Fact Sheet 04 EN
June 2021

Technical functionality of large fish protection screens confirmed in practice

Operational experience with large screen systems

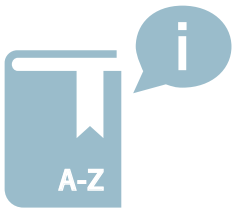
F O R U M
FISCHSCHUTZ
& FISCHABSTIEG

Key messages

» The statement of the German Forum on Fish Protection & Downstream Migration that the current state of knowledge and technology allows functional fish protection screens at hydropower sites (up to approx. 50 m³/s discharge per screen) to be realised, is confirmed. They can be operated to protect fish larger than 10 cm and include the necessary cleaning technology.

» The use of screen cleaners with tooth- or brush-like elements can avoid problems with permanent congestions of fish protection screens with small bar spacing.

» Planning, design, and technical implementation of fish protection screens and screen cleaning are of major importance for the functionality of the hydropower site.



Definition of fish protection screen

A screen that blocks the migration corridor towards the turbine without causing damage to the target stages of the target fish species and guides them to bypass inlets due to its angular flow, is a fish protection screen.

Background

As a result of intensive and ongoing discussions in the German Participatory Forum on Fish Protection and Downstream Migration, a mutual understanding was reached in 2014, up to which screen size a functioning mechanical fish protection and bypass system including the necessary cleaning technology can be realised (Forum Fischschutz & Fischabstieg 2015, p. 36).

Common statement of the forum

With vertical screens (up to approx. 30 m^3/s per screen) and horizontal screens (up to approx. 50 m^3/s per screen) there is currently a state of knowledge and technology with which functional, mechanical fish protection and bypass systems, including the necessary cleaning technology, can be realised for fish larger than 10 cm.

(Source: Empfehlungen und Ergebnisse des Forums Fischschutz & Fischabstieg 2015)

The discharge values mentioned do not refer to the total discharge of the hydropower site, but to one screen panel each. The above-mentioned statement of the German Participatory Forum on Fish Protection and Downstream Migration refers to the purely technical feasibility in the sense of a safe operation of screens including screen cleaning with a discharge of up to 50 m^3/s and a bar spacing of 10 mm. This Fact Sheet is dedicated to this aspect. Additionally, fish protection screens with larger bar spacing are also considered. The question of how effective fish are guided by screens and transferred to tailwaters is addressed in Fact Sheet 05 EN.

Installed screens reach the sizes mentioned by the German Participatory Forum on Fish Protection and Downstream Migration

This Fact Sheet is based on research that aimed to examine whether the statement of the German Participatory Forum on Fish Protection and Downstream Migration is confirmed in the realistic operation of existing fish protection screens. It has not been assessed here whether fish is safely guided and transferred by the fish protection systems (see Fact Sheet 05). The technical functionality was first evaluated at hydropower sites with fish pro ENtection and bypass systems of the respective

size. The atlas of the German Participatory Forum on Fish Protection and Downstream Migration, which is presented in Fact Sheet 06 [German], is helpful for this.

Fish protection screens in Germany with currently highest discharge per screen panel

Bar spacing	Vertical screen			Horizontal screen		
	Name	Discharge per screen panel	Number of screen panels	Name	Discharge per screen panel	Number of screen panels
10 mm	Willstätt	25 m³/s	1	Öblitz	48 m³/s	1
	Unkelmühle	6,0 m³/s 10,5 m³/s	1 2			
15 mm	Mihla	21 m³/s	2	Muldestausee	69 m³/s	1
				Kemnade	35 m³/s	1
20 mm	Kostheim	80 m³/s	2	Raguhn	88 m³/s	1
				Planena	50 m³/s	1

Source: Ingenieurbüro Floecksmühle GmbH 2021

The largest hydropower sites in Germany equipped with a vertical screen (**10 mm**) currently include the Willstätt hydropower site on the Kinzig river and the Unkelmühle power plant on the Sieg river. Looking at the discharge per screen panel, Willstätt has the highest discharge with 25 m³/s. The screen is thus somewhat smaller than the 30 m³/s postulated by the German Participatory Forum on Fish Protection and Downstream Migration.

The largest horizontal protection screen with 10 mm bar spacing is currently installed at the Öblitz hydropower site on the river Saale. It has a discharge of 48 m³/s, i.e., almost 50 m³/s. Horizontal screens have so far only been built in Germany with one screen panel or with two screen panels arranged in a V-shape with a bypass between the turbines.

Screen panels with bar spacing of more than 10 mm are less susceptible to accumulate debris and can therefore be subjected to higher discharge rates. With a bar spacing of **15 mm**, a vertical screen follows at the Mihla hydropower site on the river Werra with 21 m³/s per screen panel and two horizontal screens with 69 m³/s at the Muldestausee and with 35 m³/s at the Kemnade hydropower site on the river Ruhr.

Large screens with a bar spacing of **20 mm** have been realised in many locations. The Kostheim hydropower site on the river Main has a discharge of 80 m³/s per screen panel (vertical approach flow) and Raguhn on the river Mulde has a flow of 88 m³/s for a horizontally angled screen panel. Planena, with a discharge of 50 m³/s, is also one of the larger sites.

Unkelmühle, Muldestausee and Öblitz have the largest screen sizes

The discharge is a suitable measure to estimate the approximate size of a hydropower site and the associated screen. However, other dimensions are important for the planning, construction, and operation of the screen. The maximum possible dimensions result, apart from the requirements of the fish, primarily from the performance of the screen cleaning machines.

For vertical screens, the screen bar length is relevant which results from the water depth and the inclination of the screen. The screen bar length determines the length of the cleaner arm. Since the cleaner must exert a certain pressure on the screen, limits are given here. The cleaning interval or the cleaning speed is also relevant. Screens with small bar spacing need to be cleaned more frequently than screens with wider bar spacing. In continuous operation, the screen cleaner must be able to clean the screen reliably, which is more difficult with longer bar lengths. Amongst the vertical screens listed above, Unkelmühle (10 mm bar spacing) has the largest bar length and thus cleaning length of approx. 8.10 m.

Lifting screen cleaner on the horizontal screen of the Planena hydropower site

Photo: Ingenieurbüro Floecksmühle GmbH

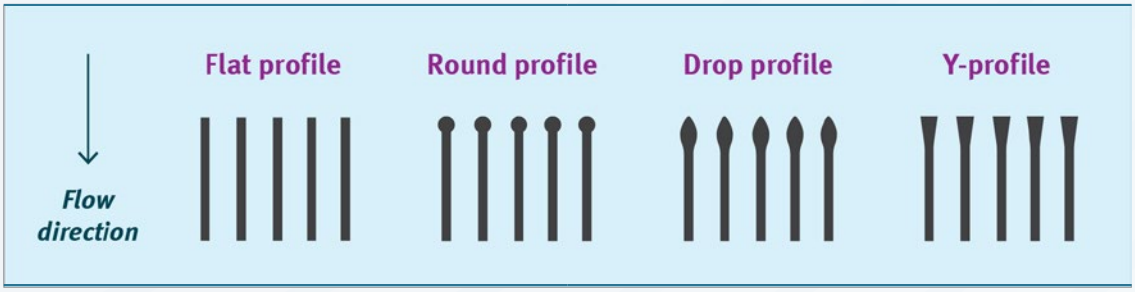
With horizontal screens, the width and the water depth are the limiting dimensions. The debris is pushed by the screen cleaner towards the tailwater. Many horizontal screen cleaners are only mounted on top. While retracting, the screen cleaner is lifted off the screen and moved to the starting position. The larger the screen, the more debris the cleaner must push in front of it. For large water depths, manufacturers offer top and bottom mounted screen cleaners to exert sufficient pressure on the screen. For horizontal screens, the largest known width built in Germany so far is 51.9 m (Muldestausee, 15 mm bar spacing) with a water depth of 3.7 m. The largest water depth is 8.10 m with a width of almost 28 m (Öblitz, 10 mm bar spacing).

Screen cleaning also serves to protect fish

Small bar spacing causes the screen to become clogged with debris more quickly. To counteract this, particularly flow-optimised screen bar shapes are used, and attention is paid to a high cleaning performance of the screen cleaning system.

Flow-optimised screens serve fish protection and power production

Examples of screen bar shapes for fish protection screens at hydropower sites



Small screen bar spacing for better fish protection also causes the screen to become clogged with debris more quickly, which can impair the operation of the hydropower plant. To counteract this, particularly flow-optimised, round, drop-shaped or Y-shaped screen bar shapes are used, as well as combinations of these shapes. Furthermore, high-performance screen cleaning is indispensable.

Source: modified after Bollrich & Preissler 1992

Cleaning the screen not only serves to maintain the operation of the hydropower site, but also to protect the fish. The approach flow velocity is more even and lower with clean than with blocked screens, thus reducing the risk of fish being pressed against the screen. Different cleaning systems are used for cleaning, depending on the bar alignment, the available space and the lifting depth. Control and monitoring of the cleaning machine can be automatic or manual. In “winter operation”, the functionality of the hydropower plant is maintained even at low temperatures and when ice forms, and damage to the system is avoided. The cleaning intervals are flexibly adapted to the respective requirements by the system control depending on the season, discharge conditions and operating status.

The cleaning elements of the screen cleaning machine can either be designed as rakes that grip between the bars, or as brushes or polymer strips that rather sit on the outside of the bar and brush along it. The manufacturers of screen cleaning machines offer fully automatic, site-adapted systems.

Technical functionality can be guaranteed for all realised screen types and sizes

To obtain information on the technical functioning of the realised sites, interviews were conducted with the operators of four sites (2020). Since the experiences are extremely site-dependent, the examples of Willstätt, Unkelmühle, Kemnade and Öblitz are presented individually below.

Key data of the screen systems at the Willstätt, Unkelmühle, Kemnade and Öblitz hydropower sites and Öblitz hydropower sites

Location spacing	Willstätt	Unkelmühle	Kemnade	Öblitz
Discharge per screen panel	25 m^3/s	2 x 10,5 m^3/s 1 x 6 m^3/s	35 m^3/s	48 m^3/s
Screen type	Vertically angled screen	Vertically angled screen	Horizontally angled screen	Horizontally angled screen
Number of screen panels	1	3	1	1
Width of screen panel	13,00 m	2x 5,20 m 1x 3,60 m	51,90 m	27,60 m
Height of screen panel	7,50 m	8,10 m	3,85 m	6,60 m
Bar length	7,50 m	8,10 m	51,90 m	27,60 m
Screen area	97,5 m^2	113,4 m^2	200 m^2	182 m^2
Inclination	30° to the horizontal	27°	not specified	38° to the power plant axis
Bar shape	Rounded profile	Drop and bar profile	Alternating flat and round profile	Drop profile
Bar spacing	10 mm	10 mm	15 mm	10 mm

Source: Ingenieurbüro Floecksmühle GmbH 2021

Willstätt

In 2010, a new hydropower site with a fish protection system and upstream fish migration facility was built in Willstätt on the Kinzig river. The fish protection system consists of a vertically angled screen with a bar spacing of 10 mm, a collection channel near the surface that also serves to remove finer debris, and a bypass to guide the fish into the tailwater. Above the water surface, the screen has a bar spacing of 300 mm. The wider and the finer screen are separated by a sheet metal apron, which has inlets for downstream fish migration.

An articulated arm cleaner with a cleaning bar made of hard plastic is used to clean the screen. Various programmes (standard, leaf, fish protection, ice programme) are stored in the control software of the screen cleaner. In the fish protection programme, for example, the cleaner is slowly moved upwards and lifted off the screen a few decimetres before the water surface so that fish can escape. The cleaning process is then continued.

Further information on the Willstätt site can be found in the Atlas Fish Protection & Downstream Fish Migration at: forum-fischschutz.de/willstätt [German]

Screen with screen cleaner at the Willstätt hydropower site

Photo: Ingenieurbüro Floecksmühle GmbH

Operating experience Willstätt

From the operating staff's point of view, the screen cleaner works well. Sheet metal plates welded to the spacer sleeves of the screen for better cleaning has proven to be problematic. Fibres, grass, and sand get caught on these plates and form a solid conglomerate that can no longer be removed by the screen cleaner. According to the operating staff, smooth operation would be possible without the welded-on plates.

In addition, the mechanical stress on the screen reveals weak points in the galvanisation. In some places this leads to rust dents, which cause a narrowing of the bar width, which in turn leads to a stronger congestion of the screen. At the Öblitz site, this effect was counteracted with cathodic corrosion protection.

Unkelmühle

The Unkelmühle hydropower site on the river Sieg was converted into a pilot site for fish protection from 2011 onwards to enable fish to ascend and descend at this site. In the inlet area of each of the three turbines, vertically angled fish protection screens with 10 mm bar spacing were installed, as well as a new screen cleaning system. Several bypass openings were installed at the upper edge of the screen, through which the fish first reach a bypass and then the tailwater.

Because of the pilot character of the site, three different screen bar profiles were installed: a drop profile, a Y-profile, and a screen with alternating Y- and bar profiles. Three articulated arm cleaners with a plastic cleaning bar are used for cleaning. While the bar rests on the screen, an additional brush takes care of the cleaning between the bars (MULNV NRW 2019).

Further information on the Unkelmühle site can be found in the Atlas Fish Protection & Downstream Fish Migration at: forum-fischschutz.de/unkelmühle [German]

Operating experience Unkelmühle

The same metal sheet plates were welded to the spacer sleeves on the screen of the Unkelmühle hydropower site as in Willstätt. Here, too, the plates intensified screen congestion. For this reason, the middle screen panel was replaced with a drop profile without the aforementioned plates on the spacer sleeves, as the Y-profile used additionally increased congestion of the screen. This measure has led to a considerable improvement in the cleaning operation. The inspection gates in front of the screens have proven to be useful. They allow manual cleaning at short notice and without the use of divers after the screens have been fully clogged, and therefore downtimes can be reduced. The problem with galvanisation, as observed in Willstätt, is also observed in Unkelmühle.

The operational experience from the pilot project confirmed that planning, design and technical implementation of the screen and screen cleaning contribute significantly to its functionality.

Clogged screen at the Unkelmühle hydropower site

Photo: Ingenieurbüro Floecksmühle GmbH

Kemnade

The Ruhrverband operates the Kemnade hydropower site on the river Ruhr, completed in 2011. A 15 mm horizontal screen is installed for fish protection. To avoid congestion, flat and round bar profiles have been arranged alternately. The weir flap, which is temporarily open, is used as a near-surface bypass, through which the floating debris is also discharged. In addition, a near-bottom bypass was installed to support eel migration. A telescopic arm cleaner mounted on a rail vehicle is used for screen cleaning. It is equipped with a rake that reaches between the screen bars.

Further information on the Kemnade site can be found in the Atlas Fish Protection & Downstream Fish Migration at: forum-fischschutz.de/kemnade [German]

Screen with flat and round profiles

Photo: Stephan Heimerl

Operating experience Kemnade

According to statements by the operating staff, the cleaning works well, but not very well. Congestions due to waterweeds (Elodea) that occurs in the river Ruhr prove to be problematic. A baffle is to be installed as additional protection.

Öblitz

In September 2017, the Öblitz hydropower site on the Saale was equipped with a fish protection system according to Ebel, Gluch & Kehl (cf. Ebel et al. 2015). A horizontally angled screen with a bypass at the downstream end of the screen was put into operation. The clearance of the horizontally arranged screen bars is 10 mm and a drop profile was chosen as the bar shape. To further reduce the screen losses, every second bar was notched on the downstream side, thus reducing the bar depth from 60 to 30 mm. The screen bars were not mounted on tie rods with spacer sleeves but were welded to vertical comb-like elements on the downstream side. The screen cleaner was equipped with teeth to completely cover the area between the bar heads that is susceptible to clogging, thus eliminating the possibility of permanent congestion. During the production and assembly of the screen panels and cleaning machines, attention was paid to precise design to ensure a good fit between the bar gaps and the cleaning teeth (Kehl et al. 2021).

Further information on the Öblitz site can be found in the Atlas Fish Protection & Downstream Fish Migration at: forum-fischschutz.de/öblitz-bei-goseck [German]

Operating experience Öblitz

Based on 3 years operational experience for the Öblitz hydropower site, the operators have found that horizontal screens with 10 mm bar width are suitable for a discharge of at least 50 m³/s per screen panel, even on overflowing hydropower plants. For non-overflowing hydropower sites, even more favourable operational characteristics can be expected, provided that the screen platform is combined with a baffle (Kehl et al. 2021). Information on the investments for the fish protection system can be found in a paper by Ebel et al. (2018).

Sample of the 10 mm screen with rake of the hydropower site Öblitz

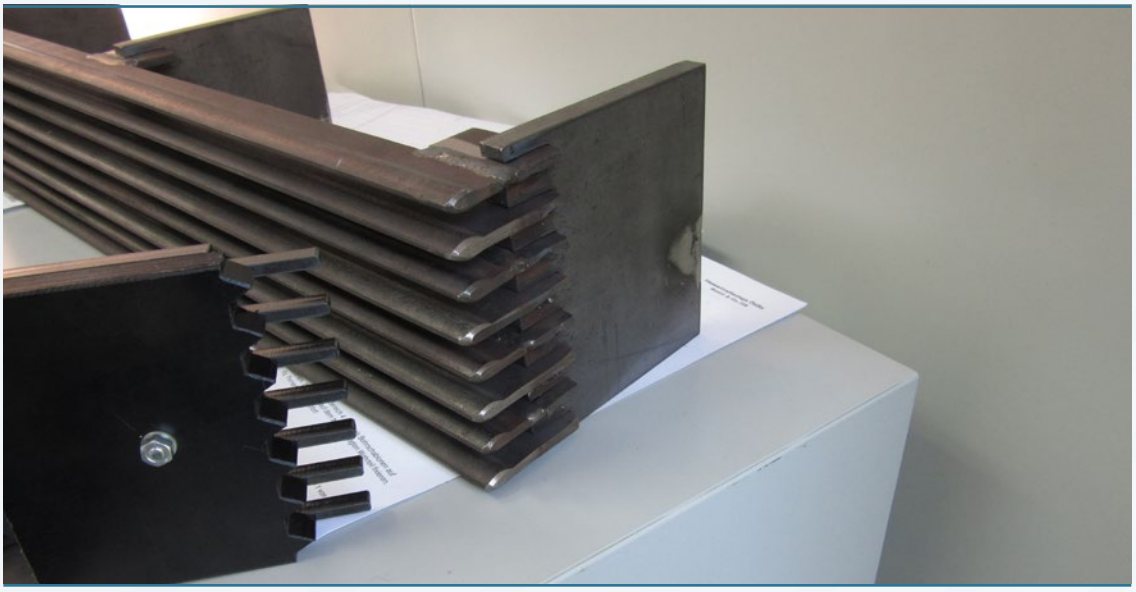


Photo: WKA Öblitz GmbH & Co KG

Summary result

It could be confirmed that there are currently functioning vertical fish protection screens up to 30 m³/s discharge per screen panel and horizontal fish protection screens up to 50 m³/s discharge per screen panel, including the necessary cleaning technology and suited for the protection of fish larger than 10 cm. Although the risk of clogging increases as the bar spacing decreases, bar widths of 10 mm are suitable for operation. The problems described with the cleaning of the vertical screens are due to the welded plates and are not to be expected without them. Operational experience with the systems shows that safe operation is possible if special attention is paid to the compatibility of screen bar profile and high-performance screen cleaning during planning, design, and technical implementation. In this respect, from a purely technical point of view, a functioning fish protection technology is available for most hydropower sites in Germany.

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Photo: Ingenieurbüro Floecksmühle GmbH, installing a fish protection rake at the hydropower plant in Roermond on the river Rur.

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About the German Participatory Forum on Fish Protection & Downstream Migration

The German Participatory Forum on Fish Protection & Downstream Migration is a series of events that serves to exchange information and experiences on fish protection and downstream fish migration from a professional point of view across interests. In the context of the forum, fish protection is understood to be plant-related fish protection and not the general protection of fish to preserve the population and the species.

The Forum was founded by the German Federal Environment Agency in 2012. It is funded within the framework of the Environmental Research Plan of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

More information on the forum, on the results of the workshops, on fish protection and fish descent facilities as well as on research projects is available at: www.forum-fischschutz.de [German].