# Chapter 16
# Integrated approach to the conservation and restoration of Danube salmon, *Hucho hucho*, populations in Austria

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**Abstract**

The Danube salmon, *Hucho hucho*, is among the most endangered fish species in Europe. In Austria, as a consequence of river channelisation and hydropower development, only 10% of its former distribution (about 4500 km river length) harbours self-sustaining populations. This chapter focuses on the development and implementation of an integrated approach to protect and restore Danube salmon populations in NATURA 2000 areas within the EU LIFE-NATURE project. The project is located on two tributaries of the Danube in Lower Austria (rivers Pielach and Melk) that are disconnected from the latter by weirs and artificial drops blocking spawning runs. The objectives of the project are to develop, implement and monitor rehabilitation measures, in particular the re-establishment of the continuum (fish passes) and the improvement of habitat conditions (channel rehabilitation). Pre-implementation monitoring showed that the largest population of Danube salmon currently inhabits the Pielach River (21 km), with an estimated population size of 532 individuals and 162 adults. The population is divided by several migratory obstacles into six sub-populations with sizes ranging from 0 to 50 adults. In the Melk and Mank River (24 km), only 9 and 17 adults were present. Remaining populations are small and fragmented and lie close to or below requirements of minimum population sizes. Rehabilitation measures aim to provide free passage and population extensions within a Danube tributary river network of 78 km to enhance the viability of the populations and the long-term survival of the species.

Keywords: current status, Danube salmon, distribution, habitat restoration, minimum population size.

## 16.1 Introduction

The Danube salmon, *Hucho hucho* L., is one of the most endangered fish species in Europe. Austria represents the centre of its natural distribution, but hydroelectric

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power developments and river channelisation have left only a few populations. The Danube salmon is listed in Annex II of the Habitat Directive, forcing Austria to nominate protected areas and set actions for the rehabilitation of the species under the European Union (EU) NATURA 2000 network of protected areas (Habitat and Bird Directive). Within these areas, LIFE-NATURE projects, have been promoted to conserve natural habitats and wild fauna and flora of EU interest.

This chapter focuses on

(1) the description of the former and current distribution of the Danube salmon in Austria;
(2) the development and implementation of an integrated approach protecting and restoring Danube salmon populations in NATURA 2000 areas within the LIFE project 'Living space of Danube salmon' (LIFE99 NAT/A/006054; from 1999 to 2003); and
(3) the characterisation of the status of Danube salmon in the project area prior to implementation of a comprehensive monitoring programme.

## 16.2 Status of Danube salmon

The Danube salmon is the largest salmonid and one of the biggest freshwater fish species in the world (length >140 cm, weight >60 kg, age >15 years). It is a rheophilic species, spawning on gravel (lithophilic) in early spring after migrating upstream in the main river or into tributaries. Its piscivorous behaviour is well pronounced even in the juvenile stage. *Chondrostoma nasus* (L.) and *Thymallus thymallus* (L.) are its main prey fish.

Austria lies in the heart of the natural distribution of this species, endemic to the Danube catchment. Beyond Austria, larger populations within the natural zoogeographical distribution were once found in Bavaria (Germany), former Yugoslavia, Slovakia and western Ukraine, although only few of them still remain (Harsanyi 1982; Holcik, Hensel, Nieslanik & Skacel 1988; see also Freyhof, Chapter 1).

Before human alterations, the species inhabited the Austrian Danube and its larger tributaries belonging to the grayling and barbel zones over a total of >2500 km (Table 16.1, Fig. 16.1). The largest stock occurred in the River Danube and strongly depended on intact connectivity to the tributaries for spawning; it had already declined dramatically by the late 19th century (Jungwirth 1984a). The long-term viability of populations in smaller tributaries, due to their small sizes, probably relied on exchanges with other populations to maintain genetic diversity and to balance population fluctuations. According to meta-population theory, the type and intensity of connectivity between sub-populations are the decisive factors in regulating population exchange. Schmutz & Jungwirth (1999) discussed several potential meta-population structures of the former situation in Austria:

(1) a single, large, genetically homogeneous population within the Danube and separate populations within the tributaries with very limited exchange;
(2) several sub-populations in the Danube defined by their areas of reproduction within the tributaries; or

**Table 16.1** Historic distribution of the Danube salmon in Austria

| Main river | Tributary | River segment | References |
|---|---|---|---|
| Donau | | Total length | Jungwirth 1980; 1984a; Harsanyi 1982; Holcik *et al.* 1988; |
| Inn | | Mouth to Landeck | Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988; Jungwirth, Schmutz & Waidbacher 1989; Haidvogl & Waidbacher 1997 |
| | Salzach (r): Saalach, Lammer | Mouth to Mittersill | Kollmann 1898; Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988; Wiesbauer, Bauer, Jagsch, Jungwirth & Uiblein 1991; Haidvogl & Waidbacher 1997 |
| Großache | | Lower course | Kähsbauer 1961 |
| Große Mühl | | Lower course | Koller 1907; Harsanyi 1982; Holcik *et al.* 1988 |
| Traun | | Mouth to Traunfall | Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988; Haidvogl & Waidbacher 1997 |
| | Alm (r) | Lower course | Harsanyi 1982; Holcik *et al.* 1988 |
| | Krems (UA)(r) | Lower course | Jungwirth 1980; Holcik *et al.* 1988 |
| | Ager (l): Aurach, Vöckla | Lower course | Hawlitschek 1895; Koller 1907; Holcik *et al.* 1988 |
| Enns | | Mouth to Haus | Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988; Woschitz 1991; Haidvogl & Waidbacher 1997 |
| | Palten (r) | Lower course | Krafft 1874; Haidvogl & Waidbacher 1997 |
| | Salza (r) | Mouth to Fachwerk | Hampel 1882; Haidvogl & Waidbacher 1997 |
| | Steyr (l) | Lower course | Hawlitschek 1895; Kähsbauer 1961; Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988 |
| Ybbs | | Mouth to Waidhofen | Harsanyi 1982; Jungwirth 1980; Holcik *et al.* 1988 |
| | Url (l) | Lower course | |
| | Ferschnitz (r) | Lower course | Jungwirth 1984b |
| Erlauf | | Mouth to Scheibbs | Jungwirth 1980 |
| Melk | | Mouth to Oberndorf | Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988 |
| | Mank (r) | Lower course | Jungwirth 1984b |
| Pielach | | Mouth to Kirchberg | Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988 |
| Krems (LA) | | Lower course | Wedland 1965 |
| Traisen | | Mouth to Lilienfeld | Hawlitschek 1895; Jungwirth 1980; Holcik *et al.* 1988; Haidvogl & Waidbacher 1997 |

**Table 16.1** continued

| Main river | Tributary | River segment | References |
|---|---|---|---|
| Kamp | | Lower course | Anonymus 1907; Harsanyi 1982; Holcik *et al.* 1988 |
| Schwechat | | Lower course | Starmühlner 1969 |
| Mur | | Jugoslavian border to Murau | Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988; Haidvogl & Waidbacher 1997 |
| | Pöls (l) | Mouth to Pöls | Woschitz 1991 |
| | Mürz (l) | Mouth to Kindberg | Woschitz 1991 |
| | Kainach (r) | Lower course | Kreissl 1991; Woschitz 1991 |
| | Sulm (r): Schwarze and Weiße Sulm | Mouth to Brunnpolfing | Wallner 1917; Kreissl 1991; Woschitz 1991 |
| Drau | | Jugoslavian border to Lienz | Hartmann 1898; Jungwirth 1980; Harsanyi 1982; Holcik *et al.* 1988; Haidvogl & Waidbacher 1997 |
| | Isel (l) | Lower course | Hartlieb 1948; Michor 1990 |
| | Möll (l) | Lower course | Hartmann 1898; Jungwirth 1980; Holcik *et al.* 1988; Jungwirth, Moog, Schmutz & Wiesbauer 1990 |
| | Lieser (l) | Lower course | Jungwirth *et al.* 1990 |
| | Gail (r) | Mouth to Kötschach-Mauten | Hartmann 1898; Honsig-Erlenburg & Schulz 1989; Holcik *et al.* 1988; Jungwirth *et al.* 1990 |
| | Gurk (l) | Mouth to Straßburg | Hartmann 1898; Jungwirth 1980; Holcik *et al.* 1988; Jungwirth *et al.* 1990 |
| | Glan | Lower course | Jungwirth *et al.* 1990 |
| | Vellach (r) | Lower course | Hartmann 1898; Holcik *et al.* 1988; Jungwirth *et al.* 1990 |
| | Lavant (l) | Mouth to St Andrä | Hartmann 1898; Holcik *et al.* 1988; Jungwirth *et al.* 1990; Haidvogl & Waidbacher 1997 |

l, Left-sided tributary; r, right-sided tributary, UA, Upper Austria, LA, Lower Austria (compare with Fig. 16.1).

(3) the Danube functions exclusively as a habitat for sub-adults and adults (sink), while reproduction and development of larvae and juveniles take place in the tributaries (source).

As a consequence of river channelisation and hydropower development, most of the populations collapsed. Today only 10% are self-sustaining populations (based on natural reproduction and recruitment, Fig. 16.1). The largest population inhabits a 110-km reach of the River Mur between the cities of Murau and Leoben (Styria), consisting of

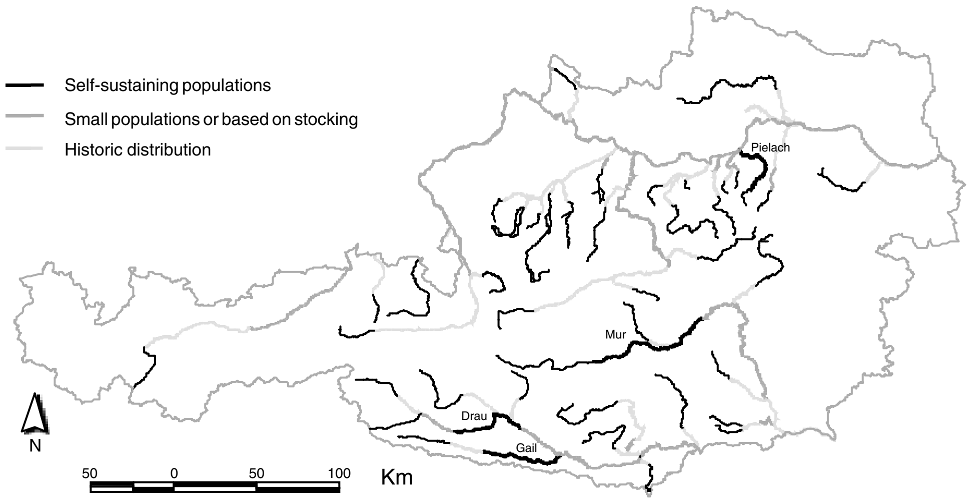


**Figure 16.1** Historic and current distribution of the Danube salmon in Austria (*cf*. Table 16.1)

about 2000 adult individuals (Kaufmann, Muhar, Raderbauer, Rathschüler, Schmutz, Waidbacher & Zauner 1991). The most reproductively viable population is in the River Pielach, which is covered by the LIFE project (see below). Smaller populations still exist in the upper River Drau and one of its tributaries (lower River Gail). All other occurrences (shown in Fig. 16.1) are based on extremely low densities and/or stocking. In the Danube, a comparably high density has been re-established by continuous stocking interventions over the last two decades, but access to former spawning areas in the tributaries is nearly completely blocked. Due to the extinction of most populations, the Danube salmon is classified as 'threatened with extinction' in Austria (Spindler, Zauner, Mikschi, Kummer, Wais & Spolwind 1997) and listed as an endangered species according to the IUCN criteria and the Bern Convention (Appendix III).

The size and abundance of Danube salmon made it a species of high commercial interest for many centuries. Nowadays it is a high-value species in recreational fisheries and is protected by strict fishery regulations. Comprehensive conservation activities started in the late 1970s with the development of artificial propagation methodologies to produce fish for stocking (Jungwirth 1979) and were followed in the 1980s by local habitat enhancements (Jungwirth, Muhar & Schmutz 1995) and building of fish passes (Jungwirth & Pelikan 1989).

## 16.3 Development of an integrated approach for the conservation and recovery of Danube salmon in a NATURA 2000 area

In Austria, the running water rehabilitation philosophy is based on the concept of Ecological Integrity (EI), the 'maintenance of all internal and external processes and attributes interacting with the environment in such a way that the biotic community corresponds to the natural state of the type-specific aquatic habitat' (ÖNORM/6232

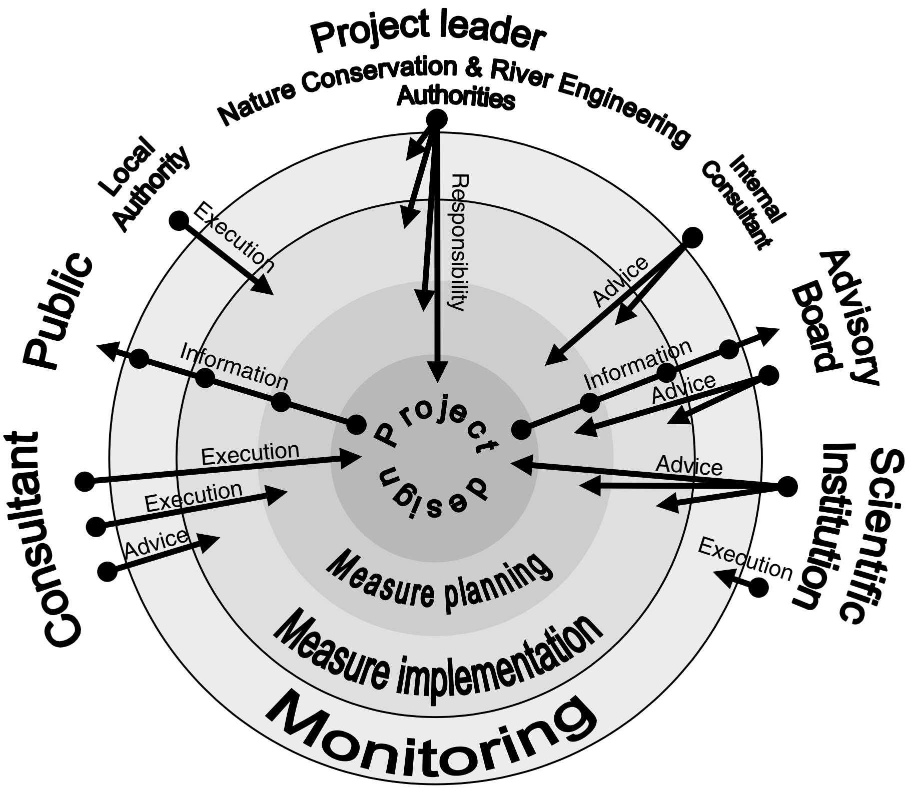


**Figure 16.2** Project design, involved parties and their functional interactions

1995; Chovanec, Jäger, Jungwirth, Koller-Kreimel, Moog, Muhar & Schmutz 2000). An interdisciplinary approach is therefore inherent in river rehabilitation methodology and is widely used in developing integrated river management plans (Muhar 1994).

The integrated approach of the project is based on an inter- and transdisciplinary network (Fig. 16.2). The regional authorities for nature conservation and river engineering co-operate as both project leaders and responsible institutions for the implementation of rehabilitation measures. Civil engineering/environmental consultants are in charge of the detailed planning of restoration measures and an NGO (WWF) is involved in wetland protection and rehabilitation activities. Together, the teams negotiate the necessary measures with landowners and users. Local authorities implement the river engineering measures through private construction companies that are supervised by the planning consultant. A scientific institute (HFA-BOKU) acts as an advisor throughout the course of the project. In addition the HFA runs the accompanying monitoring programme. Other authorities (agriculture, waste water, fishery, tourism), NGOs, and the landowners and other users are assembled in an advisory board interacting with the project team on a regular basis. As small-scale hydropower schemes are one of the major concerns, one of the hydropower operators is integrated in the project team as a consultant. Public information campaigns take place regularly in the

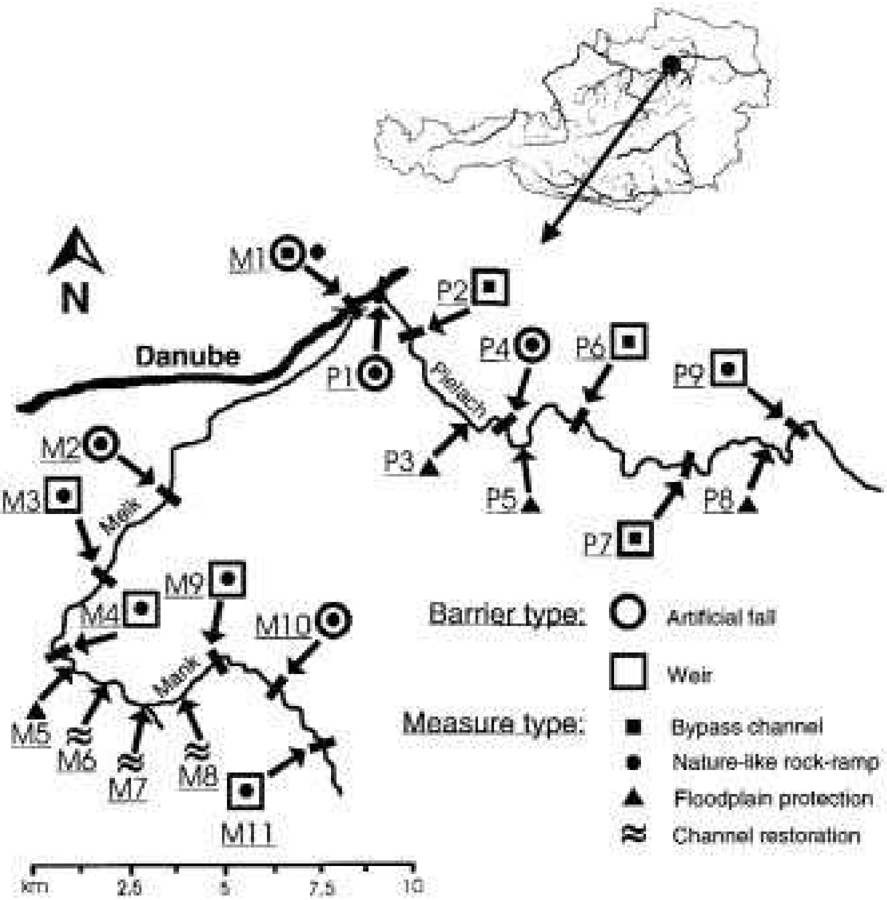


**Figure 16.3** Study area: location of migratory barriers and restoration measures (*cf.* Table 16.3)

form of press releases, folders, local presentations, excursions, etc. Hence, the integrated approach of the project is based on a balanced team of various disciplines and a functional network between authorities, executive and advisory bodies, and the public.

## 16.3.1 *Study site*

The LIFE project is located in Lower Austria and consists of a river network of a free-flowing section of the Danube (Wachau, 33 km length), the near-natural tributary, River Pielach (21 km), the channelised tributary, River Melk (16 km), and the semi-natural River Mank (8 km), a tributary of the latter (Fig. 16.3). The main characteristics of these rivers are given in Table 16.2. All three rivers are at the transition from hyporhithral to epipotamal, whereas lowland river characteristics prevail in the Melk. For example, mean summer water temperatures at the Melk are about 2°C higher (19.5°C in July–August 2000) than at the Pielach (17.5°C in July–August 2000).

**Table 16.2** Main characteristics of the rivers Danube, Melk, Pielach and Mank

| Characteristic | Danube | Melk | Pielach | Mank |
|---|---|---|---|---|
| Stream order | 9 | 5 | 4 | 4 |
| Altitude (maA) | 209–196 | 233–206 | 252–205 | 270.5–233 |
| Gradient (‰) | 0.4 | 1.6 | 2.23 | 4.6 |
| Mean flow ($m\,s^{-1}$) | ~1900 | ~3 | ~6.5 | 0.5 |
| Flow regime | Moderate nival | Nivo-pluvial | Nivo-pluvial | Winter pluvial |
| Fish region | Epipotamal | Epipotamal | Hyporhithral/ epipotamal | Hyporhithral/ epipotamal |
| Typical fish species | *Chondrostoma nasus*<br>*Barbus barbus*<br>*Hucho hucho*<br>*Leuciscus cephalus* | *Chondrostoma nasus*<br>*Barbus barbus*<br>*Hucho hucho*<br>*Leuciscus cephalus* | *Chondrostoma nasus*<br>*Hucho hucho*<br>*Barbus barbus*<br>*Thymallus thymallus*<br>*Leuciscus cephalus* | *Chondrostoma nasus*<br>*Barbus barbus*<br>*Hucho hucho*<br>*Thymallus thymallus*<br>*Leuciscus cephalus* |

The river continuum is interrupted by artificial falls as a result of river engineering measures (1–4 m height) and by weirs built for hydroelectric power production (1.2–3.5 m height). In the study area a total of 13 obstacles were identified (Table 16.3). As a consequence, former spawning runs of Danube salmon and other species are blocked at the mouth of the Melk. A few Danube salmon and hundreds to thousands of *Chondrostoma nasus*, *Barbus barbus* (L.) and *Vimba vimba* (L.) still immigrate from the Danube into the lowest section of the Pielach every year to spawn below the first larger barrier (1.6 km upstream of the mouth).

Hydropower use has a long tradition in this area and goes back to Roman times (Berger 1999). Today, large stretches in the Pielach, Melk and Mank rivers within the study area are affected by water abstraction (37%, 5%, 16%) and impoundment (15%, 26%, 11%). While the Melk and most of the Mank are channelised, the Pielach has retained some of its natural morphological characteristics, such as meandering sections, side arms, dynamic gravel bars, large woody debris and small oxbows. In addition, inundation areas and floodplain forests accompany the river along most of its course. Based on a nation-wide survey (Muhar, Kainz & Schwarz 1998), the Pielach was classified as the most nature-like, lowland river (altitude <250 m) in Austria. About one-third of its length within the project area is still in 'high' (23.6%) and 'good' (10.3%) hydromorphological condition.

## 16.3.2 *Restoration and protection objectives*

The objectives of the LIFE project are to develop, implement and monitor restoration measures between 1999 and 2003. The main focus is on re-establishing the continuum between the Danube and the tributaries and within the tributaries; the result should be

**Table 16.3** Actual situation, location (distance from mouth), height of barriers, length of stretches and type of restoration measure at the Pielach, Melk and Mank (compare to Fig. 16.3)

| River | Code | Actual situation | Distance from mouth (m) | Height, *h* and length, *l* (m) | Measure |
|---|---|---|---|---|---|
| Pielach | P1 | Artificial fall[a] | 0 | $h = 1$ | Nature-like rock-ramp |
| Pielach | P2 | Weir | 1600 | $h = 2$ | Bypass channel |
| Pielach | P3 | Nature-like stretch | 3200–5500 | $l = 2300$ | Purchase of 5 ha land |
| Pielach | P4 | Artificial fall | 5500 | $h = 1.5$ | Nature-like rock-ramp |
| Pielach | P5 | Nature-like stretch | 6300–6550 | $l = 220$ | Purchase of 1.6 ha land |
| Pielach | P6 | Weir | 8300 | $h = 3.5$ | Bypass channel |
| Pielach | P7 | Weir | 13 300 | $h = 2.5$ | Bypass channel |
| Pielach | P8 | Nature-like stretch | 15 600–17 500 | $l = 1900$ | Purchase of 5 ha land |
| Pielach | P9 | Weir | 17 500 | $h = 1.2$ | Nature-like rock-ramp |
| Melk | M1 | Artificial fall | 250 | $h = 4$ | Bypass channel + nature-like rock-ramp |
| Melk | M2 | Artificial fall | 7000 | $h = 1$ | Nature-like rock-ramp |
| Melk | M3 | Weir | 9500 | $h = 3$ | Nature-like rock-ramp |
| Melk | M4 | Weir | 12 200 | $h = 1.5$ | Nature-like rock-ramp |
| Melk | M5 | Oxbow | 13 300 | $l = 950$ | Purchase of 0.5 ha land |
| Melk | M6 | Regulated channel | 14 000–15 200 | $l = 1200$ | Channel restoration |
| Mank | M7 | Regulated channel | 15 200–15 400 | $l = 200$ | Restoration of river mouth + purchase of 2 ha land |
| Mank | M8 | Regulated channel | 15 400–16 900 | $l = 1500$ | Channel restoration |
| Mank | M9 | Weir | 17 800 | $h = 1.2$ | Nature-like rock-ramp |
| Mank | M10 | Artificial fall | 20 000 | $h = 2$ | Nature-like rock-ramp |
| Mank | M11 | Weir | 22 300 | $h = 2.5$ | Bypass channel or nature-like rock-ramp |

[a]Migration barrier at low flow condition in the Danube.

a re-connected river network 78 km long. Further objectives are to improve habitat conditions in the Melk and Mank and to protect the nature-like meandering section at the Pielach.

### 16.3.3 *Rehabilitation and protection measures*

The re-establishment of the river continuum with respect to fish migration will be realised by converting obstacles to rock ramps or circumventing them with nature-like bypass channels (measures code P1, P2, P4, P6, P7, P9 in Table 16.3, Fig. 16.3). Relevant technologies have been developed in Austria over the last two decades (Parasiewicz, Eberstaller, Weiss & Schmutz 1998) and have been successfully applied to various case studies (e.g. Eberstaller, Hinterhofer & Parasiewicz 1988; Jungwirth 1996; Mader, Unfer & Schmutz 1998; Schmutz, Giefing & Wiesner 1998).

To regain natural or at least residual flows in abstracted stretches and to supply bypass channels with adequate flows, the water abstraction rights are partly or completely taken over by providing compensation payments to the hydropower owners.

Habitat improvements will be initialised by rehabilitating the regulated Melk and Mank channel at three sites (in total about 2 km, measure code M6, M7, M8 in Table 16.3, Fig. 16.3) and further efforts will take place within the framework of continuous maintenance activities of the local water engineering authority. The rivers will be rebuilt and adapted to the former meandering shape according to the natural type-specific reference conditions; they will also be widened to regain freedom for dynamic channel developments.

Protection of the nature-like meandering section at the Pielach and its adjacent floodplains will be supported by buying about 12 ha of riparian land (Mühlau, Neubacher Au). This will enable further dynamic development of eroding banks and meanders specific to this morphological river type.

## 16.4 Monitoring programme

The objectives of the monitoring programme are to observe and evaluate the efficiency of rehabilitation measures. Accordingly, the monitoring programme focuses on the efficiency of implemented migration facilities. In addition, the populations of the Danube salmon, its main prey species, *Chondrostoma nasus* and *Barbus barbus*, and the general development of the fish community will be observed before and after implementation.

### 16.4.1 *Monitoring methods*

The development of fish populations was monitored before, and will be monitored after, the implementation of the various measures at both representative and rehabilitated sites. Prior to sampling the fish, a habitat mapping survey will be carried out to identify major mesohabitat types and spatial distributions. In 1999, 22 and 15 mesohabitats (pool, run, riffle) were sampled at the Pielach and Melk rivers, respectively, by electric fishing using the removal method. Due to electric fishing selectivity, small-sized species were excluded from estimations. Fishes $>$200 mm were tagged with VI tags and the fin clipping technique was used for Danube salmon $<$200 mm. Populations were estimated by weighting mesohabitat values proportionally to their occurrence in the specific river sections. In the River Mank, due to its small channel size and clear water conditions, a combination of visual observation and snorkelling techniques was used to assess population densities and structures of the entire study area. Further details are given in Zitek, Zobel, Schmutz & Jungwirth (2000).

**Table 16.4** Species composition of the rivers Pielach, Melk and Mank

| | | River | | |
|---|---|---|---|---|
| Family | Species | Pielach | Melk | Mank |
| Balitoridae | *Barbatula barbatula* | f | f | F |
| | *Cobitis aurata* | – | r | – |
| | *Cobitis taenia* | r | – | – |
| Cottidae | *Cottus gobio* | d | f | 0.2 |
| Cyprinidae | *Alburnoides bipunctatus* | f | f | – |
| | *Aspius aspius* | – | 0.1 | – |
| | *Barbus barbus* | 18.5 | 6.9 | 7.8 |
| | *Carassius auratus* | – | r | – |
| | *Carassius auratus gibelio* | – | 0.3 | – |
| | *Chondrostoma nasus* | 18.2 | 28.3 | 13.5 |
| | *Cyprinus carpio* | 0.9 | 0.1 | – |
| | *Gobio gobio* | f | d | 3.9 |
| | *Leuciscus cephalus* | 42.0 | 51.6 | 59.8 |
| | *Leuciscus leuciscus* | r | r | – |
| | *Phoxinus phoxinus* | d | d | D |
| | *Rutilus rutilus* | – | 2.9 | – |
| | *Scardinius erythrophthalmus* | – | 1.4 | – |
| | *Vimba vimba* | s | | – |
| Esocidae | *Esox lucius* | – | 0.2 | – |
| Gadidae | *Lota lota* | 0.5 | 0.5 | – |
| Gobiidae | *Proterorhinus marmoratus* | – | r | – |
| Percidae | *Perca fluviatilis* | 0.1 | 0.5 | – |
| | *Zingel zingel* | 0.6 | 0.02 | – |
| Salmonidae | *Hucho hucho* | 3.6 | 1.5 | 2.8 |
| | *Oncorhynchus mykiss* | 2.0 | 0.5 | 1.8 |
| | *Salmo trutta* | 1.9 | 4.3 | 3.5 |
| | *Salvelinus fontinalis* | 0.2 | 0.2 | – |
| | *Thymallus thymallus* | 11.5 | 0.8 | 6.7 |
| Number of species | | 19 | 26 | 11 |

Categories for small-sized species: d, dominant; f, frequent; r, rare.

### 16.4.2 *Monitoring results of the situation prior to measure implementation*

In total, the fish fauna of the rivers Pielach, Melk and Mank comprises 19, 26 and 11 species, respectively (Table 16.4). *Leuciscus cephalus* (L.) dominates in all three rivers, followed by *Chondrostoma nasus* and *Barbus barbus*. The lower number of species and the higher proportion of *Thymallus thymallus* in the Pielach (11.5%) and Mank (6.7%) underline their more rhithralic character compared to the Melk (0.8%).

The largest population of Danube salmon occurs in the Pielach (total number of individuals in the study area is 532) accounting for 3.6% of the total fish density (17% of total biomass). Of those, about 162 individuals were adults ( >70 cm total length). The length frequency distribution of the population showed a high proportion of

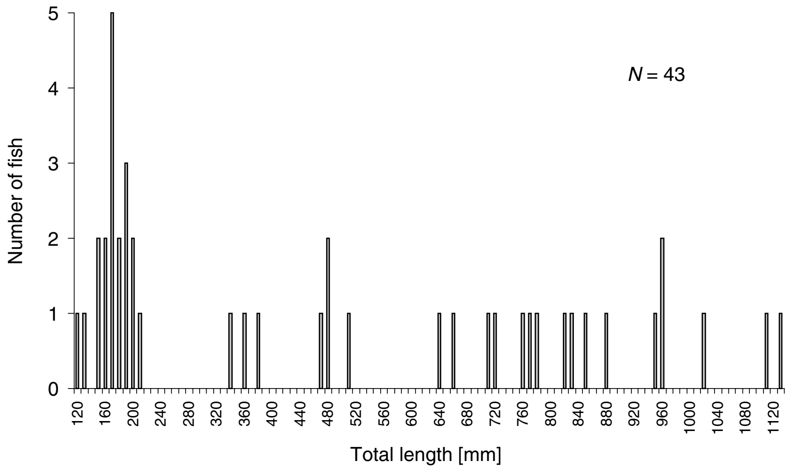


**Figure 16.4** Total length distribution of the Danube salmon captured ($N = 43$) in the Pielach River

**Table 16.5** Number of adult fish between migratory barriers in the Pielach (impoundments are excluded) (compare Fig. 16.3, Table 16.3)

| Section | 1 | 2 | 3 | 4 | 5 | 6 | Median | Total |
|---|---|---|---|---|---|---|---|---|
| Barrier code | P1–P2 | P2–P4 | P4–P6 | P6–P7 | P7–P9 | P9 | | |
| Length (m) | 1760 | 3703 | 2884 | 4918 | 4420 | 864 | 3294 | 18549 |
| Species | | | | | | | | |
| *Leuciscus cephalus* | 402 | 1235 | 710 | 1391 | 1397 | 200 | 973 | 5336 |
| *Barbus barbus* | 129 | 530 | 315 | 707 | 620 | 116 | 423 | 2418 |
| *Hucho hucho* | 0 | 47 | 24 | 35 | 50 | 6 | 29 | 162 |
| *Chondrostoma nasus* | 190 | 362 | 241 | 478 | 428 | 165 | 301 | 1864 |

0+ along with representatives of all successive size classes (Fig. 16.4). Danube salmon rarely exceeds a total length of 1 m in the Pielach. The population is divided by several migratory obstacles into six sub-populations with sizes ranging from 0 to 50 adults (median: 30, Table 16.5).

In the Melk and Mank, a total of 250 and 50 Danube salmons were present, with adults accounting for only 9 and 17 individuals, respectively (Table 16.6).

Although the estimated total population sizes of the three dominant species per river were high, the values between the barriers were below 1000 individuals except for *Leuciscus cephalus* (Tables 16.5 and 16.6). Figure 16.5 shows the length frequency distribution of the three dominant species in the Pielach. All three were dominated by large adults and showed significant deficiencies of juveniles or even a complete lack of sub-adults (*Chondrostoma nasus*).

**Table 16.6** Number of adult fish between migratory barriers in the Melk River (impoundments are excluded) (compare Fig. 16.3, Table 16.3)

| Section | 1 | 2 | 3 | 4 | Median | Total |
|---|---|---|---|---|---|---|
| Barrier code | M1–M2 | M2–M3 | M3–M4 | M4–M6 | | |
| Length (m) | 4855 | 2325 | 1728 | 2391 | 2358 | 11 299 |
| Species | | | | | | |
| *Leuciscus cephalus* | 1081 | 531 | 107 | 819 | 675 | 2539 |
| *Barbus barbus* | 34 | 0 | 144 | 829 | 89 | 1006 |
| *Hucho hucho* | 0 | 0 | 0 | 9 | 0 | 9 |
| *Chondrostoma nasus* | 501 | 239 | 621 | 74 | 370 | 1435 |

## 16.5 Discussion

The decline of fish populations and the extinction of sensitive species in cultural landscapes are rarely caused by a single human impact; they mostly involve the consequences of many activities and their complex interactions. Rehabilitation and protection strategies must target every potentially responsible party and operate within an integrated strategy. From the onset, the LIFE project strove to integrate administrative, executive, scientific and public bodies into a common approach. This represents the first comprehensive and integrated effort to restore and protect Danube salmon populations in Austria.

The main threats to Danube salmon are from hydropower development and river engineering. Rehabilitation activities should therefore focus on these issues. The project design accomplished this by giving the administrative bodies responsible for river engineering activities and for nature conservation a co-operative leadership role. Scientific knowledge is provided by a research institution that advises the project team through the planning and implementation phases and that is also responsible for monitoring the ecological effects of rehabilitation measures.

The general situation of the Danube salmon in Austria is well known, as this species receives wide publicity. A reduction to 10% of its natural distribution justifies its classification as a species ‘threatened with extinction’ (Spindler *et al.* 1997). This is underlined by there being only two large populations, one in the River Pielach, remaining. A single fish kill could easily reduce the genetic variability of the species. The risk of further population declines is high since the existing populations are fragmented by migratory barriers: this yields small, isolated sub-populations lacking the ability to balance natural and artificial population fluctuations. Access to spawning grounds in upstream areas and tributaries is prohibited by weirs and numerous artificial falls. Reduced flows caused by water abstraction for hydropower use additionally affect large-sized species such as Danube salmon that have high requirements with regard to habitat dimension. Further threats include hydropeaking and flushing of impoundments. The situation has reached the stage where even cormorant predation on the prey fish of Danube salmon is considered to be a serious threat in the few remaining populations.

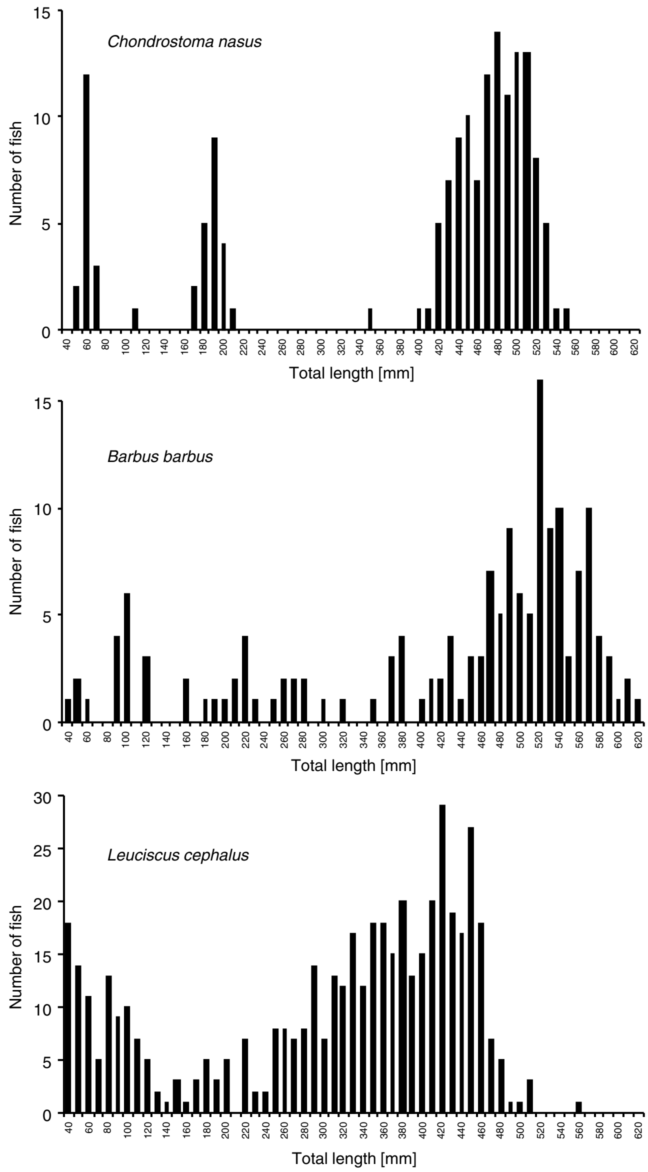


**Figure 16.5** Total length distribution of the three dominant species – *Chondrostoma nasus*, *Barbus barbus* and *Leuciscus cephalus* – captured in the Pielach River

Although the general situation of the Danube salmon is well known, detailed information about population sizes, specific threats and restoration opportunities are mostly lacking. In the original project proposal it was roughly estimated that a population size of several hundred adults existed in the River Pielach and about 50 in the Melk and Mank. This represents a considerable overestimation even if the population of the

Pielach upstream of the project area of about 60 adults is included (G. Unfer, personal communication). According to Franklin's 50/500 rule (Franklin 1980), 162 adults in the studied stretch of the Pielach lies at the lower level for minimum population size requirements. In addition the sub-division into six sub-populations of 0–50 adults is far below the above-mentioned thresholds. As a consequence, genetic variability may drop and spawning migrations and the finding of adequate mating partners may be hindered. The populations of Danube salmon in the Melk (9 adults) and Mank (17 adults) are fighting for survival, but have persisted over many years and do represent an important resource for recolonisation of rehabilitated habitats. Although piscivorous species with comparably low natural population densities, such as the Danube salmon, are more likely run the risk of approaching or falling below minimum population sizes, even abundant species such as *Chondrostoma nasus* and *Barbus barbus* can be threatened in channelised and/or multiply fragmented rivers.

The dominance of the eurytopic species *Leuciscus cephalus* in all three rivers is an indication of degradation. This species takes advantage of its more resident behaviour compared to the migratory *Chondrostoma nasus* and *Barbus barbus*, which would prevail under natural conditions.

In the Pielach the Danube salmon, accounting for about 17% of the total biomass, is probably close to the carrying capacity of the river. This assumption is supported by the target size of prey fish of adult salmon, at between 15 and 35 cm, which is significantly lacking in the population structure of the dominant prey species. Hence, the protection and rehabilitation of Danube salmon relies not only on measures directly focusing on the target species, but also on those that focus on prey species. The reaction of prey species to opening of the continuum and habitat improvements therefore also has to be of special concern.

Due to disconnection, the tributaries have lost their function as spawning and nursery areas for the Danube population. Re-opening the river continuum and observing the subsequent migratory exchange processes during the monitoring programme will demonstrate the importance of the tributaries as crucial elements of the Danube river system.

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