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OPTIONS FOR RE-ESTABLISHING RIVER CONTINUITY, WITH AN EMPHASIS ON THE SPECIAL SOLUTION “FISH LIFT”: EXAMPLES FROM AUSTRIA.

OPÇÕES PARA RESTABELECIMENTO DA CONTINUIDADE FLUVIAL, COM ÊNFASE NA SOLUÇÃO PARTICULAR “ELEVATÓRIAS DE PEIXES”: EXEMPLOS DA ÁUSTRIA.

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Abstract

The European Water Framework Directive (WFD) became a major tool in European water policy. All the member states had to develop River Basin Management Plans (RBMPs). Austria’s first National Water Resource Management Plan was published in 2009 and describes measures to be set. Depending on the catchment size, ecological targets were defined on water body level, to be reached by 2015, 2021 or 2027. A priority goal is the re-establishment of river continuity. Therefore the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management published a “Guideline for the construction of fish passes” in 2012. This paper provides an overview on measures to re-establish river continuity that were recently planned or already established at the Inn catchment, a major tributary to the upper Danube River. Planning principles, details from the construction phase and monitoring concepts as well as first results are presented. Founded in 1924, TIWAG started its business with the construction of the hydropower plant (HPP) Achensee, at the time one of Europe’s largest storage facilities. Since then TIWAG has been designing, constructing and operating hydro power plants in Tyrol. In the first river basin management cycle at three hydropower plants, located in the “priority river network” (HPP Langkampfen, HPP Kirchbichl and HPP Imst - the latter with the weir Runserau and the water intake at Wenns), measures had to be developed to overcome discontinuity. During planning phase it was tried to apply “standard solutions” according to the Austrian guideline. This was possible for three sites, where slot fish passes in combination with natural bypass channels were planned. To enable upstream migration at the weir Runserau, different alternatives were evaluated, but it was not possible to use a “standard solution”. A review about existing fish lifts was the basis for a promising solution. The chosen design combines a conventional fish migration facility (vertical slot) with a fish lift. Linked together those facilities are offering new, additional possibilities. The characteristics of this new concept and its advantages are presented.

Key words: fish pass, vertical slot, fish lift

Resumo

A Diretiva Europeia Quadro da Água (DQA) tornou-se uma ferramenta central na política europeia da água. Todos os Estados membros tiveram que desenvolver Planos de Gestão de Bacias Hidrográficas (PGBH). O primeiro Plano de Gestão de Águas da Áustria foi publicado em 2009 e descreve as medidas a serem tomadas. Dependendo do tamanho das bacias, metas ecológicas foram definidas ao nível dos corpos de água, a serem atingidas até 2015, 2021 ou 2027. Um objetivo prioritário é o restabelecimento da continuidade fluvial. Por isso, o Ministério Federal da Agricultura, Florestas, Ambiente e Gestão da Água publicou um "Guia para a construção de passagens para peixes" em 2012. Este artigo fornece uma visão geral sobre as medidas para restabelecer a continuidade fluvial que foram recentemente planejadas ou já estabelecidas na bacia do rio Inn, um importante afluente do alto rio Danúbio. Princípios de planejamento, detalhes da fase de construção e conceitos para o monitoramento, bem como os primeiros resultados são apresentados. Fundada em 1924, TIWAG iniciou suas atividades com a construção da usina hidrelétrica (UHE) Achensee, na época uma das maiores instalações de armazenamento da Europa. Desde então TIWAG tem realizado a concepção, construção e operação de usinas hidrelétricas na região do Tirol. No primeiro ciclo de gestão das bacias hidrográficas definidas por três usinas hidrelétricas, localizadas na "rede fluvial prioritária" (UHE Langkampfen, UHE Kirchbichl e UHE Imst - esta última com a represa Runserau e a tomada de água em Wenns), medidas tiveram que ser desenvolvidas para superar a descontinuidade. Durante a fase de planejamento foi tentado aplicar "soluções padrão" de acordo com a diretriz austríaca. Isso foi possível em três locais, onde foram planejadas ranhuras verticais para a passagem de peixes em combinação com canais de desvio naturais. Para permitir a migração para montante na represa Runserau, foram avaliadas várias alternativas, mas não foi possível a utilização de uma "solução padrão". Uma revisão sobre elevadores de peixe existentes foi a base para uma solução promissora. O projeto escolhido combina um dispositivo convencional para migração de peixes (ranhura vertical) com um elevador de peixes. Ligadas entre si, estas instalações estão oferecendo possibilidades adicionais. As características deste novo conceito e as suas vantagens são apresentadas.

Palavras chave: passagem de peixes, ranhura vertical, elevador de peixes

INTRODUCTION

The introduction was adopted from a recent publication, which was prepared in occasion of a meeting of the “VÖU – Verein für Ökologie und Umweltforschung” in German (SCHLETTERER *et al,* 2016).

Many fish species migrate in different phases of their life cycle, which are related to different reasons, i.e. (1) spawning migration, (2) dissemination and return migration of juveniles, (3) exploration of feeding-habitats, (4) migration towards protecting-habitats (e.g. winter/summer habitats) and (5) compensation related to drift events JUNGWIRTH *et al.* (2003). Trigger for those migrations are various factors such as currents, physico-chemical parameters (temperature, oxygen content), food availability, seasonal aspects or flood events.

The following migration types can be distinguished: ozeanodromous fish (migration patterns within the sea / saltwater), potamodromous fish (migration patterns in the fresh water) and diadromous fish (migration patterns between sea and fresh water). Within the diadromous fish it possible to differentiate sub-types:

- **anadromous**: reproduction in freshwater – e.g. Atlantic salmon (*Salmo salar*)
- **catadromous**: reproduction in the ocean – e.g. European Eel (*Anguilla anguilla*)
- **amphidromous**: alternating between sea and fresh water (brackish water) – e. g. European Flounder (*Platichthys flesus*)

These fish migrations can be exemplified with "migration-rings" (PAVLOV, 1989). In this context, the "home range" concept has to be considered, which is used for the classification of fish populations, i.e. the "home range" is defined as area in which a fish spends most of time (SCHWEVERS, 1998). Originally, the reproductive period (which triggers spawning migrations) was not considered in this concept (GERKING, 1953). Including spawning areas the "home range" becomes very large, therefore, a "core-living area" (core home range) for describing the operation radius outside the spawning season has been proposed (SAMUEL *et al.,* 1985).

In relation to the migration behaviour, long distance (diadromous fish species such as Atlantic salmon, European eel), middle-distance (potamodromous middle distance spp., as barbel, salmon, nase, lake trout) and short-distance (potamodromous short distance spp., for example, trout, roach) can be distinguished. The following examples from Austria related to re-establishment of river continuum are all dealing with potamodromous short- and medium-distance migrants. The European water policy was fundamentally reformed by the EU Water Framework

Directive (EU-WFD, 2000/60/EC). The EU-WFD was implemented in Austria in 2003 by the amendment to the Water Act 1959 (BGBl. Nr. 215/1959 i.d.g.F.) in national law. According to the WFD inland waters have to remain at least in / or have to reach good ecological status respectively potential. The approach of "stepwise achievement of objectives" (2015/2021/2027 - goals) was developed, because it would have not been possible to reach all goals by 2015, due to technical and financial reasons.

Within a hydromorphological survey, obstacles for fish passage were assessed in Austria recently: In the river network > 100 km² catchment area 3,148 (= 1 transverse structure per 3.6 km river) and in the river network > 10 km² catchment area even more than 27,000 obstacles are reported (ZITEK *et al.* 2007). Only about 10% of these not-fish-passable transverse structures can be attributed to hydropower. However, WFD objectives (achieving or maintaining good ecological status or good ecological potential) are affected by all interruptions of the continuum, because the fish passability is essential for obtaining stable fish populations (BMLFUW 2012). Therefore, the restoration of the continuity of the waters for the local fish fauna in the natural fish habitats and habitat connectivity is one of the key measures in the National Water Management Plan 2009 (BMLFUW, 2009).

Measures to re-establish connectivity

To implement the “2015 goals” the Governor of Tyrol ordained a program of measures for the rehabilitation of rivers on 01/12/2011. The restoration of passability at migration barriers in priority stretches was defined as "2015 goal", thus stipulating measures at three HPPs of TIWAG: the power plant Langkampfen, the power plant Kirchbichl and the power plant Imst (with the weir Runserau and the water intake Wenns).

HPP Langkampfen and HPP Kirchbichl are assigned to the fish region epipotamal, the weir Runserau is located in a metarhithral section (which is located in between hyporhithral sections upstream and downstream), while the water intake at Wenns is a typical metarhithral. In Table 1 we provide a characterisation of the fishways that extend over 3 biocoenotic regions (metarhithral, hyporhithral, epipotamal).

Fish pass Hirnbach (HPP Langkampfen)

The HPP Langkampfen is in operation since November 1998. In the permit, the establishment of one fish pass was prescribed by the authorities. Even two fish passes were installed (bypass channels north and south). However, during the assessments related to the National Water Management Plan 2009 - NGP 2009 (BMLFUW, 2009) it became evident that the existing fish passes had shortcomings, i.e. due to technical (flow velocities and water depths) and natural (beaver dams were blocking the channels) reasons. Thus adaption was needed. During the planning it was decided to keep the existing fish pass orographic left (bypass channel north) in its existing form with biotope as well as the beaver dams. Adaptions were carried out in the bypass channel south (orographic right), i.e. it was adjusted based on fish ecological needs. It was possible to use the existing channel of Hirnbach partially, which became connected to the main river with two vertical slots (entrance and exit). The fish pass is basically divided into the following system components:

- “entry” - vertical slot (below the weir)
- natural bypass channel - Hirnbach
- “exit” - vertical slot (above the weir)

The construction work for the fish pass Hirnbach was carried out during the low flow period in winter, i.e. between November 2014 and April 2015. This new "fish pass Hirnbach" (Plate 01) on the orographic right side replaced the two existing systems and ensures the passability at the HPP Langkampfen.

Fish pass Kirchbichl (HPP Kirchbichl)

TIWAG-Tiroler Wasserkraft AG operates the power plant Kirchbichl at Inn since its establishment in the 40-ies of the last century. With the implementation of WFD measures for fish migration and residual flow are needed. Thus a fish pass, similar to the one at HPP Langkampfen, i.e. a vertical slot in combination with a natural bypass channel is planned. The extension of the power station Kirchbichl bears the legal requirements - in terms of the restoration of fish passability - and also includes the establishment of a new, additional power house; thus it is underlying the regime of Ecological Impact Assessment (HEEL *et al.* 2013) and the process of approval is ongoing.

Table 01: Characteristics of the presented fishways, that were build according to (BMLFUW 2012)

	HPP Imst (Wenns)	**HPP Imst (Runserau)**	**HPP Langkampfen**
Fish region	metarhithral	metarhithral (with hyporhithral sections up- and downstream)	epipotamal
Fish species	Brown trout, grayling (50 cm)	Brown trout, grayling (50 cm)	Danube salmon (100 cm)
Vertical slot			
Slope [%]	6.4	6.3 / 4.2*	2.7
pool dimensions: length x width [m] (resting pool)	2.6 x 1.7 (5.2 x 1.7)	2.7 x 1.7 (-)	3.1 x 2.1 (6.2 x 2.1)
slot width [m]	0.2	0.2 / 0.37*	0.35
min. depth [m]	0.7	1.1 / 1.1*	1.1
water level drop [m]	0.18	0.18 / 0.12*	0.10
discharge [L/s]	250-450	400 / 600 *	550-650
pool volume [m³]	3.3	3.3	7.0
energy dissipation [W/m³]	<130	<130	<100
Natural bypass channel			
Slope [%]	0.3	-	0.05
width [m]	1.75	-	3.00
depth [m]	25-80	-	40-110

* upper / lower entrance (the dimensions of the vertical slot towards the lower entrance were adopted in order to bring a higher discharge to the lower entrance).

Fish pass Wenns (HPP Imst)

Another measure was set at the Pitze River, a right hand tributary of the Inn. At the weir Wenns an approximately 140 m long fish pass consists also of a "vertical slot" in combination of a natural bypass, which enables fish – in this river section mainly brown trout – to bypass the weir (**Plate 02**). In addition, the minimum flow was adapted to 600 L/s. Construction work was carried out between October 2013 and April 2014.

Fish lift Runserau (HPP Imst)

TIWAG-Tiroler Wasserkraft AG was also obliged to enable fish upstream migration on the Tyrolean River Inn at Runserau weir of the HPP Imst. The plant is existing since 1954 and the Runserau weir provides the diversion of river Inn. The reservoir level of the headwater as well as flow patterns in the tailwater are characterized by high fluctuations and also space (next to existing structures) is strictly limited, therefore common fish pass types were not applicable.

Thus the design phase was initiated by a thorough literature review on the "special solution fish lift". A summary of this review about fish lifts on a global scale was published recently (SCHLETTERER *et al.*, 2015a) and herein we provide a detailed table with fish lift facilities (n = 55) including references (Tab. 02). Mechanical fish lifts (i.e. transport of the fish cage outside of the water) can be categorized into three types: (1) a vertical lift to overcome height (most common type, **Plates 03 and 05**), (2) an inclined lift (e.g. Wyaralong Dam, Teviot Brook, **Plate 04**) and (3) a cable car (Frieira dam, Miño river, **Plate 04**). In general the principle of a fish lift (fish elevator) is considered similar to that of a passenger lift, i.e. "…*fish are attracted by a current to swim into a kind of tank",* which is periodically *"… raised up, with the fish in it. In the upper position, the tank is tilted and the water, together with the fish, is drained via a chute or pipe into the headwater. Then, the tank is lowered in the initial position and the cycle starts again.*" (FAO, 2015).

One of the first fish lifts, i.e. a 800 foot long cableway fish lift to transport collected fish in small steel tanks to the top of the dam, was operated at the Lower Baker Dam in Washington State since 1927 (BECKWITH *et al.,* 2013). In the 1930ties some fish lifts have been developed in the US and Canada to overcome high dams, since that a couple of fish lifts evolved worldwide, i.e. in Argentina / Paraguay (1), Austria (1), Australia (3), Brazil (3), Canada (3), France (12), Spain (1), Germany (2), Portugal (2), Switzerland (5), Russia (2) and the United States (20) (Table 02; some are not in operation any more, due to dam removal – e.g. at Granjean). In Europe the first facilities were installed in Russia as well as in France, where a lot a research was carried out. In general two operation schemes are applied: (1) a lift with an integrated trapping tank is used for Salmonids (e.g. Atlantic Salmon, trout) or (2) a lift with a mechanical crowder (i.e. the fish are attracted to a holding pool and with the help of a crowder [moving screen] directed into the fyke) is used in potamal watercourses, where thousands of fish are likely to use the facility (TRAVADE and LARINIER, 2002a). Some fish lifts are also used in the context of "trap and truck fish passage systems" (e.g. POMPEU and MARTINEZ, 2007) or related to monitoring activities (e.g. MEIßL, 2015). At sites with limited space, water level fluctuations and big heights, special solutions like lifts or locks evolved (TRAVADE and LARINIER, 1992, 2002; ARCADIS, 2015) and if the position of the entrance (findability) is correct, those technical solutions could be the optimal layout to overcome those obstacles.

Table 02: Compilation of mechanical fish lift facilities on a global scale

Country	Location (river)	References
Argentina/Paraguay (1)	Yacyretá-Dam (Paraná River)	OLDANI AND BAIGÚN (2002), RONCATI *et al.* (2002), MAKRAKIS *et al* (2007), OLDANI *et al.* (2007),
Austria (1)	Runserau (Inn)	SCHLETTERER *et al* (2015), OBERWALDER AND SCHLETTERER (2016)
Australia (3)	Paradise Dam (Burnett River)	WINDERS (2009), LINTERMANS (2013)
	Tallowa Dam (Shoalhaven River)	NSW DPI (w.y.)
	Wyaralong Dam (Teviot Brook)	MAHER *et al.* (2010)

Continuation

Country	**Location (river)**	**References**
Brazil (3)	Engineer Sérgio Motta Dam (Paraná River)	MAKRAKIS *et al* (2007)
	Funil-Dam (Rio Grande)	SUZUKI *et al.* (2011)
	Santa Clara Power Plant (Mucuri River)	POMPEU AND MARTÍNEZ (2006, 2007)
Canada (3)	Beechwood (St-John River)	WHITFORD (2006)
	Mactaquac Dam (St-John River)	BEAMISH and POTTER (1975), JESSOP (1990), JESSOP and HARVIE (2003), JONES *et al.* (2006), WHITFORD (2006)
	Malbaie River	BEAULIEU (1993)
France (12)	Poutès (Allier)	GRÉGOIRE and TRAVADE (1987), TRAVADE and LARINIER (1992, 2002), LARINIER and TRAVADE (2006), DE MOMBYNES-LEMÉNAGER (2007), PHILIPPART (2009)
	Golfech (Garonne)	GRÉGOIRE and TRAVADE (1987), TRAVADE *et al.* (1992), TRAVADE and LARINIER (1992), BALLERIVA and BELAUD (1998), CHANSEAU *et al.* (2000), TRAVADE and LARINIER (2002a), DELMOULY *et al.* (2007), CROZE *et al.* (2008), MIGADO (2014, 2015)
	Carbonne (Garonne)	MIGADO (2010, 2013)
	Tuilières (Dordogne)	TRAVADE and LARINIER (1992), FAO/DVWK (2002), LARINIER and TRAVADE (2006), EPIDOR (2006), DE MOMBYNES-LEMÉNAGER (2007), MIGADO (2014, 2015)
	Bergerac = Salvette (Dordogne)	DE MOMBYNES-LEMÉNAGER (2007), EPIDOR (2009)
	Castet (Gave d`Ossau)	TRAVADE and LARINIER (1992), MIGADO (2011)
	Saint Cricq (Gave d`Ossau)	MIGADO (2011)
	Baigts (Gave de Pau)	CHANSEAU and LARINIER (2001), LARINIER and TRAVADE (2006)
	Montrigon (Isère)	LOHEAC and VALLET (2007), PALUMBO (2011)
	Granjean (Loire)	PEYARD (2016)
	Grosbois (le Doubs)	HYDROSTADIUM (2013)
	Prècy-Saint-Martin (L`Aube)	MONNIER *et al.* (2013)
Spain (1)	Frieira dam (Miño river)	BUSTIO GUTIERREZ (2002)
Germany (2)	Augst-Wyhlen (Rhine)	LUBW (2007), GUTHRUF (2008)
	Geesthacht (Elbe)	MEIßL (2015)
Portugal (2)	Touvedo-Dam (Lima River)	SANTOS *et al.* (2002, 2016)
	Pedrogão-Dam (Guadiana River)	CATITA *et al* (2014)
Switzerland (5)	Grellingen (Birs)	HINTERMANN (2000)

Continuation

Country	**Location (river)**	**References**
Switzerland (5)	Magere Au (Saane)	FELLAY and ROSSIER (2007)
	Fuhren (Gadmerwasser)	MUELLER ET AL. (2013); MEYER ET AL. (2016)
	Moulinets (L'Orbe)	SUISSEENERGIE (2014)
	Eglisau-Glattfelden (Rhine)	IKSR (2009), MERKT (2016)
Russia (2)	Krasnodar (Kuban)	PAVLOV (1989), PAVLOV and SKOROBOGATOV (2014)
	Saratov (Volga)	PAVLOV (1989), PAVLOV and SKOROBOGATOV (2014)
USA (20)	Holyoke Dam [Robert E. Barrett Fishway] (Connecticut River)	BARRY and KYNARD (1986), KILLAM and PARSONS (1986), ASMFC (2008), DAVIS and SCHULTZ (2009)
	Emporia Dam (Meherrin River)	AFS (1990), QUINN (1994), ASMFC (2008)
	Essex Dam, Lawrence (Merrimack River)	MILLER (1993), BROWN *et al.* (2006), DAVIS AND SCHULTZ (2009), TCAFMMRB (2010), KEER (2011), LAWRENCE HYDROELECTRIC ASSOCIATES (2013)
	Pawtucket Dam, Lowell (Merrimack River)	MILLER (1993), KEER (2011)
	Conowingo Dam (Susquehanna River)	QUINN (1994), CADA (1998), DYBAS (1998), FERC (2004), LARINIER and MARMULLA (2004), ASMFC (2008), TRYNINEWSKI (2012)
	Cataract Dam (Saco River)	FERC (1996), FERC (2004), MDMR (2014)
	Skelton Dam (Saco River)	FERC (1996), FERC (2004), MDMR (2014)
	Holtwood Dam (Susquehanna River)	FERC (2004), ASMFC (2008), TRYNINEWSKI (2012)
	York Haven Dam [Safe Harbor fish lift] (Susquehanna River)	FERC (2004), TRYNINEWSKI (2012), SAFE HARBOR WATER POWER CORPORATION (2015)
	Greenville Dam (Shetucket River)	FERC (2004)
	Pejepscot Dam (Androscoggin River)	BROWN *et al.* (2006), FERC (2012a)
	Worumbo Project (Androscoggin River)	BROWN *et al.* (2006), FERC (2012b)
	Tunnel Dam (Niangua River)	ASMFC (2008)
	Benton Falls Dam (Sebasticook River)	ASMFC (2008), FRIEDMAN (2009)
	Burnham dam (Sebasticook River)	ASMFC (2008)
	Lockwood Project (Kennebec River)	ASMFC (2008), NextEra Energy (2010), MDMR (2014), FERC (2016)
	Winooski One hydroelectric facility [Winooski Fish Lift] (Winooski River)	GOLDFARB and AYER (2009), BROOKS *et al.* (2011)

Continuation

Country	**Location (river)**	**References**
USA (20)	St. Stephen Dam [St. Stephen Fish Lift] (Santee River)	AREGA and BADR (2010), SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES (2015)
	Milford Dam (Penobscot River)	OPPERMAN *et al.* (2011), MDMR (2014)
	Brasfield Dam (Appomattox River)	SEAGRAVE (2012)

On the basis of the literature review it was decided to start the planning process for the first fish lift in Austria. For installation of a fish pass at the existing HPP Imst that imposed certain boundary conditions, a fish lift was found to be the only feasible design. The fish lift Runserau (**Plate 5**) consists of different fish migration facilities that are linked together, with each of them focussing on separate tasks.

The first element, the "entrance structure" is primarily used for "findability of the fishway in the tailwater". In contrast to conventional pool-type fishpasses, the overcoming of height is not decisive. In this case, short vertical slot -type fishpasses are aligned in order to connect two optimal situated fishway entrances in the tailwater (KOPECKI *et al.,* 2014) with the entrance of the fish lift. Emphasis is put on the attraction flow, as it is possible to apply different attraction flow rates towards the two entrances, which enables for a wide range of flow conditions.

The second element, the "fish lift", serves to “overcome the difference in height". The lift’s topmost position can be reached regardless of fluctuating levels of the headwater with the main advantage that the total lifting height can be increased easily. Intermittent operation of the lift (every hour during the spawning period of brown trout and grayling and every 4 hours during the rest of the year) is not affecting the findability, as the entry structure is supplied continuously by residual flow. The fyke (lifting tank) has a length of 2.0 m and a width of 1.4 m; during the lifting phase the remaining water depth in the fyke is about 20 cm and the volume 480 l, thus it is meeting the recommendations of TRAVADE and LARINIER (2002a). The operating cycle of a lift with integrated trapping tank includes (1) Fish trapping phase (**Plate 6a**), (2) Tank raising and emptying phase (**Plate 6b-c**) and (3) Tank lowering phase (**Plate 6d-e**), as described in detail by TRAVADE and LARINIER (2002a).

A fish lift has the advantage that it can be built higher than the obstacle, which provides flexibility in terms of discharging fish upstream, i.e. in combination with a bypass, normally used for downstream passage. Thus the third element, in order to "overcome differences by location", is a “fish-pipe” used as a fish-flume that is inclined (1 %) against the river slope, to flush the fish in upstream direction back into the reservoir. The pipe is ending at a preferable site shortly above maximum head water level with free fall into the reservoir (SCHLETTERER *et al.,* 2015a). Although the inclination has to be accurate in order to provide sufficient flow velocity and depth, the dimensions of the pipe and its invert altitude offer flexibility in alignment and installation nearby the existing reservoir regardless ongoing operation. Therefore the fish lift Runserau could be recognized as a standard solution, i.e. a “conventional vertical slot (good findability), with continuous fyke-monitoring (fish cage / trap) in the uppermost pool and automatic discharging of the fish upstream, 600 m upstream the weir – at a suitable location”.

The fish lift Runserau is basically divided into the following system components:

- water-inlet-building in the reservoir
- water-delivery via tunnels from the intake structure to the slot and to the entrances (additional attraction flow)
- pumphouse to supply the fish-pipe
- entrance structure: "vertical slots" with distribution basins and 2 entrances.
  - 15 pools: Dh=0.12 m + Q=0.6 m³/s
  - 10 pools: Dh=0.18 m + Q=0.4 m³/s
  - auxiliary flow 4 m³/s

- fishlift: height 16.6 m
- fish-pipe (bypass): length 600 m, diameter 0.37 m, flow = 170 L/s, velocity ~ 2.5 m/s

The fish lift was built between September 2014 and December 2015. The adapted minimum flow of 5 m³/s ensures the migration corridor in the river section and also improves the habitat suitability for the aquatic benthic fauna, as well as for fish, significantly, with positive effects on the whole residual flow downstream to the powerhouse at Imst.

OUTLOOK

For the monitoring of fish passes we use the automatic fishcounter "RiverWatcher" of the Icelandic company VAKI (www.vaki.is, www.riverwatcher.is), which provides a fish-friendly (non invasive) alternative to fyke-monitoring or electrofishing, as fish are swimming through the system during their passage of the fish pass. Besides the verification of function, such a monitoring system provides valuable information about the intensity of spawning ascent as well as general migration patterns (SCHLETTERER *et al*., 2015b). In the scanner unit two consecutive light barriers (infrared) are located: each fish passage causes an interruption of individual light signals between the diode and receiver leads to a signal. The height of each fish is measured by the system and also the swimming direction as well as speed can be determined. With the maximum height (in front of the dorsal fin), the software calculates the length of every fish based on species specific height/length ratio. The data is stored with a time stamp and characteristic fish silhouettes can be analyzed on the computer. In species-rich water bodies in addition to the scanner unit a camera tunnel is used, which enables the determination of species.

For more information on environmental measures and details about the fishways at TIWAG hydro power plants, see http://wasserkraftausbau.tiwag.at/oekologie/.

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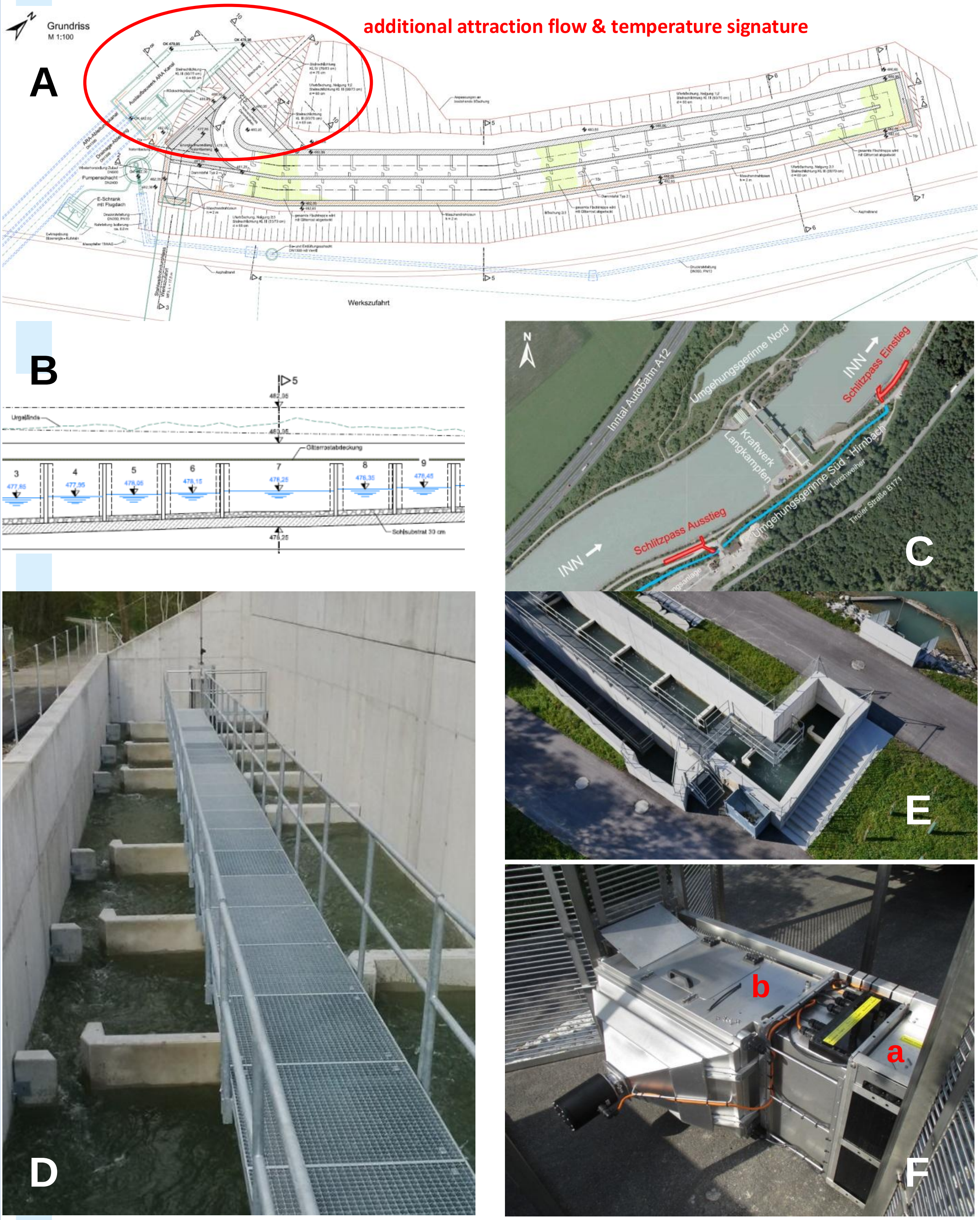

Plate 1: Fish pass “Hirnbach” at HPP Langkampfen: site plan (A) and longitudinal section – including a “resting pool” (B) of the vertical slot below the weir. The schema (C) shows the location of the vertical slots (“entry” and “exit” in red) and in between the natural bypass channel. D - provides a view on the vertical slot (upstream the weir), E - is a view on the “exit” with a boom to avoid debris loading and F - shows the monitoring system “VAKI Riverwatcher”, with the (infrared) scanner unit (a) and camera tunnel (b).

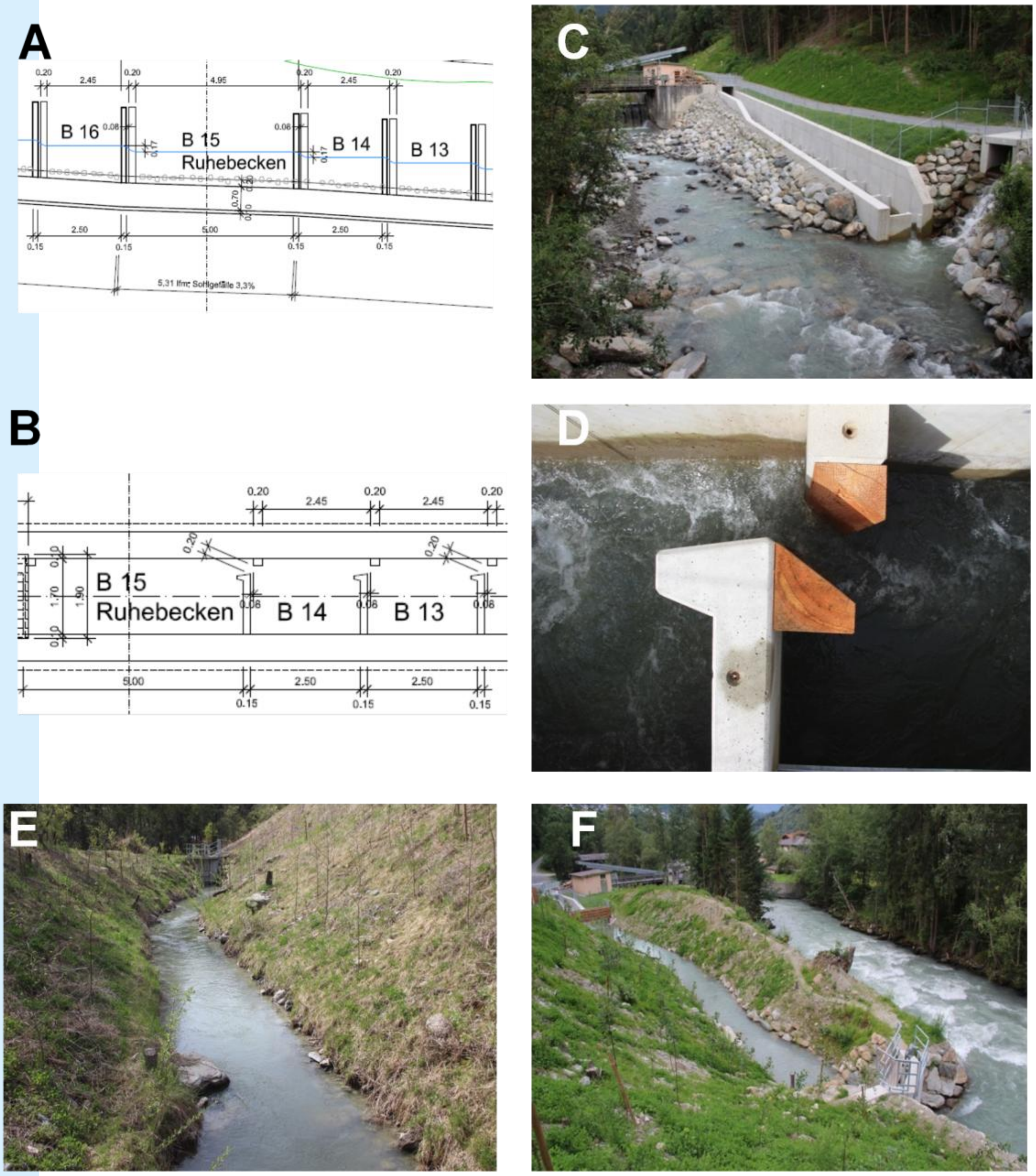

Plate 2: Fish pass “Wenns”, a weir of the HPP Imst: A vertical slot with 28 pools overcomes the height (C); details are available on the site plan (A) and the longitudinal section (B) – both of the sketches show usual pools as well as the “resting pool” B15. The trial operation revealed low water depths, which was overcome with wooden applications at the cross-wall (with hook-shaped projection) as well as the deflecting blook (D). The vertical slot fishway leads into a natural bypass channel (E + F), which connects to the main river.

Plate 3: “Standard” construction of a fish lift, e.g. the fish lift at Grellingen in Switzerland (A) and Europe`s largest fish lift at the Pedrogão dam in Portugal (B, tower and a detail view on the fyke).

Plate 4: Photos of special lift solutions: A + B the inclined fish lift at Wyaralong dam (from: Richard Herweynen, Hydro Tasmania), as well as C + D - photos of the inclined fish funicular at Frieira dam (from: António Pinheiro, Instituto Superior Técnico - University of Lisbon).

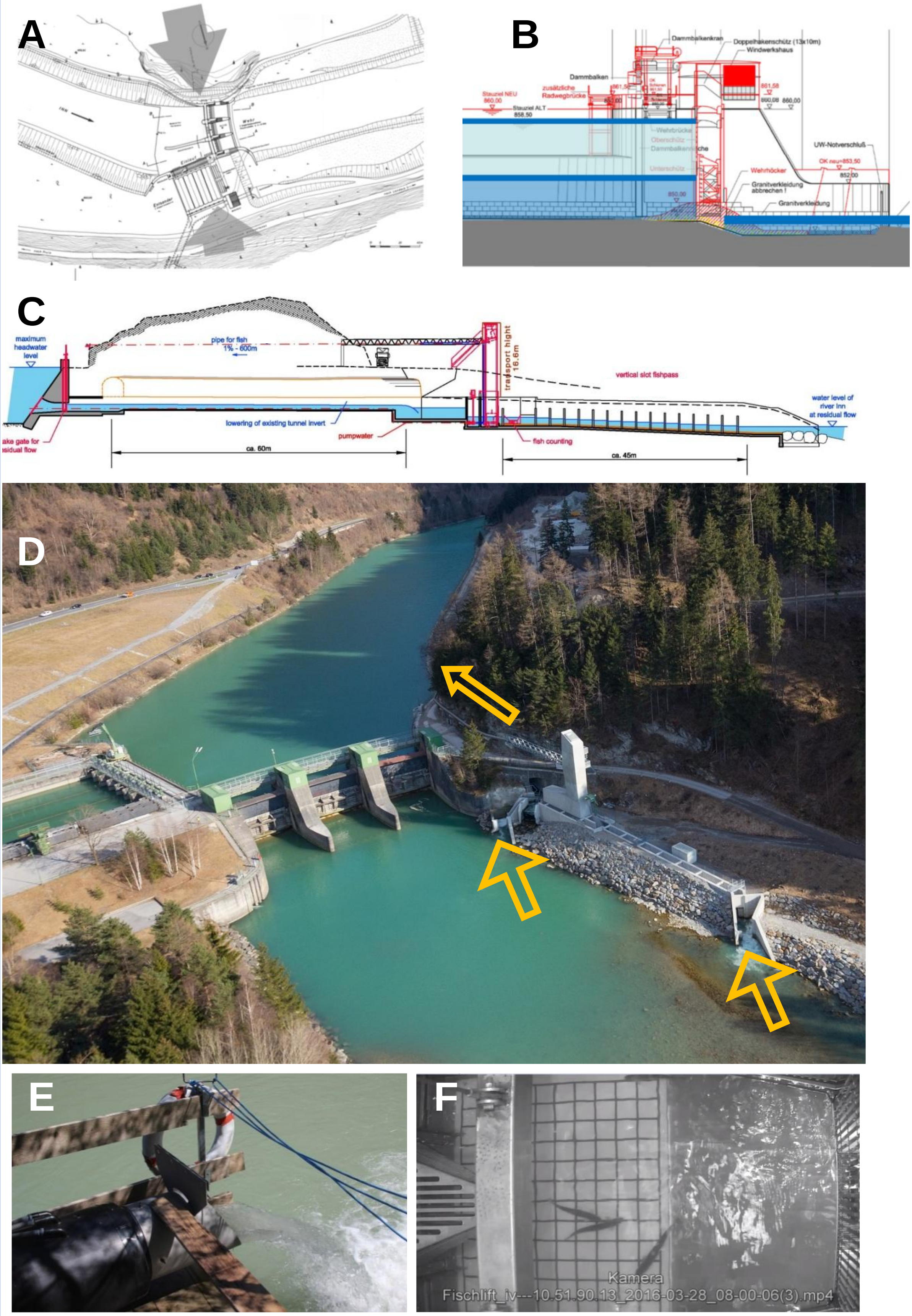

Plate 5: Fish lift “Runserau” at the main intake of the HPP Imst: Plan and section of the existing weir (A), longitudinal section – indicating water level fluctuations in the headwater (B), aerial view of the fishlift with entrances in the tailwater, the lift itself, the fish-pipe exiting the lift 6 m above the max. headwaterlevel (D) and outlet of fish pipe 600 m upstream of the weir (E). Cameraview into lifted fyke with three fish (trout) inside (F).

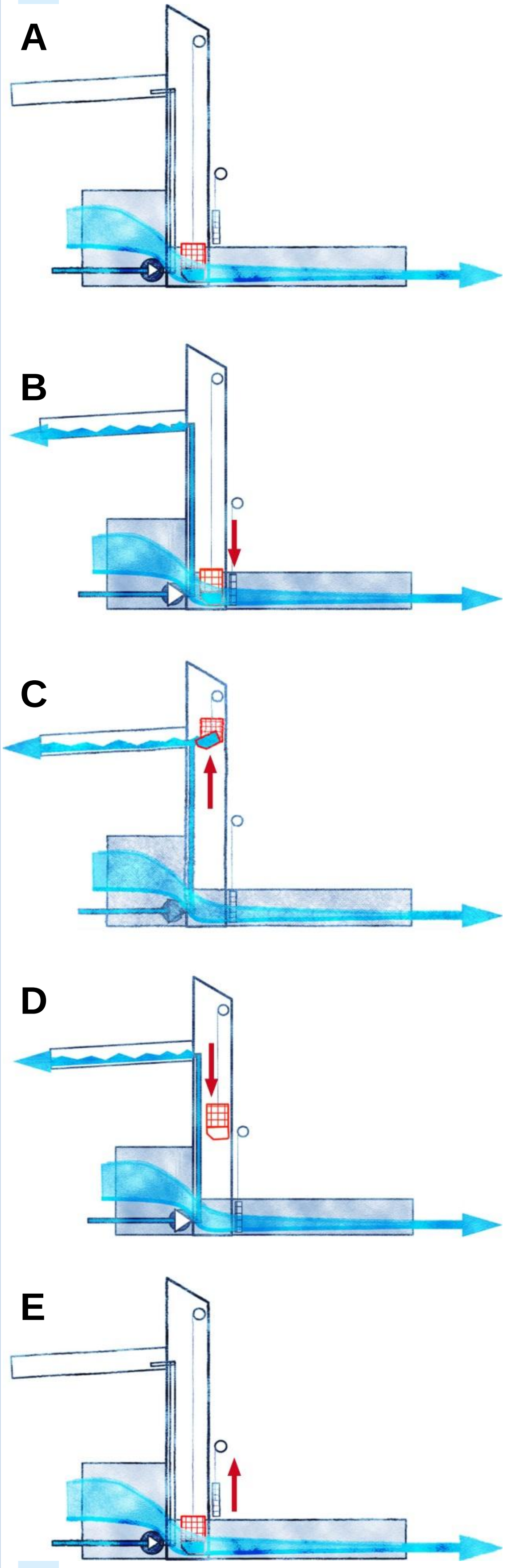

Plate 6: Functional principle of the fish lift Runserau: (A) trapping position - fish can swim from the vertical slot into the fyke (fish cage and tank), (B) gate (moving screen) in front of the fyke closes and the fish-pipe is filled with water, (C) lifting of the fyke and tilt in the uppermost position to release fish into the fish-pipe, (D) while the lowering of the fyke takes place, still water is pumped to the fish-pipe (to ensure that all fish reach the headwater) and (E) again in trapping position, the gate opens and the cycle starts again.