide continuous and unbiased information on the results and the progress of the project to the public and the scientific community, to foster synthesis and networking of participants and knowledge.

In summary, the aims can be grouped as (i) documentation and assessment, (ii) analysis and identification of causes, and (iii) development of measures and interventions for remediation (Fig. 4).

Tools

Several tools were developed to facilitate co-ordination and development of synergies. These are maintained by the following ongoing activities:

(i) A list of projects relevant to the aims of Fishnet, in Switzerland and abroad was compiled and is regularly updated.

(ii) A collection of relevant published and grey literature on issues relevant to Fishnet is available to the sub-projects and the management team.

(iii) A “sample and material archive” was launched. This comprises all material collected by Fishnet sub-projects, giving the date, location and type of material, what was sampled, how it was sampled, where it is stored, etc. Sampling is announced in advance, so that other researchers have the opportunity to collaborate in the sampling or ask for additional material to be collected at the same place and date.

(iv) In specifically launched monitoring studies, the spatial extent of selected effects is assessed, such as the abundance of 0+ fish, the incidence of a disease, etc.

(v) In case studies, the relationship between suspected causes is investigated in greater detail, concentrating on selected issues. These include reproductive failure, fish health problems, river degradation and reduced habitat quality, water chemistry and climatic changes.

(vi) Expert hearings, open discussions, and workshops are organized with selected experts to pose questions on specific topics. The purpose is to ascertain the current state of knowledge or discuss methodological approaches.

Products

A broad range of products of Fishnet were identified and some of them have already been developed (Table 1). Examples include:

Table 1. Objectives, criteria for success, possible methods to reach the aims and products anticipated in the project Fishnet. As of September 2001, the number of sub-projects and involved person/month spent for these activities are listed.

Objectives	Criteria for success	Possible methods	Products	No. of sub-projects (running, planned/finished)	Involved person/month	Other activities
1 a) Survey of national and regional development of catches and population abundance, and fish health, over the last 30 years	Correlation between angling statistics and population abundance is recorded Temporal variation in fish abundance and fish health is recorded, by geographical relation Population abundance and health in representative rivers is recorded with a precision that provides secure data on large effects	Evaluating angling statistics Recording angler behaviour Record and evaluation of population abundance Record of the status of fish health	Reports on the temporal and spatial development and status of angling catch Population abundance Angling behaviour Fish health Synthesis documents on these topics	2 6 1 15 1	36 96 24 107 60	
1 b) Establishing the basis for a standardised monitoring system	System to record population abundance and fish health quantitatively, scientifically sound and practicable	Evaluation of existing methods, possible adaptation and introduction into practice Field studies with established methods	Methodological document Educated experts	1	3	
1 c) Evaluating success: prepare future monitoring studies	Desired values and deficits are known	Use of models for biological integrity of fish populations	Concept for evaluating success	1	3	
2) Describe and understand most important factors, consider disposing capacity	Causes most relevant to the alterations are identified Arguments for the importance of the factors are accepted by the scientific community, sources and public at large Anthropogenic factors distinguished for effects which are widespread or diffuse	Modelling and quantification of flux of compounds (as far as is useful) Showing connections between single events; prioritising, dividing resources and scheduling Workshops on hypotheses Experimental studies	Document on the significance of individual factors (cause-effect relationships) Methodological documents	48 2	822 44	
3) Proposing counter-measures	Measures identified and adequately communicated Measures proposed to international boards	Workshops on measures with the agents concerned Publications and reports	Document on the measures (including those for evaluating success)	2	9	
4) Continuous and unbiased information on the progress of the project	Acquaintance of Fishnet in a way to facilitate co-ordination with and information to authorities and policy makers	Communication schedule Meetings of the project management team and the steering committee	<i>Fischnetz-info</i> brochure Homepage, networking Conferences of the sub-projects Workshops, special seminars			No. 1 –8 Established (different languages) 6 3 special seminars 5 workshops established 102 publications 48 lectures
5) Syntheses and networking	Findings generated which are more than the results of the sub-projects	Multivariate analyses, meta-analyses Qualitative syntheses	International networking Publications, lectures Documents on synthesis	5	92	

Measures

The result of one sub-project of Fishnet was that the geographical distribution of the proliferative kidney disease (PKD) in fish is much wider than anticipated. Acknowledging the possible impact of PKD on wild fish populations (Wahli et al., 2001) this disease was added to the list of notifiable diseases (TSV, 1995), in co-operation with cantonal and federal authorities. One consequence is that research work was initiated to adapt and develop diagnostic tools to improve monitoring of the disease and to increase understanding of the infectious cycle and the consequences for fish health.

Information tools

Fishnet is explicitly devised as an information and communication platform. Therefore, several different media are used to ensure knowledge transfer:

(i) The “*fischnetz-info*” brochure is issued regularly (2–3 issues per year, in German and French, free of charge; there are 670 subscriptions). The function of this brochure is to communicate recent developments and achievements of the project to all interested parties, and to ensure communication between them, in particular between scientists, anglers and the regulatory authorities.

(ii) The high level of public awareness of and sensitivity to issues of fish and water in general is reflected in the numerous press activities. Press releases are produced, as well as interviews for radio and television. As of September 2001, 87 articles dealing with Fishnet have been published in the press, 73 of them in daily newspapers – of these, 27 articles were published in daily newspapers with circulations over 50,000 – 14 in specialised journals, and three in foreign journals.

(iii) Regular seminars (special seminars of Fishnet, held regularly in May with approximately 180 participants), seminars given at meetings of fisheries associations, NGOs and cantonal events, and publications in non-scientific media (Holm, 2000).

(iv) To co-ordinate the activities and increase synergies between the sub-projects and to accelerate knowledge transfer, open meetings for all participants of the sub-projects are organised twice a year. At these conferences, specific workshops are organised to provide training in conceptual approaches and methodological questions. Additionally, the different sub-projects, whether they are in the planning, realisation or final phase, are presented and discussed.

(v) Further products include publications at scientific conferences and in peer-reviewed journals (Wahli et al., 2001, Ahel et al., 2000a, Peter et al., 2001) to guarantee scientific credibility, continued discussion among experts, and the establishment and extension of personal networks.

Synthesis documentation

Building a synthesis from existing study results and monitoring data requires much more than simply combining reports from different disciplines. It requires integration, discussion, and analysis against the background of the whole problem. It has been suggested that for a successful multidisciplinary project, 70% of the total time should be for cross-sectoral analyses and 30% on analysis of discrete disciplines (Cairns and Niederlehner, 1995). To date Fishnet has produced reports providing a synthesis of several sub-projects, organised according to specific topics (Bernet, 2000a) or defined geographical regions (Bassi et al., 2001).

Obstacles and risks

The project aims to develop solutions to the decline in fish catch and fish health, and thus demands an integrative approach spanning many disciplines. Similar to other inter- and transdisciplinary environmental research, the project must achieve political aims on the one hand and fulfill the requirements of good scientific practice on the other (Scheringer et al., 2001). A fundamental difference between these “worlds” is that in science a lack of knowledge is the catalyst for further studies, while in politics it presents an obstacle to action. This lack of knowledge also carries the risk of following the track of the research process instead of focusing on the main problem and its solution (Zehnder, 2001). Clear cause-and-effect relationships must be “proven” before any measures can be proposed. However, the degree of proof required by the political world is fundamentally not achievable in environmental research (Schäfer, 1993; Jaeger, 1998). Accordingly, decisions and actions have to be made under conditions of uncertainty (Reckhow, 1994; Scheringer et al., 2001). Therefore, involved parties must agree on the degree of uncertainty that will be acceptable for each decision.

The network character of Fishnet implies the use of data from very different types of projects, including previous projects. A disadvantage of the use of data of previous projects is that the data were often not collected using standardised methods, so that the results may not be comparable with those from other studies. Standardised methods were therefore considered to be important to provide the base for a standardised monitoring system (cf. Table 1). Quality assurance programmes were also found to be essential in providing reliable and comparable data in a UK national monitoring programme (Anon, 1998).

The time needed for planning, initiation and delivering of the projects and actions is so significant that most end goals and improvements will not be achieved during the project’s lifetime. The distinction between the important and trivial factors is crucial, especially since data on

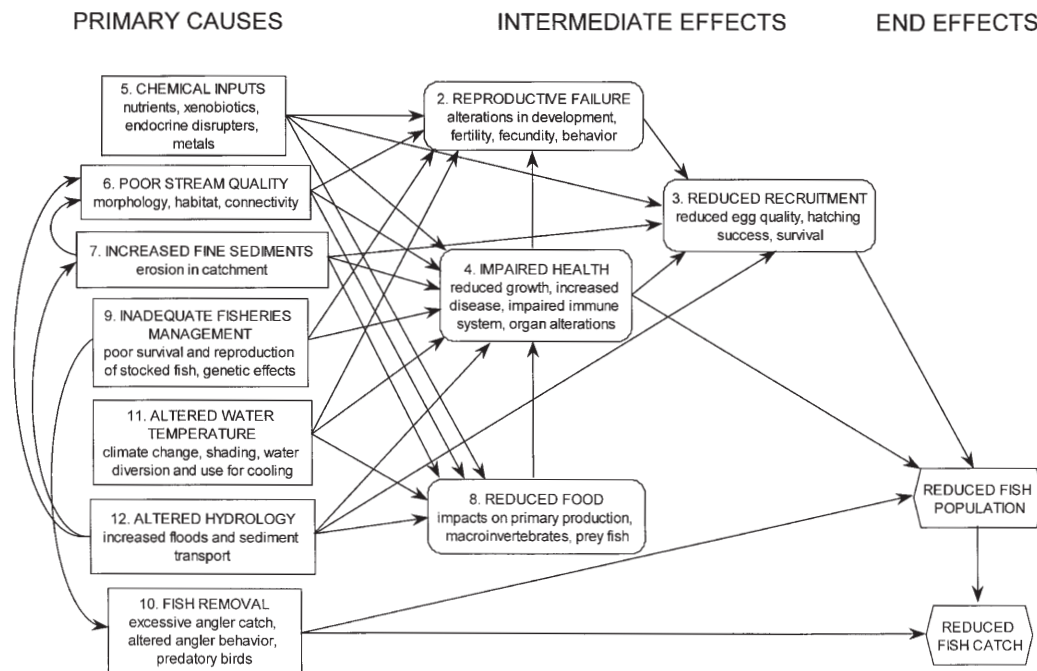


Figure 5. Conceptual influence diagram of the relationships among causes and effects. Primary causes, for which control measures are possible, are indicated by rectangles, intermediate causes are indicated by rounded rectangles, and end effects are represented by hexagons. Arrows indicate the directional influence of one factor on another. Numbers correspond to the numbered hypotheses in the text.

which decisions are based are not always reliable (see above). In consequence, finding projects of the “right” priority in which to invest time and money is a particular challenge. Further, the aims of the sub-projects initiated and performed by external experts sometimes differ considerably from those of Fishnet, and it remains a challenge to build synergies and avoid frustration and disappointment.

Hypotheses

Taking into account the general aims of the project, 12 hypotheses on possible causes of the observed decline in fish catch have been formulated. These hypotheses include cause-and-effect relationships at multiple levels, and so there is some degree of overlap and interaction among them. The relationship between primary and intermediate causes and population-level effects is currently being investigated as one of the Fishnet sub-projects (Fig. 5; Borsuk et al., 2002). One result of this project will be the identification of causes that operate at a more consistent level. The current set of hypotheses includes the following:

1. The decline in fish is due to more than one of the factors that follow, with each factor having a different significance depending on the geographical region involved.
2. The fish population is suffering from reproductive failure of adult fishes.

3. The fish population is suffering from reduced recruitment of young stages.
4. The health of fish and their fitness is impaired.
5. Chemical pollution (both nutrients and synthetic compounds) is responsible for the fish decline and impairment of health.
6. Poor morphological quality of the streams and a lack of longitudinal connectivity (highly restricted upstream migration of fish) are responsible for the decline in fish.
7. An increased amount of fine sediments in streams is responsible for the decline in fish.
8. Reduced amount of food leads to the decline in fish.
9. The decline in fish is caused by inadequate management of fisheries.
- 10a. The decline in fish is the result of an increased removal of fish, or
- 10b. The decline in fish catch reflects altered behaviour of anglers.
11. Changes in the water temperature have led to a decline in fish population abundance and fish catch.
12. An altered hydrological regime and modified sediment transport are responsible for the decline in fish.

Since these hypotheses are instruments to help us identify the causes of the decline and impaired health status over the last two decades, it is crucial to focus on the factors that changed significantly over this time period (or some time before, depending on the time lag before effects become manifested). Obstacles to evaluate each of those

hypotheses include a lack of existing data (e.g. length of degraded river stretches, concentration of pesticides in fish or incidence of diseases), heterogeneous data sets (e.g. in terms of methodology), and variable quality of the available data. Furthermore, most fish data pertain to brown trout which is the most abundant species in Switzerland, is the primary target of anglers, and is being stocked in many rivers.

Hypothesis 1: The decline in fish has many causes, each of which may have a different significance depending on the geographical region involved

The different potential causes are mutually dependent and linked to each other and to various internal and external factors. To express and quantify these inter-relationships, a Bayesian probability network (Reckhow, 1999) is being constructed. Such a model graphically implies a set of assumptions about the dependencies among system variables, which simplifies the problem of working with imprecise knowledge (Borsuk et al., 2001). Experimental studies elucidating the relationships between different factors that may be responsible for the observed phenomena will also be conducted.

Regional variation is an important factor to be considered when evaluating the cause-effect relationships. For example in a synoptic survey of the biological status of Swedish lakes and reservoirs (Brunberg and Blomqvist, 2001), most aquatic systems were subject to several types of disturbance, interacting in a complex pattern that made it difficult to link the visible effects to the true causes. To perform an evaluation of the impact of anthropogenic influences on lake ecosystems, Brunberg and Blomqvist divided the effects of different types of damage into 4 classes and applied a scale on the degree of threat of these effects to the ecosystems (Brunberg and Blomqvist, 2001). In this study, toxic substances appeared to be a greater threat than eutrophication and acidification in the investigated area relative to comparable studies in other regions.

A regional variation with respect to health status was also found in most of our monitoring studies. The health status of brown trout in the Swiss midlands was worse than in the alpine and Jura mountain region (Ochsenbein, 2000). Regional differences might be caused not only by variations in natural factors such as altitude or geological background but also by different types of anthropogenic influences (e.g., differences of sewage treatment plant technology is thought to be responsible for differences in the extent of endocrine disturbances in fish in UK and USA). Finally, some problems arise in the interaction between regional conditions and specific stressors (e.g., acidification). In addition, the characteristics of point source discharges must be considered as well. For example, although a number of sewage treatment plants have

been investigated in terms of their effects on the fitness of fish populations downstream of the discharge in the Swiss midlands, no general statements were possible. Each sewage treatment plant must be considered in terms of its own characteristics, such as technical standard, dilution ratio of the discharge, watershed, etc. (Bernet, 2000b).

Hypotheses 2 to 5

These hypotheses concern alterations in fish health that may be induced by chemicals (*sensu lato*, see below). In general, it is difficult to establish cause-and-effect relationships between any stressor in a field situation and the health of an organism, because of the multitude of environmental factors that can influence or modulate the response pattern of the organisms to particular stressors. In addition, most responses are not specific to particular stressors but may be induced by a number of triggers. Molecular biomarkers are considered to be most sensitive and to react most rapidly, but they show low ecological relevance compared with endpoints at higher levels of the biological hierarchy. A biomarker approach is thus often proposed, using a suite of responses at several levels of biological organisation (Adams, 1990). Such parameters are also useful in evaluating improvement after remediation activities or decrease in level of contaminants, and thus should be included as a performance indicator to evaluate success of policy changes.

Hypothesis 2: The fish population is suffering from reproductive failure

This hypothesis postulates that reproduction is impaired, with resulting adverse effects on the fish population. One possible cause for such an impairment could be changes in endocrine physiology due to the action of environmental agents (endocrine active substances). Fish from a variety of contaminated ecosystems have been described as showing injury due to alterations in endocrine function, alterations in sexual development, and changed fertility, fecundity and reproductive behaviour (Kime, 1995; Sumpter, 2000; Tyler and Routledge, 1998). A link between these chemicals and reproductive impairment can not be conclusively stated for fish in Swiss rivers, because the cause-and-effect relationship was only discovered in recent years. Only indirect effects, such as the lack of young fish, could be observed (cf. hypothesis 3). Several countries, such as the United Kingdom, Canada and Sweden now have databases available to show that wild fish suffer from endocrine disruption. However, the databases in many other countries, including Switzerland, are still too fragmented to support firm statements on whether endocrine disruption is a threat for wild fish populations. Recent studies indicated that the (xeno)estrogens so far investigated are present in Swiss effluents and

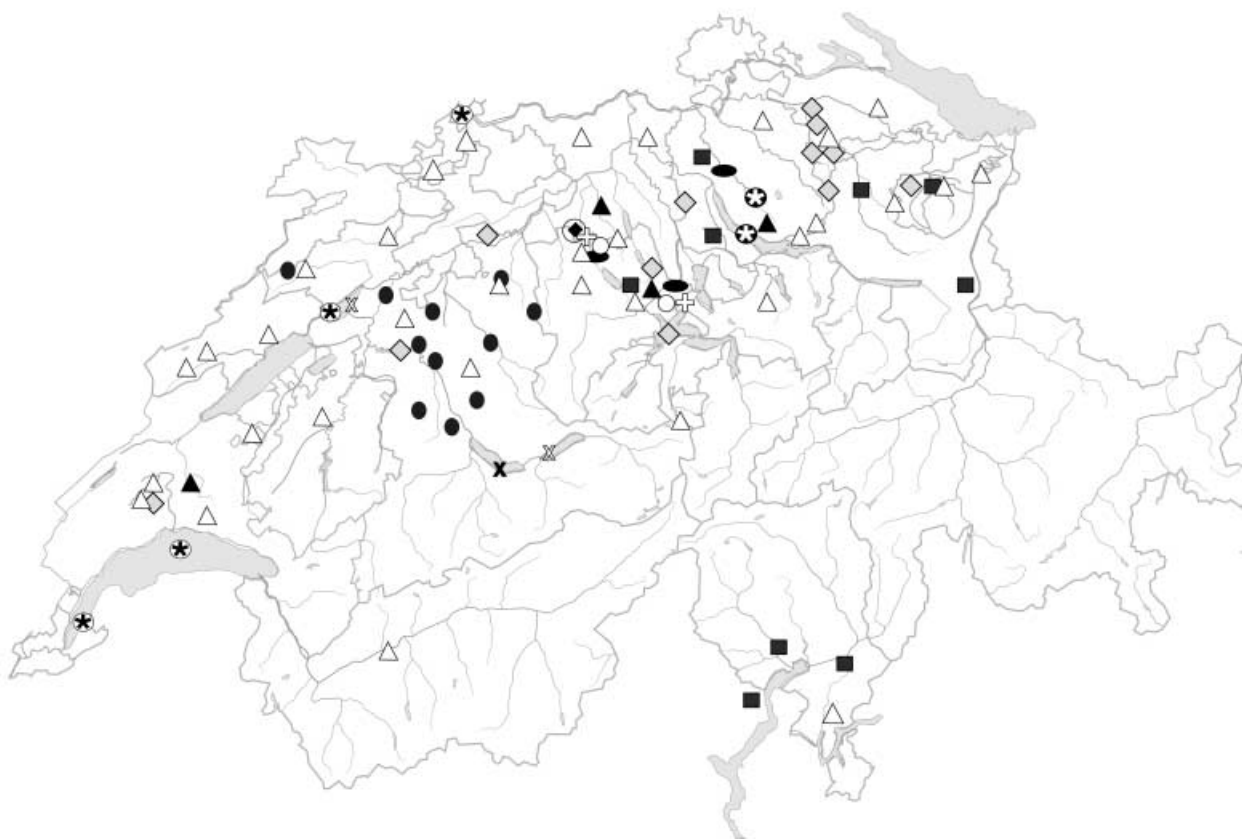


Figure 6. Potential hot spots for exposure to endocrine disruptors or endocrine effects in Switzerland: ⊙ Luciferase, gonad cells, rainbow trout, RTG-2 reporter-gene assay (Ackermann et al., 2001); ▲ △ VTG, liver brown trout immunohistochemistry, black: positive; white: negative Burkhardt-Holm and Wahli, 1999); ● VTG, liver, rainbow trout, mRNA (Hollert et al., 2000); ■ Proliferation, MCF-7 cells, E-Screen, A-Screen (Durrer, 1999); ● VTG, blood, caged rainbow trout, ELISA, immunochemistry, under investigation (COMPREHEND, 2001); ◇ Yeast assay, sewage effluents, YES, under investigation, (COMPREHEND, 2001; oral communication M. Suter, EAWAG, 2001); ⊕ VTG, blood, gudgeon, ELISA, immunochemistry, under investigation (COMPREHEND, 2001); ○ Ovotestis, gudgeon, histology (Faller et al., 2002); ⊗ ⊙ Ovotestis, roach, histology, black asterisk: positive; white asterisk: negative (Bernet and Wahli, 2000); ✕ ✕ Gonadal malformations, whitefish, histology, black: positive; white: negative (press release Küng, 2001).

surface waters at levels comparable to other countries (Ahel et al., 2000a; Ahel et al., 2000b; Bennie, 1999), suggesting that similar effects may occur in fishes from Switzerland.

Potential hot spots with regard to endocrine activities have already been determined from data of sub-projects or studies associated with Fishnet. In most cases, these are sites downstream of the effluent outlet of sewage treatment plants. In 15 of 47 investigated sites, wild fish exhibited elevated levels of vitellogenin (VTG, a yolk protein induced by (xeno)estrogens and established as a reliable biomarker of exposure to (xeno)estrogens, (Burkhardt-Holm and Wahli, 1999; Ochsenbein, 2000); in 6 out of 8 sites, gonadal malformation was observed (Bernet and Wahli, 2000; Faller et al., 2002); and in the waste water of 9 sites, estrogenic activity was found (Durrer, 1999; Fig. 6). A weakness of the mentioned studies is the lack of comparability due to the application of dif-

ferent methods, and statements can only be made on the level of individuals.

In the EU programme, COMPREHEND (= Community Programme of Research on Endocrine Disruptors and Environmental Hormones, <http://www.ife.ac.uk/comprehend>), the occurrence and distribution of endocrine-disrupting effluents is being examined across a range of European countries, using existing fish-exposure techniques to detect reproductive interference. In Switzerland, three sites are under investigation. In the Swiss project HORSIA (= *Hormonaktive Stoffe im Abwasser*), endocrine activity in affluents and effluents of selected sewage treatment plants is being studied (Durrer, 1999), in parallel to an analytical chemistry on estrogens and nonylphenols. Effluents of the 9 investigated sewage treatment plants showed a proliferative effect in MCF-7 cells (breast cancer cell line) of about 20 to 44% relative to that of estradiol (Durrer et al., 2000).

Hypothesis 3: The fish population is suffering from reduced recruitment of young stages

Although a low number of young fish is not really a causal factor for a population decline, we considered this possibility separately for the sake of clarity in developing further research directions.

There is already some support for this hypothesis: (i) In numerous streams and rivers, an absence of young-of-the-year fish has been observed. (ii) During the early life stages, fish are most sensitive to 80% of the chemicals investigated (Fent, 1998). In consequence, a lack of young fish was hypothesised to be a key factor responsible for the decline in fish populations in certain rivers. To elucidate this, the project “quantitative assessment of young trout” is being performed over two consecutive years. In the first year, 59 stream reaches have been investigated to examine whether the natural reproduction, measured by the number of 0+ fish, is enough to guarantee a healthy population (Peter and Schager, 2001). In the second year more detailed analyses are being performed on 11 of the most interesting streams analysed in the first year.

Hypothesis 4: The health of fish and their fitness is impaired

Impaired health may lead directly to increased mortality or it may indirectly increase the risk of an earlier death in conjunction with other stressors.

Several causes of impaired health have to be considered:

- a) Diseases: viral, bacterial, parasitic.
- b) General impairment of the immune system.
- c) Organ alterations due to physical (e.g. fine sediments, episodic hydrological regimes), biological (in addition to infectious agents, starvation or malnutrition) or chemical factors associated with direct toxicology (see hypothesis 5).

Diseases. The last statistical survey of the incidence of fish diseases diagnosed by the National Fish Disease Laboratory of Switzerland was in 1988, and this survey did not indicate any increases in the incidences of infectious agents or other causes of disease over the preceding ten years (Wahli et al., 1992). Recently, our findings on PKD (proliferative kidney disease) indicated (i) a much broader geographical distribution than expected from routine diagnostic studies and single studies previously performed (Wahli et al., 2001), and (ii) a possible role for this infection in the decline in trout abundance in several rivers (Schneeberger, 1995; Schmidt-Posthaus et al., 2001).

The fact that most of the diseased fish were found in the Swiss midlands north of the Alps points to the pres-

ence of other factors favouring PKD, such as temperature (see hypothesis 11). A PKD epizootic in rainbow trout is expected when the ambient temperature rises above 15 °C. In addition to temperature, an increase in nutrient load, and decreased velocity of the water flow – factors which are relevant in the midlands – favour the proliferation of the invertebrate host, the filter-feeding bryozoa (de Kinkelin et al., 2001).

Parasites are often used as indicators of environmental perturbations. Especially those which have complex life cycles, delicate short-lived, free-living transmission stages, are sensitive to environmental changes. Conversely, parasites with simple life cycles are often more resistant than their hosts and tend to increase in numbers in polluted condition (Mackenzie, 1999), however, with enormous variations in the responses of different taxa to different types of pollution (Lafferty, 1997). Furthermore, they are indirectly favoured due to adverse effects of the pollutants to the fish host, like a suppression of the immune system (CEFAS, 2000).

Bacteria occur more often in and on fish downstream of sewage treatment plants. This may be at least partly due to their opportunistic pattern of occurrence; they particularly affect fish that have already been compromised. However, endogenous factors such as age, sex or physical condition also modulate the susceptibility of fish to infectious disease. Furthermore, the incidence of the disease fluctuates between seasons and among years (Wahli et al., 1992).

General impairment of the immune system. Immunity is developed during early life stages, which may explain the higher incidence of some parasitic diseases (*Costia*, *Ichthyophthirius*) in young fish (Wahli et al., 1992). Few data are available on the natural range of indicators of the trout immune system (such as phagocytic activity, lymphocyte proliferation, etc.), and even less on a possible immune impairment in brown trout or other fish species native to Switzerland (Bassi et al., 2001). However, a suspicion for an impairment of the immune system was formulated in several studies (Schmidt-Posthaus et al., 2001; Bernet et al., 2000).

Organ alterations due to environmental factors. In most of the sub-projects concerned with fish health, the histology of one or more organs is investigated. Trout from the Rhine river in the canton St. Gallen showed conspicuous alterations in liver and kidney in the year 2000, compared to 8 years previous when this stretch had been assessed as a reference (Bassi et al., 2001). In this and other studies distinct histopathological alterations were almost exclusively restricted to, or were more pronounced in, fish from river stretches in the midlands, compared to fish from alpine or Jura mountain region (Bassi et al., 2001; Bernet, 2001; Ochsenbein, 2001). Downstream of

two sewage treatment plants in the midlands, a correlation between poor health status and the contamination by effluents has been confirmed (Gerecke et al., 2001).

Hypothesis 5: Chemical pollution (both nutrients and synthetic compounds) is responsible for the fish decline and impairment of health

Chemical pollution of aquatic systems can arise from point sources such as wastewater effluents, or from non-point sources such as airborne inputs or surface run-off. A wide range of toxic compounds has been detected in Swiss rivers – both the “classic toxicants” such as heavy metals, persistent halogenated aromatic hydrocarbons, pesticides, persistent organic pollutants and surfactants (for review see Bättscher et al., 1999; Behra et al., 1993) as well as compounds such as alkylphenolic derivatives that have attracted more recent attention due to their potential endocrine disrupting activity (Ahel et al., 2000a) or emerging contaminants such as pharmaceuticals or flame retardants. In addition, excess nutrient load (nitrogen, phosphorus) can pose a hazard to aquatic life by causing eutrophication.

The primary objective within this hypothesis is to determine if the levels of contaminants found in Swiss rivers could have adverse effects on the fish fauna and be responsible for the observed decline in fish populations. Fishnet approaches this important objective through several strategies. One approach is to critically evaluate the available databases of analytical data on past and current concentrations of chemicals in surface waters in Switzerland. One problem with this approach is that we will obtain results only for those compounds that have been measured previously in analytical laboratories; no data are available for compounds that were not considered to be toxicologically relevant. For instance, there is almost no information on the metabolites derived from the bacterial metabolism of xenobiotics in wastewater treatment plants, which may be toxic to fish (Baumann, 2001).

A second approach for elucidating a possible role of chemicals in fish decline is to study changes in the emission of chemicals over the last 20 years, in order to ascertain whether there have been pronounced changes in the emission volumes of certain substances or substance groups.

The chemical data collected by the two sub-projects described above will have to be linked to toxicity data. This can be done by collecting laboratory toxicity data for individual chemicals and then undertaking a PEC/PNEC¹ procedure for hazard assessment. However, this strategy may give inaccurate estimates of toxicity, since the actual exposure of fish in the rivers is complicated by complex

mixtures of chemicals, and the presence of interacting factors such as temperature, diseases, etc. In the approach that is currently followed in a sub-project of Fishnet, the “Effect study”, the available data on adverse alterations – whether at the population, individual or suborganism level – of fish in Swiss rivers is compiled in order to compare those effect data with the chemical data of the inputs study. Bringing together the results from both sub-projects, we hope to be able to identify certain “hot spots” where enhanced chemical loads and impaired health status of fish coincide, thereby provide a starting point for more in-depth studies on the question of whether these coincidences represent a causal relationship.

Hypothesis 6: Poor morphological quality of the streams and a lack of longitudinal connectivity (highly restricted upstream migration of fish) are responsible for the decline in fish

Fish populations are highly dependent on natural or near-natural (no, or minimal, human influence) streams and rivers. In addition to water quality (chemical quality, temperature, oxygen, turbidity) and water flow (see hypothesis 12), the morphological qualities of the stream play a key role for the structure and function of the aquatic ecosystem. Variations in depth and width, stream bed roughness, substrate size and quality, pool-riffle pattern and floodplain interactions are important elements of river morphology. On a microscale, shading, structure, and cover (hiding places) are essential habitat features. The habitat requirement of trout includes the adjacent riparian border, which is an important interface between the aquatic and terrestrial ecosystems, ensuring good quality of habitat and water. The quality of the streambed gravel (low amount of fine sediments, high oxygen levels) depends on streamside vegetation, which also provides food (i.e., terrestrial animals) for fish. In addition to the lateral habitat connectivity that provides the interactions with the terrestrial ecosystem possible, longitudinal connectivity within streams and between tributaries is of vital importance for fish populations. Many streams and rivers currently lack longitudinal connectivity. Due to impassible barriers, former spawning areas can no longer be reached by spawning fish. In Switzerland, the number of artificial barriers in running waters is extremely high; Peter and Gonser (1998) reported the presence of 568 artificial barriers in the 59.7 km long Toess river (compared to only 35 natural barriers). The threat to ecosystem health presented by fragmentation is, according to some authors, more important than the impairment due to toxic chemicals (Cairns and Niederlehner, 1995).

Floodplains must be considered as hot spots for biodiversity (Willson et al., 1998). In particular, the floodplain closest to the mouth of a river is inhabited by a large number of fish species. In Switzerland, floodplains must

¹ PEC: predicted effect concentration; PNEC: predicted no effect concentration.

be considered as endangered ecosystems with a very limited area (0.26% of the total area of Switzerland; Peter, 1999).

Many human activities (hydroelectric power generation, agriculture, commercial and residential development) have led to the loss and degradation of riverine habitat. The potential for river re-habilitation in Switzerland is therefore very high; approximately 12,600 km (Willi, 2001). This corresponds to about 20% of the total stream length in Switzerland. In addition, about 18,000 km stream length is in culverts, illustrating the urgent requirement for stream rehabilitation action.

Efforts to halt and reverse the unsuitable ecomorphological conditions of streams began in the 1980s, with a total of 10.6 km rehabilitated per year (Peter et al., 2001), however, the actual rehabilitation speed is still low and should be markedly increased.

Hypothesis 7: An increased amount of fine sediments in streams is responsible for the decline in fish

Fine sediments (particle sizes of 2 mm or less) present a far-reaching problem especially to benthic spawners like trout. The egg burial depth of trout is 5-30 cm depending on the size of the female, on gravel composition, and on water velocity (Crisp, 2000). Fine sediments affect the oxygen supply by reducing intragravel flow and hindering the movement of the alevin (sac fry) from the egg pocket up through interstitial spaces to the surface of the streambed (entrapment of emerging fry). In very general terms, Crisp (2000) suggests that a satisfactory incubation gravel is likely to have a mean grain size of 20–30 mm and contain less than 10–20% of fines. In addition to the negative effect of fine sediments (bed load) on reproductive success, suspended sediments (< 62 µm) can also cause direct mortality or sublethal effects including reduced feeding and growth, respiratory impairment, and reduced tolerance to disease and toxins (Waters, 1995; Newcombe and Jensen, 1996).

Fine sediment is suspected to have increased over the last 20 years in Switzerland, mainly due to agriculture and urban development. In agriculture, the steadily increasing cultivation of corn (1969: 17300 ha; 1985: 63700 ha, Bundesamt für Statistik, 1980; 1987) is an important factor.

Cornfields have extraordinarily high erosion rates, with estimates of erosion rates range between 2 to 15 t of soil per hectare per year, compared to theoretical average erosion rates of 0.4 t per hectare per year in general (Mosimann et al., 1991). Both, modernization of farming techniques and structures and expanding of urban development resulted in condensed or sealed soil structures, and, as a consequence, instant run-off and increased erosion. Together, agriculture and urban development have

led to the loss of ecologically important habitats such as swamps and numerous small water courses, and many buffer zones have disappeared (Bundesamt für Raumplanung et al., 1994). Where the latter are absent, eroded materials are easily transported into streams.

Cases of disturbance to the ecosystem by fine sediments in Switzerland are reported and are under investigation. To further document the impact of sediment on streams, a search of the literature and available data will be undertaken. Rivers showing a decline in fish catch and indications of the effect of fine sediments are currently being investigated.

Hypothesis 8: Reduced amount of food leads to the decline in fish

In running waters, food for fish comprises mainly prey fish, benthos, drift, and insects at the water surface. In small river stretches, allochthone input can comprise between $\frac{1}{3}$ and $\frac{1}{2}$ of the total amount of food for trout in summer (Hynes, 1970; Reed and Bear, 1966). The biomass production of benthos is often underestimated (Hynes, 1970; Waters, 1977).

The dynamics of macroinvertebrate communities can vary greatly from year to year, depending on variations in weather and flow regime (Benke, 1984; Matthaei et al., 1997). Between spring and autumn, biomass may differ by a factor of 100, with considerable spatial and temporal variation. Food organisms are negatively affected by hydropeaking, due to the increase in current velocity (Statzner, 1981; Poff and Ward, 1991), and the de-stabilization of the substrate (Cobb and Flannagan, 1990; Peckarsky, 1991). Habitat changes are also followed by changes in the community structure of benthos as, for example, chironomids and tubificids are associated with soft substrata (Jones et al., 1999). Contaminants like heavy metals, PCBs and PAHs may play a role in shifts in the abundance and richness of species (Jones et al., 1999). The significance of alterations in abundance and richness of invertebrate species as a causative factor in fish decline or impaired fish health is unclear. The importance of food quality is evident from the M74 syndrome in the Baltic Sea where changes in the ecological structure of food chains may play a role in producing a thiamine deficiency in the eggs and brood stocks of salmon and sea trout, leading to high mortalities associated with this syndrome (Breitholtz et al., 2001).

Macroinvertebrate fauna of small streams were shown to be severely disturbed by transient, run-off related, insecticide input. A significant reduction in species abundance, as well as an enhanced drift and mortality, was observed for up to 1 km downstream and for a period of 3 to 6 months (Liess and Schulz, 1999). This suggests a considerable deterioration in food source, especially for young fish that are not resistant to starving for such long periods.

To evaluate whether and which of the variables mentioned have changed over the last few decades to an extent large enough to affect fish populations, a data collection and analysis will be carried out as a first step.

Hypothesis 9: The decline in fish is caused by inadequate management of fisheries

Over the last years, the problem of trout decline became more critical despite massive investment in hatcheries and fish stocking practices. Swiss rivers are highly managed. Intensive stocking is conducted in almost all streams in Switzerland. About 13 million brown trout are stocked in rivers and streams every year, corresponding to one 0+-trout per 5 m stream reach (E. Staub, BUWAL, personal communication). In addition to stocking with young-of-the-year (95.3%), trout older than one year are also stocked (4.3% of all stocked trout).

Hatcheries are established throughout the country. Unfortunately, hatcheries were never intended as a component of an adaptive-management program, and the success of the stocking programme has never been scientifically documented. In general, fish produced in hatcheries appear to experience poor post-stocking survival and reproduction due to a number of morphological, physiological and behavioural problems (White et al., 1995). In intensively stocked rivers, there are also potentially harmful genetic effects, an increase in frequency of non-adaptive hatchery genes, the breakdown of natural systems of semi-isolated populations, and interspecific hybridisation (Allendorf et al., 1987). Therefore, the role of hatcheries should be re-assessed. Hatchery operation, and the use of hatchery fish, should support the recovery of wild populations and must not be detrimental to natural populations.

In workshops with experts of the fisheries associations and hatcheries, management options which can be accepted from all parties are currently being elaborated.

Hypothesis 10a: The decline in fish is the result of an increased removal of fish, or

Hypothesis 10b: The decline in fish catch reflects altered behaviour of anglers

The behaviour of anglers influences the intensity of catch, and therefore the yield. It is first necessary to determine whether the intensity of angling is responsible for the decrease of fish catch. If this is the case, clear goals for regulation have to be issued in order to prevent a collapse when excessive effort pressure is applied. These may include technical measures such as gear limitations, closed seasons, and closed areas; input control including control of access and effort; or output control including quotas and size limits (Welcomme, 2001). Some of these measures are already in place in Switzerland. Evaluations of catches should be made directly by record-

ing all fish landed. In all cantons in Switzerland, recording catches is a condition of the angler licence. An individual fisherman records the amount of fish caught during a year, or during each trip. However, in most streams the catch per unit effort is unknown. The intensity of catch has to be estimated from the number of anglers and is therefore only a very rough estimation.

In order to test this hypothesis, a country wide compilation of the development of angler licences in Switzerland should be made for streams which are characterised by both a decline and steady-state catch levels. Currently, however, no nationwide and longstanding records exist for the last 20–30 years. This is also the case for most of the cantons. The temporal development of angler licences should be analysed in cantons having the necessary documents. The canton Bern documented that the number of anglers decreased from 1989 to 1998 by about 35% (Fischereiinspektorat, 2001). The price increase for the angler licence may be one of the causes. In the same time period the catch of brown trout decreased by 48%, indicating that overfishing may not have caused the decline in fish. Since there are hints that the most successful anglers do not give up, a clear correlation between a decrease in number of anglers and the catches is not evident.

Another factor that can cause depletion effects in fish stocks is the increasing presence of fish-eating birds, especially of cormorants (Pedroli and Zaugg, 1995). There are studies in several test rivers on the effect of bird presence on fish stocks and on how surplus fish production is distributed between anglers and birds (Staub, 2001).

An altered behaviour by fishermen could also result in a decreased amount of time per year spent for angling (preference of other activities during leisure time).

Using detailed questionnaires anglers have been asked about their fishing behaviour over the previous years. In addition, information on preferred angling streams, their status regarding habitat quality and water pollution, and other relevant circumstances will be obtained. The results of the survey should be available in 2002. This baseline information will be used to assess if angler behaviour during the last 10–20 years has changed and influenced the total catch of fish.

Hypothesis 11: Changes in the water temperature have led to a decline in fish population abundance and fish catch

A significant increase of 1.5 to 2°C in the maximum annual water temperature has been documented in certain Swiss rivers over the past 20 years (the river Rhine and its parallel channels, the river Aare, the river Thur; Jakob, 1998). This increase is partly due to inadequate riparian zones which shield streams from solar radiation. This effect diminishes with increasing stream width. An increase in water temperature has also been suggested to be

the result of inputs of heated cooling water from industries, the effect of hydroelectric power stations, as well as sewage effluents which are sometimes considerably warmer than the receiving rivers (Jakob, 1998). Global warming could be a further contributing factor. Taken together with the prediction of less water in summer (Bader, 1998), the situation in terms of stream temperature is deteriorating, although many cantons have new regulations which provide for buffer zones for each stream and the replanting of reduced riparian zones. Summer stream warming can irreversibly shift a summer-cold stream into a warm-water stream, with detrimental effects on salmonid populations.

Temperature changes affect fish in many ways: growth and general condition, reproduction, migration, behaviour, status of the immune system, and health. These parameters are affected when the temperature is outside the optimum range of brown trout (8–19°C, Frost and Brown, 1967), however, the range depends on populations, different life stages, etc. (Elliott, 1994, Crisp, 2000). Of less importance for brown trout in Swiss rivers is the lethal level (probably between 26°C and 30°C (Brett, 1952; Lee and Rinne, 1980) because only a few river stretches are reported to exhibit extremely wide temperature fluctuations.

Temperature also has indirect effects on fish, since it increases the number of pathogens and parasites. Temperature changes cause alterations in the community structure of prey and food organisms. Higher temperature lowers salmon growth efficiencies as long as food is not extremely plentiful (Brett et al., 1969). An increase in temperature may also influence the migratory behaviour of brown trout resident in lakes and of spawning individuals and competition between fish species (due to different preference ranges and changes in optimal temperatures) and create habitat conditions that favour warm water species, which can thus gain a competitive advantage over salmonids (Reeves et al., 1987). A national program for the long term analysis of Swiss rivers NADUF (Nationale Dauerüberwachung Fliessgewässer) collected data over 26 years on temperature, but also on other parameter in 11 rivers (NADUF, 2000). Fishnet is currently engaged in the evaluation of these data in order to detect possible relations between an increase in temperature and a decline in trout population.

Hypothesis 12: An altered hydrological regime and modified sediment transport are responsible for the decline in fish

An altered hydrological regime includes an increase in the frequency and magnitude of flooding events in winter and a decreased discharge in summer.

Increased frequency of floods in winter. An increase in the number of floods in winter has been reported for many streams in Switzerland. As global warming increases, the amount of snow precipitation decreases whereas precipitation in form of rain would increase. An analysis of trends in precipitation shows an increase in the amount of rain in Switzerland by up to 30% over the last 100 years (Widmann and Schär, 1997). From this, it could be assumed that discharge events with associated sediment transport have also increased over the last 100 years. Climatic models predict that in the northern foothills of the Alps the number of flood events will rise in winter, and especially between December and February. However, analysis of real data collected over recent decades do not confirm this hypothesis. Additional trend analyses on flood events in 23 streams and rivers in Switzerland did not show any increase in floods in winter or summer (Schuler, 2000).

If the frequency of a certain magnitude of floods does increase, it is assumed that this has a negative effect on the incubation phase of the egg/embryo. Jager and co-workers hypothesised that, as a consequence of climatic change, winter floods that scour brown trout redds in streams of the Sierra Nevada would result in a decrease in the fall-spawning brown trout population (Jager et al., 1999). Crisp (2000) has discussed the burial and subsequent excavation of eggs at depths of 5, 10 and 15 cm. Most eggs (90%) at 5 cm, a variable number at 10 cm, and a few at 15 cm, were washed out by the type of spate that occurs several times per year. A type of spate that occurs only every 10 to 20 years, however, washed out almost all eggs at 5 and 10 cm and over 40% at 15 cm. This indicates that flooding does not necessarily lead to the washing out of eggs in every case.

The intragravel survival is highly dependent on the oxygen concentration and incubated eggs survived much better in the absence of rain (Massa et al., 1998). Therefore, sediment transport and the accumulation of fine sediments (after rainfall) appear to have a negative effect on the survival of incubated eggs. This will be more of a problem in streams that are highly burdened with fine sediments.

Reduced amount of water in summer. During summer, the smaller reserve supply of snow and the decrease in the size of glaciers, combined with reduced precipitation and increased evaporation, will all tend to suppress the peak discharge in summer (Bader, 1998). A direct consequence of the reduced amount of discharge is the heating up of water in streams. Combined with the prolonged low flow discharge, this would be expected to have negative effects on brown trout, depending on the magnitude of discharge and temperature increase (see also hypothesis 11).

Changes in the discharge regime may also be caused by damming (reservoir construction) of streams. Typical effects include a lower summer peak and higher winter peak of stream discharge. The change in discharge as a result of hydroelectric power use will exacerbate the predicted changes caused by global warming.

Conclusions and prospects for ongoing process in Fishnet

Long-term declining fish populations have been reported from several countries. In the short term, it is hard to distinguish between natural fluctuations and anthropogenically-induced declines in species with a lifecycle of three or more years, such as the native fish species of Switzerland. In addition, there is often no single identifiable causative factor but rather many factors interacting, and this complex interaction makes it particularly difficult to provide unequivocal explanations to the public, regulatory authorities and other interested parties. The problem of the complex interaction between many factors is already apparent in the difficult task of classifying and comparing different forms of damage and impacting factors (Brunberg and Blomqvist, 2001). A diversity of information, including socio-economic, chemical and other aspects, must be integrated over significant spatial and temporal scales, and the effects of the diverse factors on many different levels of biological organisation must be considered.

Progress to date in the Fishnet project includes:

- Potential causative factors are currently systematized and evaluated in about 30 sub-projects. Examples are given according to the hypotheses previously discussed.
- Promotion of numerous interactions between different involved parties. One example is a project monitoring the endocrine effects on fish, which reported an increase in VTG in male brown trout downstream of sewage treatment plants in three different cantons. On reporting these results to the responsible authorities, Fishnet (i) co-ordinated a second sampling (same time period, same laboratory performing sample assay), (ii) helped to interpret the results, and (iii) advised on the final joint report. Although interactions as described in this example are not the prime goal of Fishnet, they offer the possibility of fast, reliable networking between the involved agents in the future, which is an essential prerequisite for success.
- The conferences of sub-projects conducted as methodological workshops provided an opportunity for external experts to learn about new approaches and methods. Continued education is one product which is promoted by Fishnet (cf. Table 1). This will facilitate

the implementation of monitoring programmes and will help increase the comparability of data collected by standardised methods in the post-Fishnet phase.

- Finally, increasing awareness of the problem of fish decline by the general public, policy makers and authorities supports the implementation of further, self-financed projects. Cantons with little experience of fish projects, and even fishing clubs wanting to undertake their own studies, appreciate the willingness of the Fishnet management group to help with advice, networking, or even financial support. This appreciation is reflected in the increasing number of inquiries coming to Fishnet.

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