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Restoration of some small loess streams – a contribution of organic farming to nature conservation and management

Renaturierung kleiner Lössbäche – ein Beitrag der Ökologischen Landwirtschaft zum Naturschutz

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Abstract

As a part of the interdisciplinary research project "Integration of nature protection goals with organic farming: an the example from the Hessian "state domain" [Staatsdomäne] area Frankenhausen", different restoration measures have been carried out within this site, 15 km north of Kassel. Since 1998, intensive conventional agricultural practices have been substituted with organic farming here. One intention of the agricultural restructuring was to realise nature protection goals in cooperation with sustainable organic agricultural production.

The hydrologic portion of the project addresses both the implementation of restoration measures in rivers and streams and their scientific monitoring. Starting in July 2007, several restoration measures were carried out in the hydrologic systems of the Jungfernbach and Esse streams within the Frankenhausen site. Both systems are formed by typical loess streams (catchment size about 9 km²) which had been heavily degraded for several hundred years by intensive agriculture. The most important restoration measures were removal of a piped section of a tributary of the Jungfernbach at Totenhof, restoration of biological passability by removal of weirs and substitution of narrow pipes under farm paths, relocation of a section of the Jungfernbach from the edge of the floodplain to its original location in the centre, widening of narrow sections and partial raising of the deepened stream bed by means of rough ramps (stone bars) and racks made of oak wood or iron.

These physical restoration measures were accompanied by a scientific monitoring programme comprising morphological, hydrochemical and biological (aquatic macrophytes, aquatic macroinvertebrates, fish and amphibians) aspects.

The aim of this study was to document the original ecological conditions, the restoration measures and the early ecological effects on the stream sections for the first six months following restoration as a basis for further ecological monitoring.

The restoration measures effected clear morphological changes in cross-section and passability. The chemical condition of the streams showed slight changes in some aspects following the restoration, e. g. a reduction of phosphorus, magnesium and potassium concentration. Other than macrophytic algae in the newly shaped sections, aquatic macrophytes did not develop over the winter season before the end of the monitoring phase in April 2008. Within the newly shaped stream sections of a small tributary and of the Jungfernbach, up to 14 aquatic macroinvertebrate taxa started to colonise the new habitats 6 months after restoration.

*Fish fauna were very poorly represented in the streams and included only a few specimens of brown trout (*Salmo trutta*). This did not change markedly after restoration, possibly due to the isolation of the population caused by impassable weirs downstream of the investigation area.*

Keywords: *Organic farming; loess streams; stream restoration; morphological, chemical, biological monitoring; biodiversity; evaluation of ecological success; integrated nature conservation*

Zusammenfassung

In einem interdisziplinären „Entwicklungs- und Erprobungs-Vorhaben" der Universität Kassel „Die Integration von Naturschutzzielen in den Ökologischen Landbau am Beispiel der Hessischen Staatsdomäne Frankenhausen" wurden unterschiedliche Naturschutz-Maßnahmen auf dem Domänengelände durchgeführt. Seit 1998 wird die Staatsdomäne Frankenhausen, die ca. 15 km nördlich von Kassel liegt, ökologisch bewirtschaftet. Ein Aspekt bei der Umstellung auf ökologische Landwirtschaft war die Umsetzung von naturschutz-orientierten Maßnahmen, die in Kooperation mit dem landwirtschaftlichen Betrieb umgesetzt wurden.

Ein gewässerökologisches Teilprojekt umfasste unterschiedliche Entwicklungsmaßnahmen an und in Bächen des Jungfernbach- und Esse-Systems auf dem Gelände der Staatsdomäne ab Juli 2007. Beide Bachsysteme (Einzugsgebietsgröße jeweils ca. 9 km²) werden von typischen lössgeprägten Bördenbächen gebildet. Löss-Gebiete zählen zu den durch intensive Landwirtschaft am tiefgreifendsten veränderten Gebieten Deutschlands. Folgende wesentliche Renaturierungsmaßnahmen wurden auf dem Domänengelände umgesetzt: Entfernung der Verrohrung, Offenlegung und Neugestaltung eines Nebenbaches des Jungfernbaches am Totenhof, Rückverlegung eines Jungfernbach-Abschnitts vom Rand der Aue in seine ursprüngliche Lage im Zentrum der Aue nach historischen Angaben, Wiederherstellung der biologischen Durchgängigkeit durch die Entfernung von Wehren und den Ersatz von unpassierbaren Wege-Durchlässen durch voluminösere Durchlässe mit durchgängiger Sohle, partielle Aufweitung enger Querprofile und Anhebung der Gewässersohle durch Stein-Riegel und Sohlrechen aus Stahl oder Eichenholz.

Die Maßnahmen wurden von einem wissenschaftlichen Monitoringvorhaben begleitet. Hauptaspekte der wissenschaftlichen Begleitung waren morphologische, hydrochemische und biologische Untersuchungen aquatischer Makrophyten, des Makrozoobenthos, der Fischfauna und der Amphibien. Sie dienten der Erfassung des ökologischen Status quo der Gewässer vor Durchführung der Maßnahmen und der Doku-

mentation der ökologischen Situation der Gewässer im Anschluss an die Maßnahmen als Basis für die Beobachtung der künftigen Gewässerentwicklung.

Die Renaturierungsmaßnahmen induzierten markante Veränderungen der morphologischen Situation der ehemals zu engen und tiefen Querprofile und verbesserten die biologische Durchgängigkeit auf dem Domänengelände. An den Sohlrechen fand während der Folgemonate nach der Renaturierung wegen zu geringer Wasserführung nur ein geringer Totholztransport und damit noch keine erkennbare Sohlanhebung statt.

Die chemischen Qualitätsparameter zeigten bei einigen Wasserinhaltsstoffen (z. B. bei Phosphor, Magnesium und Kalium) einen Rückgang der Konzentrationen, der seine Ursachen im Verzicht auf mineralische Düngung mit diesen Stoffen in der ökologischen Landwirtschaft haben könnte.

Bei den Wasserpflanzen traten in den neu gestalteten Gewässerabschnitten unmittelbar nach den Renaturierungsmaßnahmen Pionierbestände makrophytischer Algen wie *Spirogyra*, *Cladophora* und *Vaucheria* auf. Über die Herbst- und Wintermonate nach Abschluss der Maßnahmen im Oktober 2009 bis zum Ende der Monitoring-Phase im April 2008 konnten sich noch keine Makrophytenbestände in den neu gestalteten Gewässerabschnitten entwickeln.

Im Gegensatz hierzu fand in diesem Zeitraum eine rasche Ansiedlung von 14 Wirbellosen-Taxa im Jungfernbach und 13 Taxa im kleinen, offengelegten und neu gestalteten Bach am Totenhof statt. In diesem Nebengewässer siedelten sich zahlreiche für Lössbache charakteristische Makroinvertebraten bachaufwärts aus dem Jungfernbach heraus an.

Die sehr spärliche Fischpopulation, die aus wenigen Bachforellen in einem einzigen Gewässerabschnitt bestand, veränderte sich infolge ihrer räumlichen Isolation durch unterhalb des Untersuchungsraums gelegene Wehre nicht nennenswert.

Schlüsselwörter: Ökologische Landwirtschaft; Lössbäche; Gewässerrenaturierung; morphologische, chemische, biologische Erfolgskontrolle; Biodiversität; Naturschutz

1 Introduction

The “Aquatic Ecology” project described in the following contribution is part of the interdisciplinary research project (development and testing programme [“E+E-Vorhaben”]). ”Integration of nature protection goals with organic farming: an the example from the Hessian ”state domain” [“Staatsdomäne”] area Frankenhausen“ conducted by different institutes of the University of Kassel. The Frankenhausen site is situated on land that has been leased from the federal state of Hessen by the University of Kassel since 1998 to allow the intensive conventional agricultural practiced there to be replaced by organic farming. Physical measures were financed by the Hessische Landgesellschaft. Scientific monitoring was financially supported by the German Federal Nature Conservation Agency (BfN).

The project consists of two major components:

1. An operative programme [“Hauptvorhaben”] to carry out different tangible restoration and development measures, e. g. restoration of streams and rivers in the region
2. A scientific monitoring programme [“Wissenschaftliches Begleitvorhaben”] to assess the ecological success of the realised measures.

The development and test programme started in spring 2006. The implementation of the first restoration measures took place in summer 2007. Scientific monitoring ended in April 2008.

The scope of the operative programme of the aquatic part of the project is to improve hydromorphological habitat conditions for aquatic and semi-aquatic plants and animals; these actions are supported by measures in the floodplain to provide more room for the sustainable ecological development of the streams within the Frankenhausen site. The measures were designed to comply with the goals and practices of organic farming and to serve as examples which might be implemented in other comparable organic farms.

The scope of the scientific monitoring programme was twofold. First, the status quo of aquatic macrophytes, invertebrates and fishes before and shortly after restoration was documented. Second, the recolonisation by benthic macroinvertebrates of newly restored stream sections was investigated. Another goal was to identify typical plant and invertebrate taxa which could be used as target species to monitor the ecological success of restoration measures in similar streams.

Typical streams of the German *Börde* landscape – an agriculturally fertile area marked by flat terrain, loess soils, and few trees – show the following features:

- Their bed materials are mostly fine-grained from input of loess.
- The watercourses have generally been straightened.
- The watercourses have often been shifted close to the edge of the floodplain.
- Their beds have mostly been deepened either by hydraulic engineering or as a consequence of straightening and vertical erosion.
- As a consequence of deepening, streams and their floodplains are often separated. Semiaquatic transition zones between the aquatic and terrestrial areas are usually missing.
- The surrounding flood plain area is frequently drained by dense drainage systems for agricultural purposes.
- In many cases open arable land is situated close to the banks. Unmaintained riparian buffer strips are often narrow or totally missing.
- A permanently high input of silt, nutrients and pesticides is common to loess streams in conventionally cultivated Börde areas.
- Dead wood, an important structural component of stream beds, is often removed for maintenance reasons.

For these reasons, particularly the ongoing input of silt which generally leads to a severe sealing and homogenisation of the stream bed, loess streams usually show a comparatively low biological diversity.

Important prerequisites for the ecological development of aquatic communities in loess streams include the following:

- Good chemical quality
  - No pesticides near the banks
  - Reduced input of silt
- Natural structures of the stream bed and bank
  - Higher structural diversity through the inclusion of dead wood.

Centuries of intensive agriculture have resulted in conditions that are increasingly incompatible with natural streams and their floodplains. In such areas the realisation of stream restoration measures is extremely difficult. In loess areas, much more than in other regions, land for restoration purposes is largely unavailable owing to their fertile soils, which are valuable for agriculture. Therefore stream restoration measures were undertaken within the Frankenhausen site, where organic farming is practised, to provide a model for comparable farming in other regions of Germany.

2 Area of investigation

The Jungfernbach, situated about 15 km north of Kassel, is part of the stream system of the Esse which flows into the river Diemel, a tributary of the river Weser (Fig. 1). Their catchment is located in a typical *Börde* landscape. Great parts of it are covered with fertile loess soils. The floodplains of the Jungfernbach and Esse system have been significantly altered by agriculture. The Jungfernbach has a total length of about 6 km, an average slope of 1.27 % (Weber 2000) and a catchment area of 9 km^2. Mean width of the stream bed is 1 to 3 meters, mean annual flow is 1.7 m^3/s, mean five-year flow 3.5 m^3/s, and current velocity ranges between 0.1 and 0.4 m/s. Bed and banks of the Jungfernbach are not stabilised, but in most sections have been significantly straightened, and the stream bed has mostly deepened down to 2–3 m below the surface of the riparian area. Within the Frankenhausen site, the Jungfernbach and its tributaries belong to the category of loess hill streams, which are rich in fine stream bed material and of moderate slope.

According to Pottgiesser & Sommerhäuser (2004, 2008), the investigated streams resemble type 6: "*small fine-substrate-dominated calcareous highland streams*" and type 18: "*small loess and loam-dominated lowland streams*". In natural alder floodplain forests, small loess brooks may develop towards type 11: „*small, organic-substrate-dominated rivers*" (Pottgiesser & Sommerhäuser 2004).

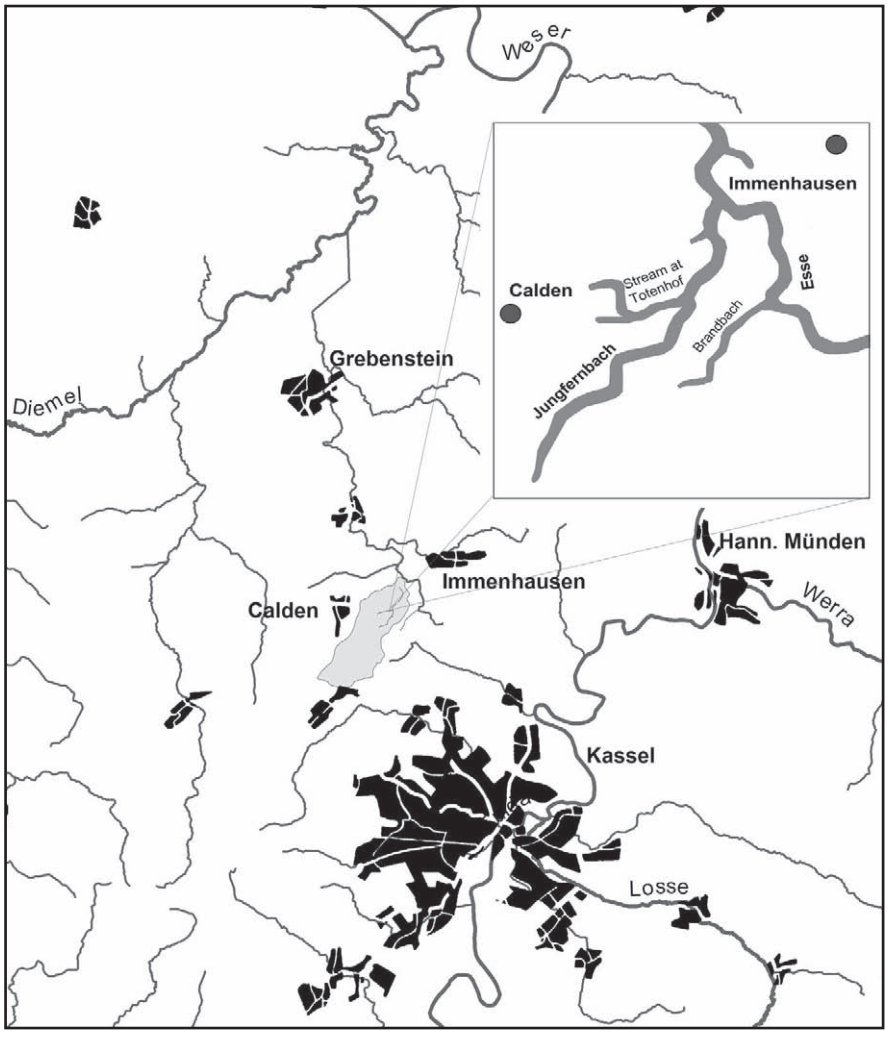

Fig. 1: Study area and map of water quality of the Jungfernbach system according to the saprobic system. All sections are classified as moderately polluted (quality class II, results for streams outside the Jungfernbach system according to HLUG 2000).

Abb. 1: *Untersuchungsgebiet und Karte der Gewässergüte des Jungfernbach-Systems gemäß Saprobiensystem. Alle Abschnitte sind mäßig belastet (Güteklasse II, Ergebnisse außerhalb des Jungfernbach-Systems nach HLUG 2000).*

A reference section of this stream type was found within the area of the Jungfernbach nature reserve. It has a length of about 200 m and is the only section of the Jungfernbach with a moderate structural quality according to LAWA (2000). This section (type 11) was used as the reference condition (*Leitbild*) for the restoration of other morphologically degraded parts of the Jungfernbach. In its semi-natural reference section, the Jungfernbach presents a meandering course without anthropogenic depth erosion of the stream bed. Here the average depth of the stream bed is about 30 to 50 cm. Within the reference section the stream passes through a nearly natural alder floodplain forest. It differs significantly from the downstream sections, which have been heavily modified by former agricultural use. They are deepened down to 3 meters, mostly straightened and bordered by narrow, patchy, wooded riparian buffers. These sections are more or less severely morphologically degraded and predominantly show a bad structural quality (Fig. 2).

As a typical loess-loam stream, the Jungfernbach and all other investigated stream sections are characterised by layers of mud of varying thickness covering their beds. Bed sediments are dominated by silt, loess, loam and fine-grained sand. Pebbles and cobbles rarely occur. Under natural conditions dead wood forms the most important coarse structures to serve as suitable habitats for benthic macroinvertebrates.

Due to nearly permanent input of loess particles from the catchment, the coarse structures like stones, leaves, twigs etc. are often silted over. Siltation leads to a severe uniformity of the stream beds, resulting in a biological diversity which is much lower than in stony mountain streams. Due to permanent turbidity caused by the silt, loess streams generally contain few water plants. Intensive cultivation of corn, sugar beets or even wine in the catchment usually leads to an increased impact of nutrients and pesticides. Thus loess streams, especially in wine-growing areas, are actually among the most degraded and biologically impoverished moving-water ecosystems in Germany and in comparable areas of Central Europe.

2.1 *Water and structural quality of the Jungfernbach system*

Water quality of the Jungfernbach and Esse systems is classified as class II, moderately polluted, in all water courses, according to the saprobic system (DIN 2003) and LAWA (1998). Compared to the biologically defined water quality, the hydromorphological quality of the streams, evaluated according to the German habitat assessment system (LAWA 2000), is much worse. Just 3 % of the total water course of the Jungfernbach is moderately degraded and classified as class 3, meeting the regulatory goals to be achieved. Most of the length of the stream (83 %) is classified as distinctly to heavily degraded, and 14 % is completely degraded. That result is typical and representative for most German loess streams. Figure 2 gives an overview of the hydromorphological condition (structural quality) of the streams specified above.

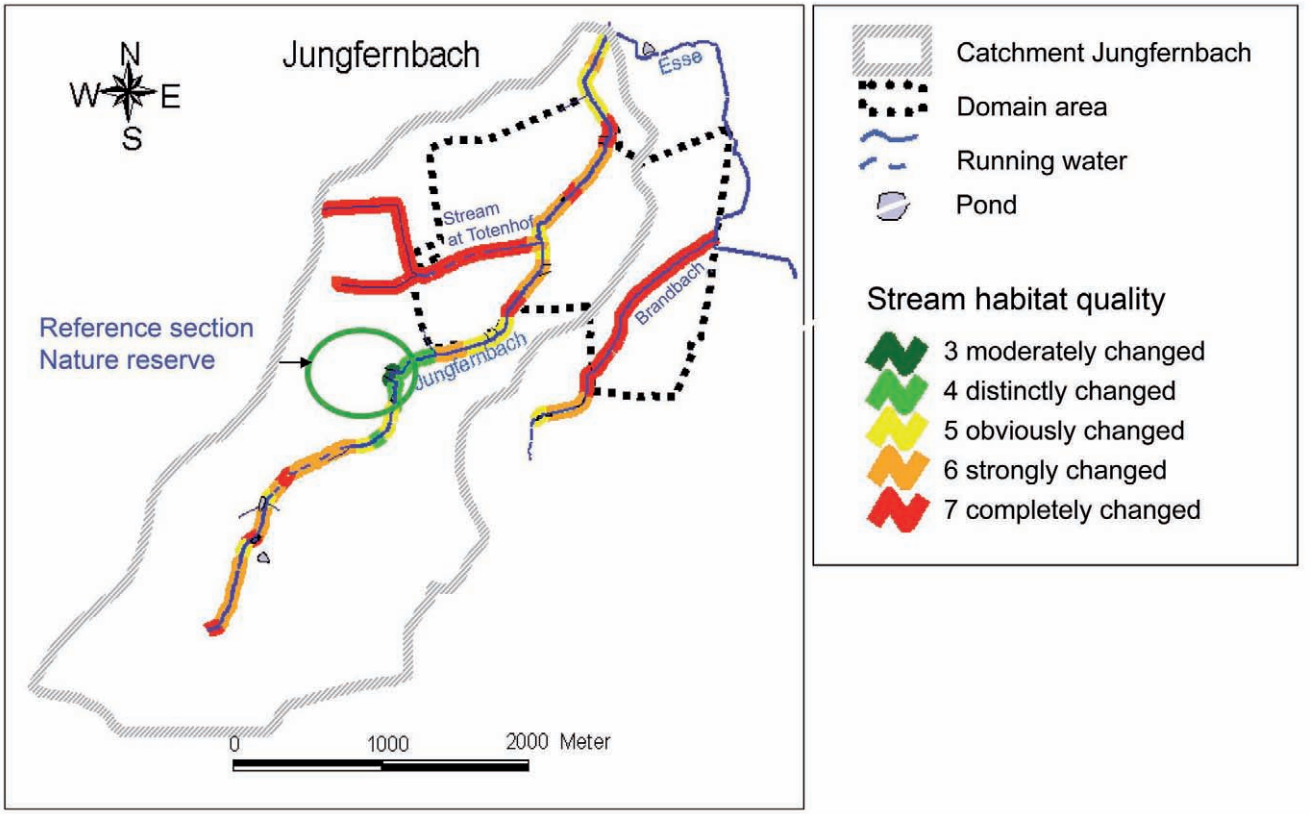

Fig. 2: Stream habitat quality of the Jungfernbach system before restoration. Only a small 200 m section within the nature reserve can be described as moderately impaired. All other sections are significantly worse. (Figure according to Weber 2000, after HMULF 2000)

Abb. 2: *Gewässerstruktur-Güte des Jungfernbach-Systems vor der Renaturierung: Lediglich ein kurzer Abschnitt von 200 m Länge (im Naturschutzgebiet) ist mäßig beeinträchtigt. Alle anderen Abschnitte sind schlechter eingestuft. (Abbildung nach Weber 2000 und HMULF 2000)*

Figure 3 presents (a, b) a near-natural reference condition of a characteristic organic-substrate-dominated loess stream like the Jungfernbach within the nature reserve and (c–f) some typical aspects of the morphological degradation of the loess streams and agricultural ditches within the Frankenhausen site.

3 Operative programme

3.1 Restoration measures in the stream systems of Jungfernbach and Esse

The restoration measures were planned and conducted by the planning consultancy "Büro für Ingenieurbiologie und Landschaftsplanung" (BIL, Witzenhausen) in cooperation with the University of Kassel, Department of Water Ecology and Management.

The first steps for the ecological development and improvement of the stream systems were carried out in the Frankenhausen farm area. The land there has been leased from the federal state of Hessen by the University of Kassel since 1998 to allow the intensive conventional agricultural practices to be replaced by organic farming. One aim of the agricultural restructuring of the site was to allow the goals of nature conservation to be pursued in close cooperation with sustainable organic production.

3.1.1 Goals of the measures

A major goal of the restoration measures was to develop and support both the natural conditions of the streams and their biodiversity, thereby complying with the economic and ecological intentions of organic farming. Another aim was the creation and development of natural areas, particularly in floodplains with supraregional bioptope connections.

The basic ecological goals of the project can be defined as follows:

- Reestablishment of passability for fish and macroinvertebrates
- Restitution of the inherent dynamic of the water bodies and a near-natural morphology; promotion of dead wood as an important structural parameter within the scope of water maintenance measures
- Reversal of vertical erosion
- Reduction of sediment and nutrient input from the catchment
- Development of a riparian buffer consisting of typical floodplain vegetation
- Support for development of greater zoological diversity

The first proposals for natural development of the watercourses within the site were developed in 2001 (Braukmann et al. 2002) based on a diploma thesis by Weber (2000). Further investigations were carried out in 2004 and 2005 (Wolf et al. 2005). More detailed planning was conducted by the planning office BIL (Haass 2008). After authorisation by the regional council of Kassel, the following measures were implemented between July and October 2007:

- The Jungfernbach was relocated from the edge to the centre of the floodplain.
- The deepened beds of Jungfernbach and Brandbach were partly raised by stone barriers. Rakes made of wood or iron bars, all passable for organisms, were installed to support an accumulation of dead wood.
- Passability of most stream sections was improved by removing existing weirs and narrow pipes under paths.
- A piped section of the ditch at Totenhof was daylighted and restructured.
- Riparian buffers and areas for succession were extended up to 20 meters on each bank.
- Several ponds and pools were created.

Figure 4 gives an overview of restoration measures carried out at the Frankenhausen site.

The following paragraphs provide a detailed overview of the restoration measures carried out in the different project streams (see also Fig. 4).

Jungfernbach: In some sections the bed was raised to about 1 meter by sills (*Grundschwellen*) consisting of regional limestone material. In other sections, coarse racks of oak wood or iron bars were installed to support natural raising of the bed through accumulation of dead wood.

Biological passability was improved by a number of measures including removal of weirs and the substitution of impassable pipes with larger ones that were dug into the natural substrate.

In the area of the nature reserve, the straightened course of the Jungfernbach was relocated from the edge of the floodplain to its original position in the middle. A new shallow bed with the potential for dynamic development and early inundation was created and protected against vertical erosion with sills made of limestone.

The drainages in the floodplain were closed. A new unperforated intercepting sewer along the border between arable land and grassland was located in the grassland area to maintain drainage of the adjacent agricultural areas which continue to be cultivated. This drain pipe was also necessary because the stream bed was raised in this section. The aim of this measure was to establish a wetland area as a suitable habitat for dragonflies, amphibians and wading birds The excavated earth was partly used to fill the former bed at the edge of the floodplain and to create back water, including areas of standing water. Below the stream relocation, the bed was partly protected against vertical erosion and raised 0.5 to 1 meter with sills and coarse iron racks.

Close to the Jungfernbach, four ponds of different depths were established for amphibians.

Small creek near Totenhof: The piped section of the small creek near Totenhof was daylighted for a length of about 400 m. A new shallow bed was established. The bottom was

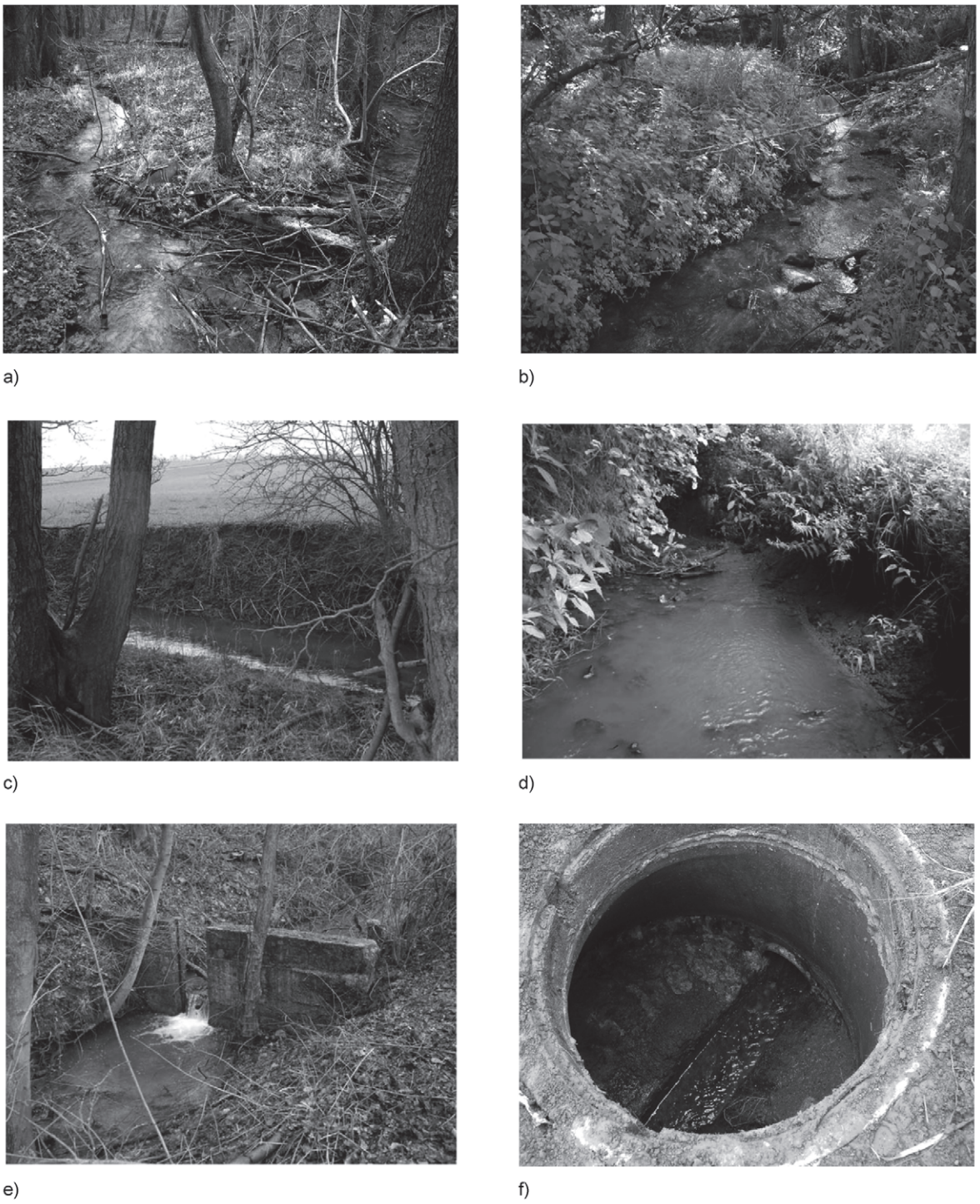

Fig. 3: **a**), **b)** Semi-natural section of the Jungfernbach stream. Reference condition of a typical loess stream with shallow stream bed and minimal vertical erosion, strongly curved to meandering, surrounded by a natural alder floodplain forest. Relevant bed structures are dead wood, some coarse sediments and larger stones; stream shows characteristics of an organic-substrate-dominated subtype. **c)** Artificially deepened stream bed resulting from straightening. Typical section without clearance for dynamic development, no riparian buffers, sharp boundaries between aquatic and terrestrial ecosystems, and no amphibian areas. **d)** Characteristic permanent turbidity caused by the input of loess-loam particles. **e)** Obstacles to ecological passability for aquatic animals caused by an old weir. **f)** Piped stream section at Totenhof; this section was daylighted and rebuilt (see Fig. 5 a, b) (Photos: a, b) Braukmann, c) to f) Rupp).

Abb. 3: ***a), b)*** *Naturnaher Abschnitt des Jungfernbaches; Referenzabschnitt eines typischen Löss-Baches mit flachem Bachbett, geringer Tiefenerosion, kurvigem bis mäandrierendem Verlauf in einem Schwarzerlen-Eschen-Bachauenwald; bedeutende Bettstrukturen sind: Totholz und einige größere Steine; Gewässer zeigt Aspekte eines organisch geprägten Gewässertyps;* ***c)*** *Unnatürlich stark eingetieftes Bachbett infolge ehemaliger Begradigung, typischer Abschnitt ohne Möglichkeit einer dynamischen Eigenentwicklung, keine Uferrandstreifen, scharfe Grenze zwischen aquatischem und terrestrischem Bereich, keine amphibische Zone;* ***d)*** *Typische permanente Trübung infolge des Eintrages von Löss-Partikeln;* ***e)*** *Wanderungshindernis für aquatische Organismen, verursacht durch ein Wehr;* ***f)*** *Verrohrter Abschnitt des Baches am Totenhof; dieser Abschnitt wurde geöffnet und neu gestaltet (vgl. Abb. 5 a, b) (Fotos: a, b) Braukmann, c-f) Rupp).*

partly protected against erosion with sills of local limestone. Below the daylighted part of the stream, the very steep borders were flattened on both sides, and the bed was stabilised and raised about 0.5 m with rough ramps. Narrow pipes below farm paths were replaced with wider ones to enable biological passability.

Stream edges were partly replanted with alders. Beside the daylighted stream section, a pond with a surface area of 320 m² and a depth of 1.5 m with shallow edges in places was created.

Brandbach: The severely deepened bed of the Brandbach was raised about 0.6 m with eight rough stone ramps. A pipe was replaced with a wider passage. In this section, alders were also replanted. Drainages were removed and some ponds were established.

Near the **Esse creek** an earthen wall was relocated 10 m away from the stream in order to develop a broader riparian area. A small headwater in the area of the Mühlberg grassland was opened and structured as a small shallow creek.

All restoration measures were carried out with the goal of improving structural and biological diversity. The aims were to support biotope connectivity, restore biological passability, and increase the amount of natural floodplain vegetation. Most of the measures improved the water regime by raising the groundwater level. Finally, all measures are expected to have a positive visual impact on the monotonous loess landscape.

Some of the most important measures are illustrated in Figure 5.

3.1.2 Outlay for the restoration measures

Gross construction expenses for the restoration measures carried out for the ecological upgrading of the water bodies amounted to 157,000 EUR (according to Haass 2008). These costs also include measures such as development of several new ponds in the floodplain of the streams.

4 Scientific monitoring

An important aim of the scientific monitoring was to gain basic knowledge of the abiotic and biotic parameters which might be influenced and changed by the restoration measures of the aquatic ecosystems within the operative programme of the project.

Another aim of the scientific monitoring was to assess the ecological condition of the stream sections before and shortly after restoration to obtain a baseline for future monitoring in the coming years. Furthermore, the study was to document the ecological effects of the hydromorphological restoration, particularly the raising of the stream bed, on the aquatic and amphibian communities. The recolonisation process of benthic organisms in restored sections of the Jungfernbach (section 7 in Fig. 6) and the small daylighted and newly shaped creek at Totenhof were also to be documented (sections No. 5 and 12 in Fig. 6).

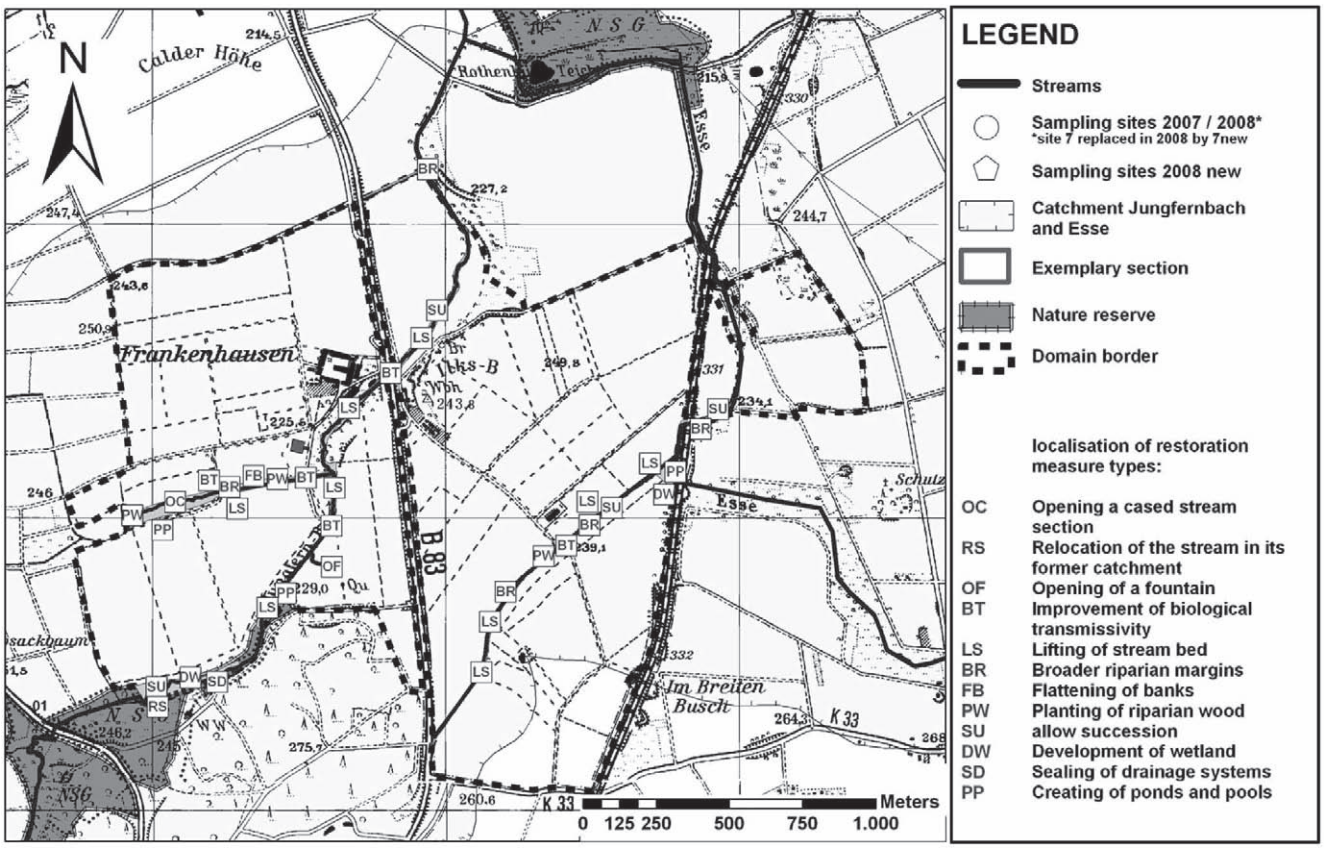

Fig. 4: Overview of main restoration measures in the Jungfernbach and Esse watershed at Frankenhausen site.

Abb. 4: *Übersicht über die wichtigsten Renaturierungsmaßnahmen-Typen im Jungfernbach- und Esse-System auf dem Gebiet der Staatsdomäne.*

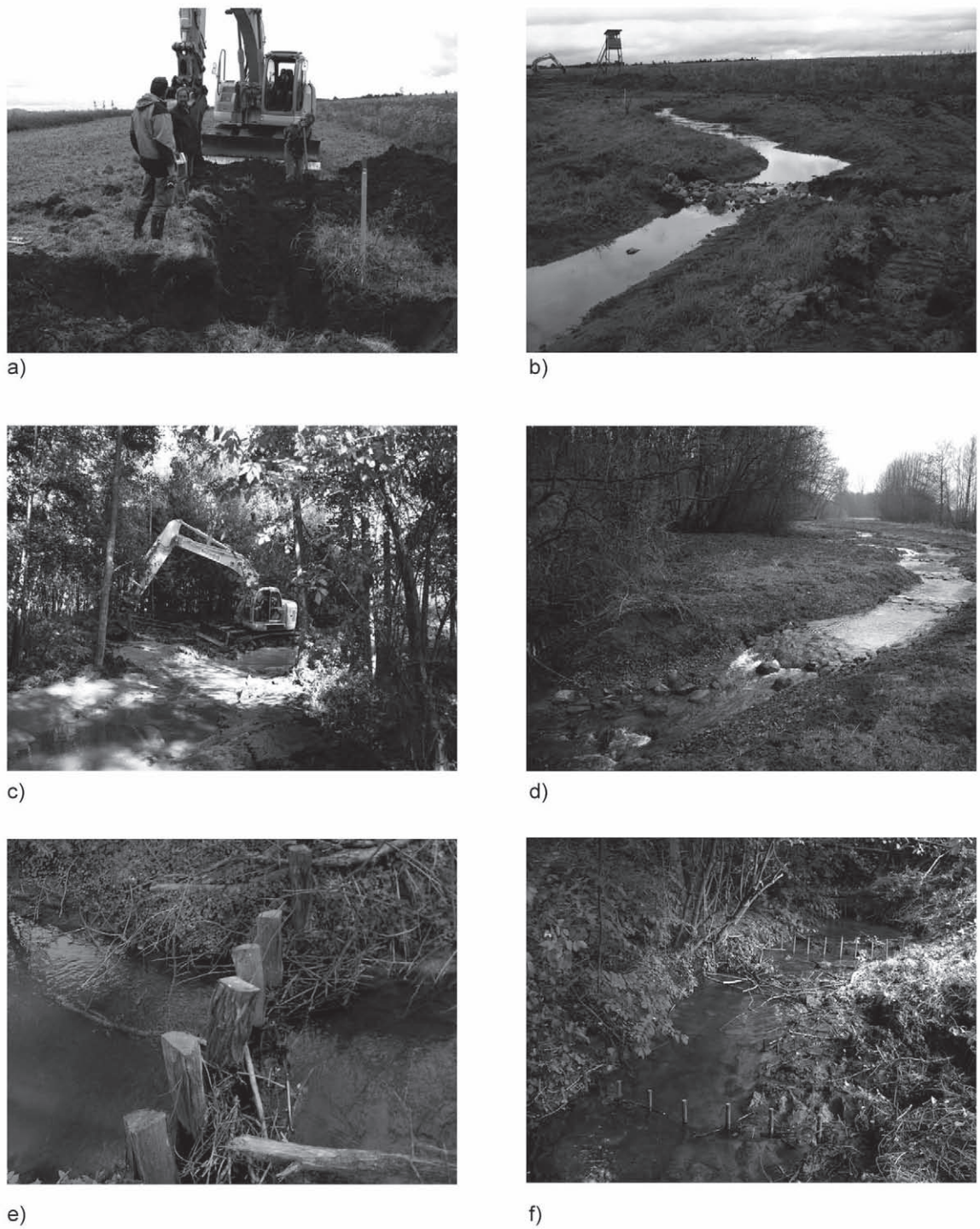

Fig. 5: Main restoration measures: **a)** Daylighting of the formerly piped brook at Totenhof; **b)** Newly built brook at Totenhof. Goals included restitution of biological passability and of a flat bed structure with the potential for dynamic development and early inundation; **c)** Relocation of the Jungfernbach into the middle of the flood-plain; **d)** Newly built section of the Jungfernbach, the shallow bed has been partly stabilised by stone bars; **e)** Lifting of the stream bed by racks made of wooden bars; **f)** Lifting of the stream bed by groups of iron bars (Photos: a, e) Rupp; b, c) Haaß; d, f) Braukmann).

Abb. 5: *Haupt-Renaturierungsmaßnahmen: **a)** Öffnen des verrohrten Baches am Totenhof; **b)** Neu strukturierter Bach am Totenhof – Ziele: Wiederherstellung der biologischen Durchgängigkeit und eines flachen Bachbetts mit dem Potential einer dynamischen Eigenentwicklung und frühzeitiger Ausuferung; **c)** Rückverlegung des Jungfernbaches in die Mitte der Aue; **d)** Neu gestalteter Abschnitt des Jungfernbaches, das flache und breite Bett wurde partiell mit Steinriegeln gegen Tiefenerosion gesichert; **e)** Anhebung der Bachsohle, initiiert durch Eichenholzstäbe; **f)** Anhebung der Sohle durch Stahlstäbe (Fotos: a, e) Rupp; b, c) Haaß; d, f) Braukmann).*

The scientific monitoring consisted of the following aspects:

- Assessment of the morphological conditions and probable changes resulting from restoration measures in 12 sections which are representative for typical loess streams, particularly:
  - Raising of the stream bed
  - Shifting of bed and bank structures
- Chemical monitoring of organic pollution, nutrients, and geochemistry
- Biological monitoring of the status quo and development of:
  - Aquatic, amphibian and terrestrial vegetation (in the riparian area)
  - Macroinvertebrates, amphibians and fish

The most important aspects of the scientific monitoring programme were as follows:

- Typification of the Jungfernbach
- Preliminary studies: four sections of the Jungfernbach were investigated in 2001 to enable the following:
  - Evaluation of the structural quality
  - Chemical and biological investigations
  - Determine reference conditions and development objectives
- The main studies were carried out in the following sites:
  - In 2007: eight sections in the Frankenhausen area, one reference section in a nature reserve, two sections of the Esse
  - 2008: nine sections in the Frankenhausen area, one reference section, and two sections of the Esse

Figure 6 shows where the sites were established for the morphological, chemical and biological monitoring programme.

4.1 Methods

4.1.1 Morphological monitoring

Morphological investigations included surveying and mapping of the composition of substrates and bed structures as well as the temporal changes in these components due to the restoration measures carried out. Morphological studies also analysed the spatial and temporal development of typical cross-sections. Morphological investigations were carried out from 2007 to April 2008 in 10 representative stream sections within the investigation area.

4.1.2 Chemical monitoring

Chemical monitoring covered water temperature, oxygen content and saturation, pH, electrical conductivity and total hardness. These were measured directly in the field.

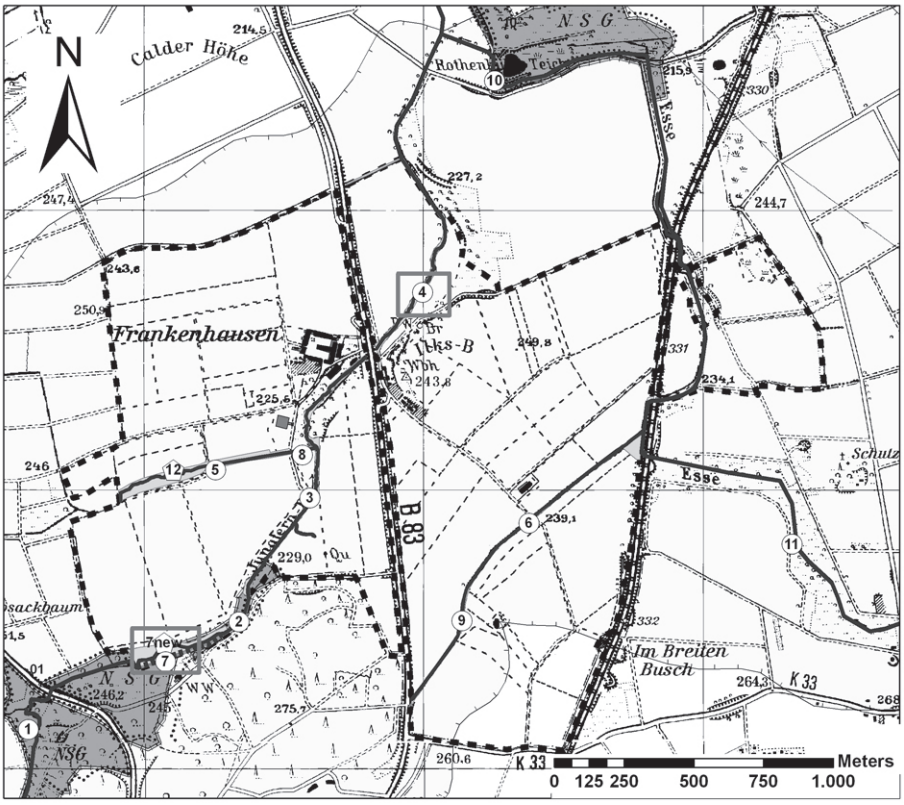

Fig. 6: Sampling sites in the investigation area; for the legend, see Figure 4.

Abb. 6: *Untersuchungsstellen im Renaturierungsgebiet – Legende siehe Abb. 4.*

The following chemical pollution and nutrient indicators were measured: biological oxygen demand (BOD_5), dissolved organic carbon (DOC), nitrate-nitrogen, ammonium-nitrogen and ortho-phosphate-phosphorus. For the characterisation of geochemical and water quality parameters, calcium, magnesium, potassium, sodium, chloride and sulphate were measured in the laboratory. Measurements were carried out according to DEV (1992).

In 2007 measurements in the field took place every 2 months and twice in the lab. In 2008, after completion of restoration, chemical parameters were measured four times.

4.1.3 Biological monitoring

Biological studies presented below include assessments of aquatic macrophytes, aquatic macroinvertebrates, fish and amphibians. Aside from amphibians, these groups are generally used as biological quality indicators in the European Water Framework Directive (WFD 2000).

Aquatic macrophytes

Monitoring of aquatic macrophytes was carried out according to LUA NRW (2003) on 11 representative sections. Water plants were identified according to van de Weyer (2003), and estimation of abundance according to Londo (1974).

The actual vegetation was compared with the natural vegetation of the reference condition. Each macrophyte site was related to an adequate ecological quality class based on disturbance indicators particularly considering shading of the water course by riparian trees following LUA NRW (2003).

Macroinvertebrates

Macroinvertebrates are reliable indicators of oxygen-consuming organic pollution. They also indicate habitat disturbances and degradation of morphological conditions in the watercourses (Braukmann & Biss 2004 und Lorenz et al. 2004).

Investigations were carried out in 10-m lengths of representative sections of the streams using substrate-oriented multi-habitat-sampling based on AQEM (2005), modified by Hübner (2007). A total sample of 1 m^2 consisted of 10 subsamples of 0.1 m^2 each. Sampling took place three times per year (March/April, July/August and October) in 2007 and 2008 to obtain the widest spectrum of species composition. Samples were sorted and organisms were determined to be alive in the field according to Braukmann (2000) and Hübner (2007). A more detailed determination of the subsamples was undertaken in the lab.

Fishes

Fishes were studied by electro-fishing once a year between 2006 and 2008 in 50-m stream sections. In each sample, the species were determined, and the fish were counted, sorted according to length class. The number of escaping individuals per section was estimated in the field.

Amphibians

Qualitative observations of adult amphibians, their eggs and their larvae took place eight times at 2-week intervals from the beginning of March to the middle of July in 2007 and 2008 in the newly created ponds near Totenhof and close to the Jungfernbach. Sampling site data were noted following Schlüpmann (2005).

4.2 Results

4.2.1 Hydromorphology

The assessment of the substrate structures revealed a widespread, and in some places, massive coverage of the stream bed with fine silt which had washed in from the surrounding loess area at nearly all sites. A very small amount of dead wood and other coarse material was observed. Natural limestone boulders were similarly very rare. Investigations of the cross sections in 2007 had indicated a strong vertical erosion of the stream beds which was an important reason for stream bed lifting. In part, these measures showed first small effects in the following year. The changes in cross-section and substrate composition of section 7 are illustrated in Figure 7 as an example.

4.2.2 Water chemistry

All investigated sites showed chemical characteristics typical of carbonate streams with electrical conductivity values well above 300 µS, the threshold range between silicate and carbonate stream types (Braukmann 1997). The Jungfernbach system is characterised by generally higher values than the Esse (Fig. 8). All sites show low pollution levels by oxygen-consuming organic substances as characterised by BOD_5 values shown in Figure 8. BOD values in 2007 met the German chemical quality class I-II standards (according to LAWA 1998), except those from the sites Jungfernbach 2 and Esse 10, which were classified as class II.

DOC values in the Jungfernbach system were also generally lower than in the Esse. A maximum DOC value of 12 mg/L was registered at Jungfernbach 1. Median DOC in the Jungfernbach was 2 mg/L, whereas in the Esse it was about 4 mg/L. Based on their median BOD concentrations, all sites of the Jungfernbach can be classified as chemical quality class II, and the Esse as class II-III (according to Braukmann 2000). Thus the Jungfernbach is less contaminated with organic pollutants than the Esse.

Phosphorus concentrations of the Jungfernbach in 2007 generally could be assigned to quality class II, meeting the required regulatory quality target. In 2008 partly higher values at Jungfernbach 2, 4 and 7 (reaching class II-III) and at Jungfernbach 1 (class III) were measured.

The regulatory target of quality class II for nitrate-N was not achieved. The lowest values were measured in the Esse. The Jungfernbach presented higher values and was classified as class II-III. Ammonium-N values were rather low, within quality class I-II.

A broader, less intensively used riparian area should lead to better nutrient loads in the future. The range of some major chemical parameters characterising typical loess streams is shown in Figure 8.

4.2.3 Biology

The results of biological surveys of aquatic macrophytes, macroinvertebrates, fishes and amphibians are presented below.

Aquatic Macrophytes

Based on their aquatic vegetation, the watercourses in the project area can be divided into three characteristic loess stream types:

- Macrophyte-free type (streams less than 10 m in width)
- *Berula erecta* community type
- Helophyte type.

In 2007, immediately after the restoration measures had been completed, only a few or no macrophytes were found in the modified sections. The macrophyte-free type also dominated in unrestored shaded sections. This corresponds well to the naturally vegetation-free type of loess streams. In unshaded or just moderately shaded unrestored sections, the *Berula erecta* community or the helophyte type prevailed. Therefore all sites, except site 3 of the Jungfernbach, were characterized as good or very good quality according to LUA NRW (2003). Section 3 of the Jungfernbach was unshaded and heavily dominated by *Phragmites australis* which covered the whole bed of this brook area. This section belonged to the helophyte type and therefore also corresponded to one of the typical phenotypes of loess streams (LUA NRW 2003).

Other than in a few patches of the newly restored sections, the indicators of increased nutrient load *Cladophora* and *Vaucheria* algae were not observed in notable densities in most stream sections.

Through April 2008, only slight changes were observed compared to the situation in 2006 or 2007 before restoration. In the relocated and newly shaped watercourse of the Jungfernbach, patches of *Spirogyra* spp., *Vaucheria* spp. and *Lemna minor* were observed. Also *Equisetum palustre* and *Polygonum amphibium* were found in this section. In the newly created unshaded section of the small brook at Totenhof, green algae such as *Cladophora glomerata* developed in moderate quantities. Otherwise, in 2008, only riparian grasses grew from the borders into the middle of the bed of this narrow water body. During this initial stage, very small patches of *Berula erecta* and *Epilobium hirsutum* could be found in the watercourse.

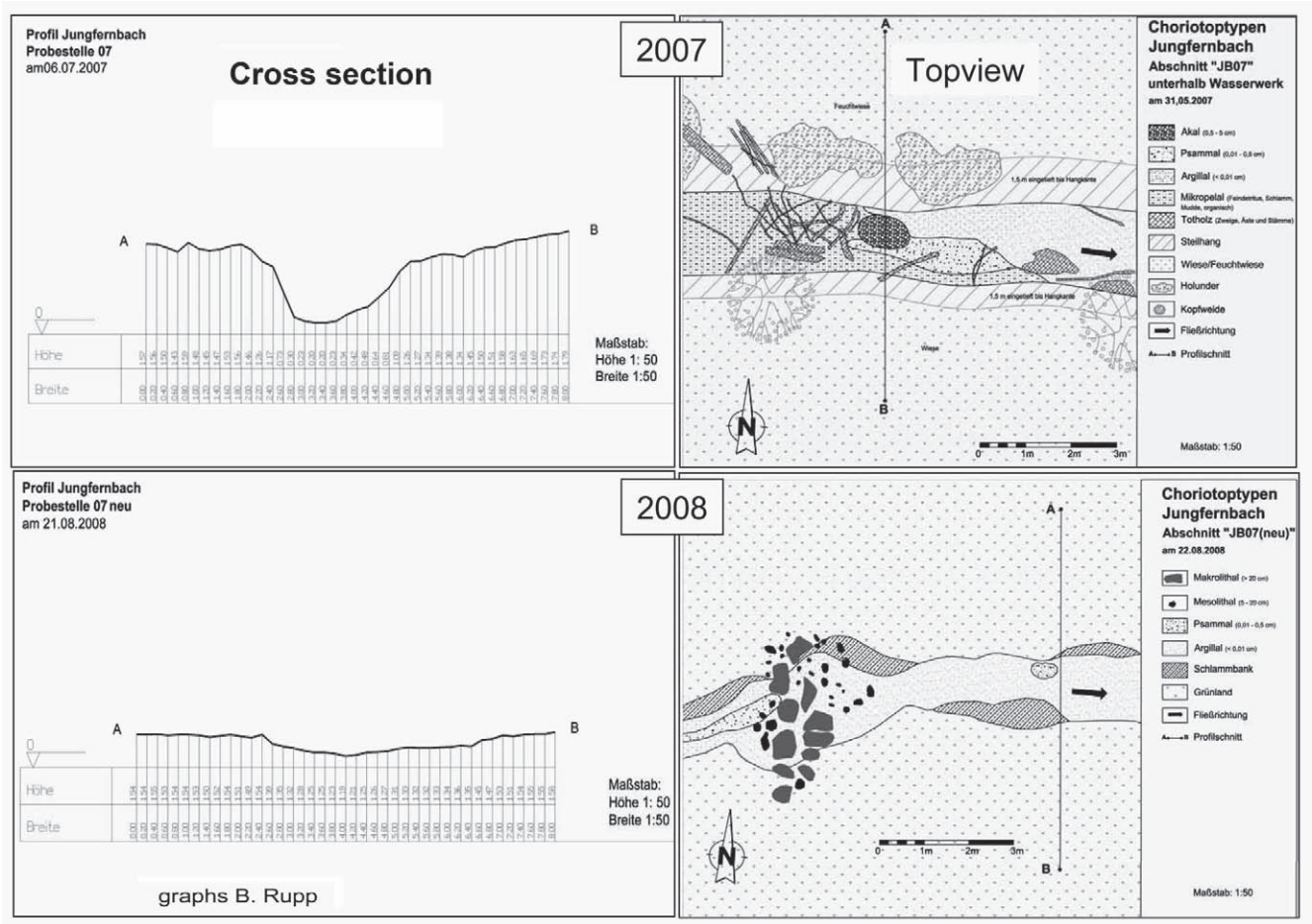

Fig. 7: Jungfernbach, section 7, left: altered cross-section, right: substrate structure, above: before, below: after restoration. The initial stage of the newly built stream bed (left) shows a lower substrate diversity because no dead wood had drifted into this section shortly after restoration.

Abb. 7: *Jungfernbach, Abschnitt 7, links: Veränderung des Querprofils, rechts: Substrat-Struktur, oben: vor, unten: nach der Renaturierung. Das Initialstadium des neu gestalteten Bachbetts (links) zeigt noch eine geringe Substrat-Diversität, da kurz nach der Renaturierung noch kein Totholz in diesen Abschnitt eingetragen wurde.*

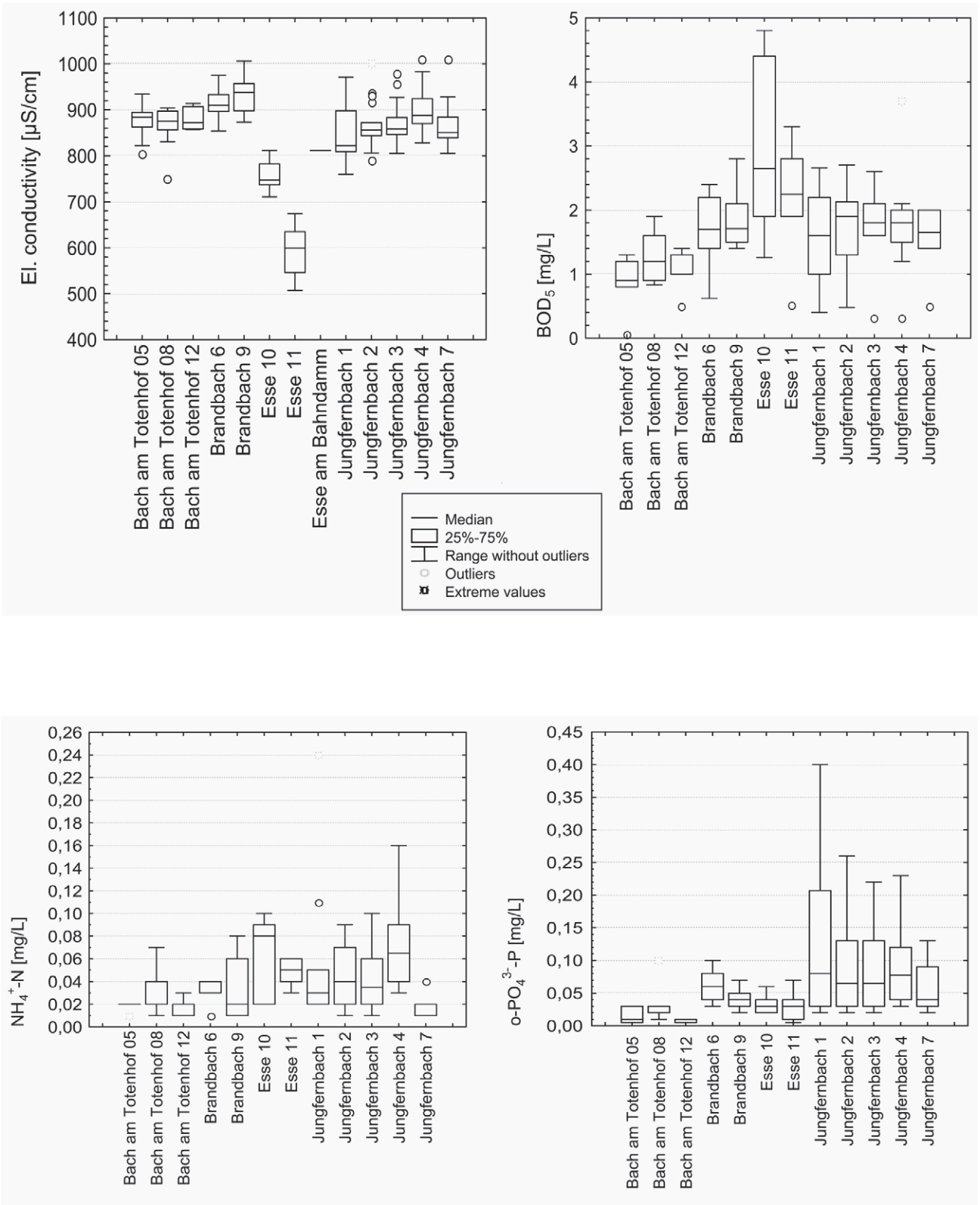

Fig. 8: Chemical quality parameters:
a) Electrical conductivity and biological oxygen demand over 5 days (BOD_5).
b) Ammonium-nitrogen (NH_4^+-N) and ortho-phosphate-phosphorus (o-PO_4^{3-}-P).

Abb. 8: *Chemische Qualitätsparameter:*
a) *Elektrische Leitfähigkeit und Biochemischer Sauerstoffbedarf (BSB_5).*
b) *Ammonium-Stickstoff (NH_4^+-N) und Ortho-Phosphat-Phosphor (o-PO_4^{3-}-P).*

In its initial stage, the newly shaped, unshaded Brandbach also showed areas where algae including *Vaucheria* began to spread shortly after restoration.

Macroinvertebrates

Macroinvertebrates were studied intensively over the period before, during and after the restoration measures were undertaken. As examples, the results are outlined for two streams, the Jungfernbach and the small, newly established creek at Totenhof. Figures 9 and 10 give an overview of the taxa of those sections that spread most steadily and dominated in areas where the greatest morphological changes took place.

In total, 70 macroinvertebrate taxa were found in the Jungfernbach. The macroinvertebrate community of this stream is characterised by a high dominance of gammarids (*Gammarus pulex* and *G. fossarum*). Regular occurrence of the sediment-dwelling midge species *Ptychoptera paludosa*, which prefers shallow silty areas of slowly flowing watercourses, was typical. In shady sections, larvae of the chironomid *Micropsectra* form dense, highly abundant populations. Other characteristic species of fine-grained stream beds include the mayflies *Ephemera danica* and *Electrogena uyhelyii*, which were found here in low numbers. Nevertheless, both species can be regarded as target species for the development of near-natural, unpolluted loess streams with fine sediment beds. The species are also characteristic of streams with a sufficient amount of coarse and stable structural elements, such as dead wood. Other target taxa for this stream type are the caddisflies *Sericostoma* spp., *Halesus* spp., and the beetles *Limnius perrisi* and *L. volckmari*. All are sensitive to oxygen deficits, which can easily occur in slightly polluted brooks with a large amount of fine sediment and slow current.

Figures 9 and 10 each show a list of the most consistent and dominant taxa in the Jungfernbach and the creek at Totenhof. Over the period of 2007–2008 in the Jungfernbach 29 taxa (out of 70 in total) occurred in more than 25 % of all sections of the Jungfernbach, in the creek at Totenhof 20 taxa (out of 39 in total) were present in more than 25 % of all sections of the creek at Totenhof.

Recolonisation of the newly created stream sections by benthic macroinvertebrates at sections No. 7 (Jungfernbach) and No. 12 (creek at Totenhof) (Fig. 6) in its daylighted upper part, took place rapidly 6 months after the end of restoration. In the newly structured section of the Jungfernbach 14 invertebrate taxa were found and 13 taxa in the formerly piped section of the creek at Totenhof. This result suggests that loess streams with a naturally low biodiversity (due to low flow and low substrate diversity) are also highly dynamic systems with a good potential for recovery under suitable water quality conditions.

The further development of benthic macroinvertebrates, especially the establishment of sensitive target taxa, typical for morphologically regenerated and chemically unpolluted loess streams, should be monitored in the coming years when more natural floodplain conditions will have developed and more dead wood will have accumulated.

Fishes

In the years of electro-fishing from 2006 to 2008, just one species, the brown trout *Salmo trutta fario*, could be found, and then only in a single section, No. 2 (Fig. 6). This section is located in the nature reserve and is characterised by a relatively high structural diversity in shaded surroundings with reduced siltation. The results of the fish monitoring are shown in Figure 11.

Brown trout is the characteristic species of the upper trout region of streams (epirhithral according to Illies (1961). Because the species spawns in gravelly areas, it has very limited opportunities to reproduce successfully in heavily silted loess streams like the Jungfernbach. The small population of brown trout found in section 2 in the Jungfernbach seems to be isolated and slightly reproductive. Immigration from below, particularly from the Esse, is impossible due to impassable weirs.

Amphibians

The newly created ponds had not yet been accepted as spawning habitats in April 2008. Other than the European toad (*Bufo bufo*), just one other amphibian specimen, an Alpine newt (*Triturus alpestris*), was found after an exhaustive search. Also no spawn or tadpoles were observed in any of the new ponds shortly after restoration. One reason may be that restoration ended late in the year in October after the end of the migration and spawning phase of amphibians.

5 Contribution of organic farming to restoration success in loess streams

The catchment area of the Jungfernbach upstream from the investigated area is mainly cultivated as meadow. Therefore impact from pesticides is not to be expected. Organic farming within the Frankenhausen site excludes pesticides.

Other typologically comparable loess streams in intensively cultivated catchment areas, e. g. the areas of conventional viniculture in Rheinland-Pfalz, have been studied cursorily to compare the influence of such crops on benthic macroinvertebrates in loess streams. Stream morphology and benthic invertebrates were studied in a morphologically semi-natural section of the Dörrenbach, a small loess stream in southern Rheinland-Pfalz below the village Dörrenbach. Morphologically, the Dörrenbach stream is very similar to the Jungfernbach. The following macroinvertebrate taxa were found in the Dörrenbach: *Polycelis nigra*/*tenuis* (rare), *Glossiphonia complanata* (rare), *Gammarus pulex* and *Gammarus roeselii* (both abundant). Insects were completely absent. The investigated section was downstream of a large vineyard, which partly bordered the brook. Based on these circumstances, pesticides are the obvious reason for the clear lack of aquatic insects.

In the upper catchment of the Jungfernbach, no comparable agricultural cultivation such as of corn or wine is present. In its reference section within the nature reserve, the Jungfernbach shows a much higher biological diversity with many insects.

This leads to the conclusion that the improvement of morphological structures within and along the streams and rivers by restoration measures can only offer ecological success as defined, for example, by the presence of macroinvertebrates as bio-indicators, if the water quality is sufficient and if

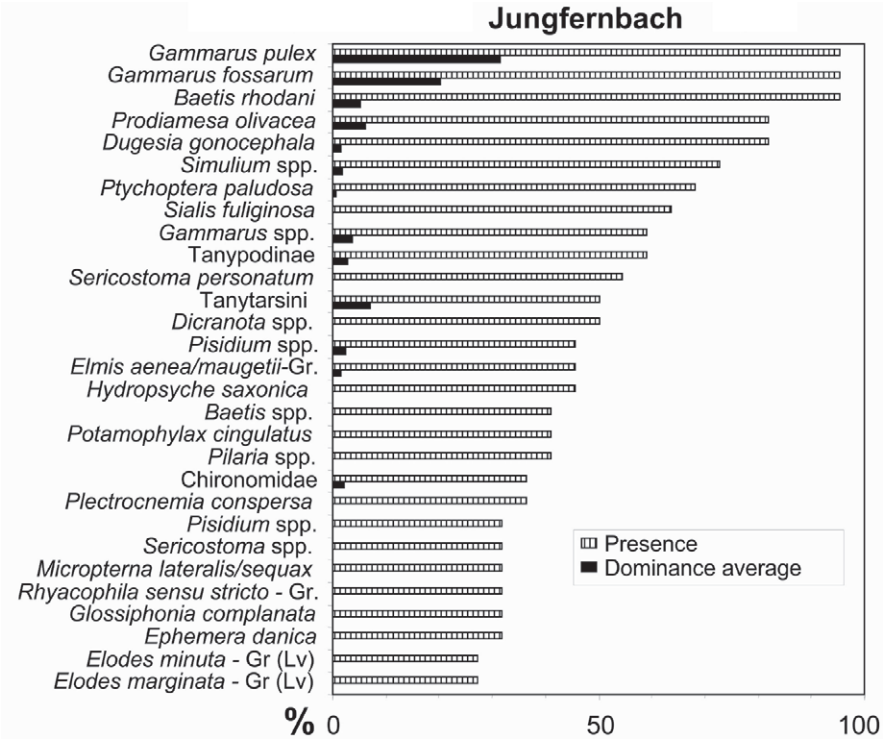

Fig. 9: Jungfernbach: 15 macroinvertebrate taxa present in ≥ 25 % of all studied sections out of a total of 70 taxa.

Abb. 9: *Jungfernbach: 15 stetige Taxa des Makrozoobenthos (Stetigkeit ≥ 25 %) von insgesamt 70 Taxa.*

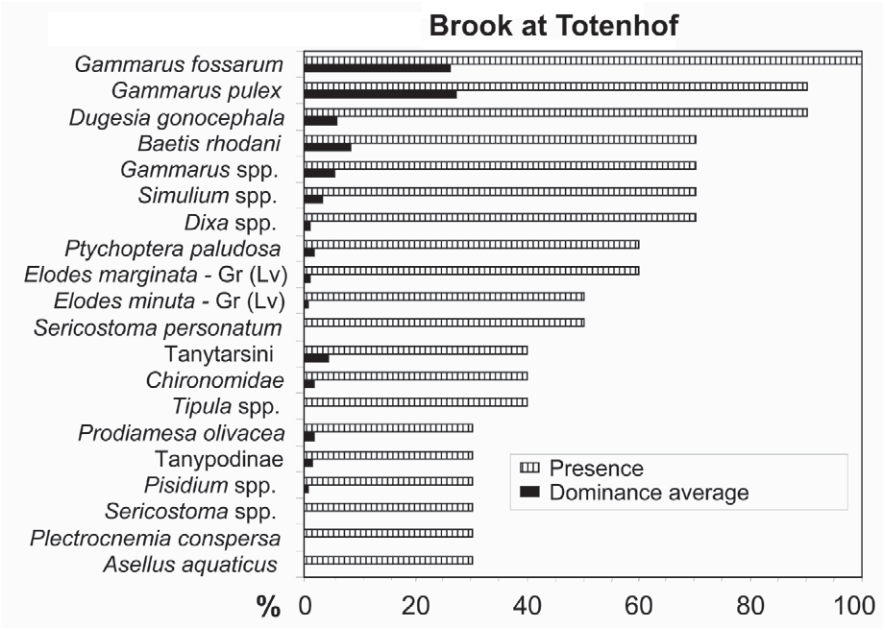

Fig. 10: Brook at Totenhof: 21 of the taxa present in ≥ 25 % of all studied sections out of a total of 39 taxa.

Abb. 10: *Bach am Totenhof: 21 stetige Taxa des Makrozoobenthos (Stetigkeit ≥ 25 %) von insgesamt 39 Taxa.*

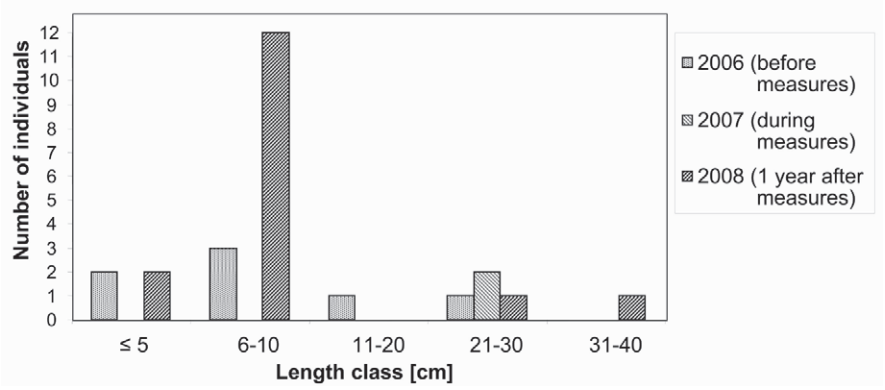

Fig. 11: Results of electro-fishing 2006–2008; 2006 (before), 2007 (during), 2008 (6 months after restoration); number of brown trout in section 2.

Abb. 11: *Ergebnisse der Elektrobefischung von 2006 bis 2008; 2006 (vor), 2007 (während), 2008 (6 Monate nach der Renaturierung); Anzahl Forellen in Abschnitt Nr. 2.*

no pesticides are introduced into the water. Pesticides may prevent any ecological success that could arise through the addition of structural improvements. In this context the importance of farming without pesticides in floodplain areas has to be emphasised as an essential foundation for a successful ecological improvement of loess streams.

6 Summary of first results less than 1 year after restoration

Morphological, chemical and biological efficiency monitoring, carried out in the years before, during and 6 months after the end of restoration revealed the following results:

The morphological situation showed a positive development.

Passability was markedly improved. The structures put in place to effect raising of the stream beds had not shown visible results as of April 2008 due to low flow after restoration.

The physicochemical status showed no significant changes. A comparison between the investigation periods 2001–2005 and 2007–2008 shows a slightly reduced concentration of phosphorus, magnesium and potassium at nearly all sites. Since in organic farming these substances are not used as mineral fertiliser the abandonment of these fertilisers might be a reason for the deminished concentration of the mentioned water constituents.

Considering the biological status, macrophytes showed a few individual settlements, and a rapid development of algae was obvious in the first initial development of the modified stream sections.

Macroinvertebrate communities changed only marginally in the initial phase of stream development, and target taxa were still underrepresented. In newly created sections, a rapid colonisation by up to 14 invertebrate taxa was observed 6 month after restoration.

The fish population showed minimal changes as well with brown trout continuing to be the only species present. Almost no reproduction took place because of isolation of the population due to barriers downstream.

7 Conclusions and perspective

1. The scientific monitoring programme ended in April 2008, 6 months after restoration. Early ecological success was evident, but the monitoring period was much too short to capture effective biocoenotic changes. More natural communities may be expected once the restored streams have developed further towards the envisaged stream type surrounded by a natural floodplain forest. Therefore, further monitoring for 10 years or more (cf. Koenzen et al. 2009) is essential to describe and survey long-term ecological effects.

2. A further restoration programme should be carried out incorporating the whole catchment of the stream systems of Jungfernbach and Esse. Because of existing weirs at the mouths of those streams, both systems should be given highest priority for restoration, in particular the sections containing the weirs.

The highest priority should be given to restoration measures in the catchment, especially in the floodplains adjacent to the water bodies. Here measures that are compatible with stream and river quality should be undertaken. A holistic approach seems necessary, particularly a change in agricultural land use leading to a large-scale conversion of arable land, which is vulnerable to floods and erosion, to grassland near the stream borders. In floodplain areas without cattle husbandry, where grass can no longer be used as green fodder, alternatively biomass from the grassland could be used for bio-energy production.

In rural areas being cultivated very intensively with agriculture, such as *Börde* areas or the northern German lowlands, suitable measures for improvement of biodiversity are especially important. Here a reduction in the nonpoint-source import of soil particles, nutrients and above all pesticides must be considered. Appropriate measures include reduction of spraying close to rivers and lakes, appropriate disposal of pesticides on farms, broader riparian buffers along streams and rivers with less intensive, unfertilised grassland management and, last but not least, conversion of conventional agriculture to organic farming in floodplain areas.

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