Drawing up a catalog of criteria for special solutions for fish passages based on the DWA-M 509 leaflet

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Abstract

The preservation of water bodies continuity is fundamental for aquatic communities, particularly for fish populations. Various structures impede watercourse continuity, impacting fish migration and habitat distribution. Conventional fish passages often fall short in diverse scenarios, prompting the development of specialized solutions. This article proposes a criteria catalog for these special fish passage solutions based on DWA leaflet DWA-A 509. It discusses the need for these solutions, presents a selection of specialized options, and outlines criteria from DWA-M 509, construction guidelines, and economic perspectives. It scrutinizes criteria ranging from target fish species to cost considerations. Three examples, including the Runserau fish lift, the bristle ramp fish lock, and the Fishcon sluice, illustrate these specialized solutions, their functionalities, advantages, and drawbacks. Additionally, the article compiles criteria from industry standards and guidelines into a comprehensive evaluation catalog. The criteria, when applied, assist in the selection of suitable fish passage solutions based on specific site conditions and fish species requirements. This holistic approach aims to optimize fishway selection, fostering the ecological sustainability of watercourses. However, this catalog remains dynamic and open to expansion with evolving research and practical application, urging further exploration and validation of these criteria through diverse case studies and technological advancements in the field.

Keywords: Fish passages, Criteria catalog, DWA-M 509, Special solution , Forms of evaluation

1 Introduction

The introduction of the European Water Framework Directive not only gives greater importance to the ecological status of water bodies. It also emphasizes continuity as a fundamental prerequisite for the development of specific aquatic communities. [1] The continuity of water bodies is of great importance for fish. In some cases, fish benefit from the change of location through targeted migration. They can make the best possible use of the resources in their habitat and the population density is optimally distributed between suitable habitats. If watercourses are not passable, this leads to a lower population density and a change in species composition. [2] The continuity of watercourses can be interrupted by a wide variety of structures with different functions and constructions [1]. This is where fish passages can provide a remedy. Conventional fish passages cannot be used in every site-specific situation. In recent years, various special solutions for fish passage have therefore been developed and successfully implemented. [1] In order to provide an overview of the special solutions for fish passage and to be able to classify and use them more specifically, this article deals with a possible list of criteria for special solutions for fish passages based on the DWA-A 509 leaflet.

2 Material and Methods

In the following chapters, the necessity of special solutions for fish passages is discussed first. A selection of special solutions for fish passages is then presented, along with criteria from the DWA-M 509 leaflet used, criteria from the guidelines for the construction of fish passage and criteria from an economic perspective. The criteria presented are then compiled in a criteria catalog and an evaluation form is drawn up. At the end of the article, the catalog is applied using the example of the two evaluation forms and ends with a conclusion and an outlook on the establishment of a possible criteria catalog for special solutions for fish passages based on the DWA-M 509. The creation and the evaluation of the criteria catalog is limited to the German-speaking countries in this article.

3 Presentation of special options for fish passages

This article presents a selection of special solutions in brief. Three of the special solutions out of the fol-

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lowing list are described below. The special solutions for fish passage are used when standard forms of fish passage are not appropriate or effective. Reasons for inadequate performance of standardized fish passage may include the following :

- height difference [1]
- availability [1]
- estuary/entry situations [3]
- high water velocities [4]
- water level fluctuations [1]
- more ecological design [3]
- costs [4]

Special solutions are used when the standard forms of fish passages are not able to adequately meet the specific conditions of a body of water or the needs of the fish species living there. They form solutions that are tailored to more difficult requirements in order to maximize the efficiency and effectiveness of fish passages. Special solutions for fish passages include the following constructions:

- Multi-structure fish pass [1]
- Fish ladder screw [1]
- Modified denil pass [1]
- Fish lift [1]
- Fish lock [1]
- Double-slot pass [5]
- Combined fish lift system [1]
- Two-chamber fish lift [1]
- Bristle ramp fish lock [6]
- Bristle fish pass [6]
- Super-active baffle pass according to Larinier [6]
- Fish canoe pass [6]

3.1 Runserau fish lift as an example

The way fish lifts work is very similar to that of a passenger elevator. The cage, which contains a water-filled tub, is similarly to an elevator car and is moved from a starting point to an end point. [1]

Fish lifts are characterized by a movable lifting basket in which the fish are transported from the level of the lower water to the level of the upper water. [7] Fish lifts can be divided into three types:

- Vertical elevators (the most common type)[1],
- inclined elevators (such as at Wyaralong Dam and Teviot Brook),[1] and
- Ropeways (such as at the Frieira Dam on the Miño River). [1]

In the example of the fish lift at the Runserau weir, there is an access structure in front of the fish lift in the form of a conventional slotted pass to ensure that it is easy to find. Two entrances, one far from the weir and one close to the weir, which were positioned due to the different discharge situations, take all discharge situations into account. In addition, an attraction flow is flexibly divided between the entrance far from the weir and the entrance near the weir. The slotted passes and the attraction flow guide the fish to the fish lift after the entrance. [1] Fish lifts can be divided into three phases:

1. catching phase [1].,
2. lifting and emptying of the cage [1].and
3. lowering phase, after which the cycle begins again [1]

Figure 1 shows the structure of a fish lift.

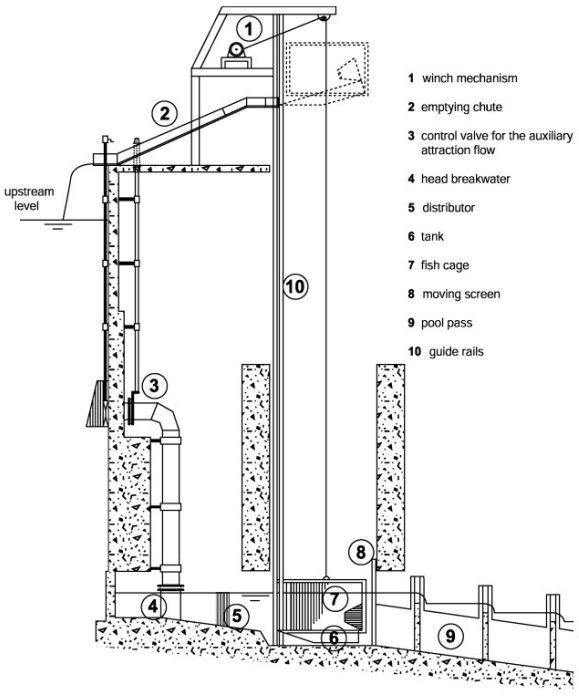

Fig. 1: Illustration of the structure of a fish lift for salmonids as a cross-section [8].

The advantages of the fish lift over conventional fish ladders are Small space requirement, suitable for large height differences and fluctuating headwater levels, can be used at locations where other fish ladders do not work. [3]

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Disadvantages of the fish lift compared to conventional fish ladders are Limited individual locations to date, insufficiently proven functionality, increased maintenance requirements, lack of long-term experience, comparatively higher construction and operating costs, offers no habitat, no possibility for fish descent. [3]

3.2 Bristle ramp fish lock

The bristle fish pass is essentially a channel with a variable wall structure. At the bottom of this channel, which has a rectangular or trapezoidal cross-section, bristle bundles are attached that serve as hydraulic roughness elements. These packages consist of several bundles of elastic individual bristles, typically 5 to 8 bristles per bundle. The operating sequences are divided into several clearly defined phases. At the beginning of the collection phase, the underwater/outlet gate is opened completely, while the knife gate valve of the upper water/intake gate opens partially in order to introduce a pre-determined attraction flow. The water flows under the gate, hits a bristle block and is distributed by percolation via the ramp into the collection chamber. Here it forms an attraction flow for immigration into the sluice chamber. This is followed by the sluicing phase, in which the underwater gate is closed to prevent the fish from leaving the sluice. The water level in the sluice rises to headwater level, while the fish follow the slowly rising current front from the bristle field and are lured up the ramp. This phase is completed as soon as the water level in the sluice box corresponds to the headwater level. [9] The exit phase with siphon operation begins by opening the exit contactor to generate an exit lock flow. Siphons start shortly before full filling and draw off exactly the amount of water required for the exit lure flow. A calmed water outflow already attracts fish back into the entry area (see fig.2). [9] This is followed by the

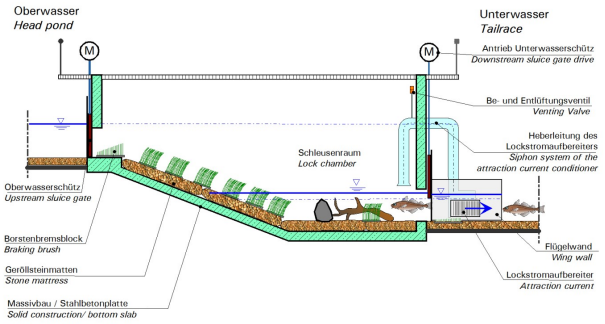

Fig. 2: Components of the Bristle fish lock (longitudinal section) [10].

emptying phase with siphons, during which the upper water gate remains closed while the siphons continue to operate and maintain the lock flow. The water level in the lock drops. At the end of the emptying phase, the underwater gate opens partially to allow water to flow out in a controlled manner and to equalize the water level between the lock chamber and underwater. Immediately afterwards, the upper water gate is pulled into the position for the collection phase to reactivate the lock flow and restart the cycle. [9]

Advantages of the bristle ramp fish sluice compared to conventional fish ladders are: simple construction, low space requirement, shape can be adapted to available space, few fittings and moving parts, fast ascent, low costs. [9]

Disadvantage of the bristle ramp fish lock compared to conventional fish ladders are: one pilot plant has been realized so far. [9]

3.3 Two-chamber fish migration aid using the Fishcon sluice as an example

The two-chamber fish migration aid, also known as the Fishcon sluice, is a further development of conventional fish sluices. It is based on a patented technology that hydraulically connects two lock chambers operated in opposite directions (see fig. 3). This configuration enables a continuous passage of fish from both sides, in contrast to conventional fish locks and elevators, which operate intermittently. This increases the efficiency of the system, which enables both the ascent and descent of fish. [1] The Fishcon

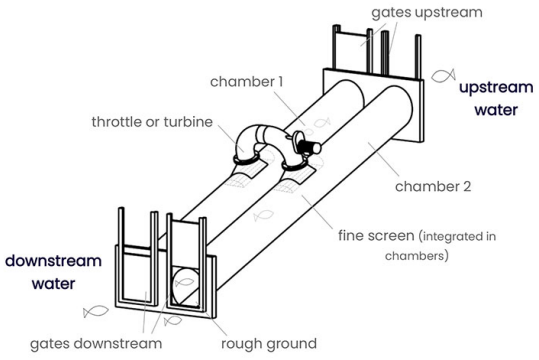

Fig. 3: Structure of the Fishcon fish pass [11].

sluice minimizes turbulence in the chambers by dissipating energy outside the fish migration area and allows the flow velocity to be adjusted for optimum fish migration. It has a continuous bed as standard, which enables the passage of bed-related fish species. The system is resistant to flooding and insensitive to fluctuating water levels. [1] The advantages of two-chamber fish migration aids over conventional fish ladders are: Small space requirement, cost-effective construction. [3] Disadvantages of two-chamber fish migration aids compared to conventional fish ladders are: Limited single sites to date, insufficiently proven

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functionality, requires multiple modules with large height differences, provides no habitat. [3]

4 Criteria for special options for fish passages

In this chapter, the criteria to be met by fish passages are presented so that they can then be summarized in a list of criteria. Criteria from the leaflet DWA-M 509 "Fish passages and fish passable structures - design, dimensioning, quality assurance" and criteria from the guidelines for the construction of fish passages from the Austrian Federal Ministry of Agriculture, Regions and Tourism as well as criteria from an economic perspective are presented.

4.1 Criteria from the DWA-M 509 leaflet

The information sheet lists eight general requirement criteria for fish passage.

- target species and target stages [2]
- operating time [2]
- migration corridor [2]
- detectability [2]
- passability [2]
- design of the exit [2]
- maintenance and operation [2]

In principle, a fish passages should allow all fish species, from low-performing to high-performing species, to migrate. The various fish species differ in terms of their behavior, growth and performance. The different species therefore have different requirements of the fish passage. In the early developmental stages of young fish, meeting certain requirements is problematic as their performance is still limited. For example, flow velocity can be a selective factor for certain fish species. [2] Fish passability should be guaranteed all year round, as fish migration occurs all year round. As this can hardly be achieved technically due to absolute high and low water levels, there is a practical compromise of 30 days on which it is acceptable to exceed the limit. The fish passage must be in continuous operation around the clock, as fish migrate both during the day and at night and sometimes take several days to ascend. [2] The migration corridor is a space that provides ideal conditions for all fish to orient themselves and swim upstream against the current. These ideal conditions are created by sufficient dimensions of the corridor and a directed current with little turbulence. The migration corridor is continuous and extends from the underwater area of an obstacle to the fish passage or structural work that can be passed by fish and extends into the upstream area. [2] The following points should be taken into account to ensure that fish passages are easy to find:

- Large-scale arrangement of fish ladders and fish passable structures in the watercourse [2]
- Character of the guiding current [2]
- Local positioning of the entrance (outlet) of a fish ladder or the migration corridor via a fish-passable structure [2]
- Design of the entrance [2]

The fish passages or a fish passable structure is considered passable if all fish species and developmental stages according to the fish species and fish stages that have found the entrance and are also able to pass the entire structure during high and low water. For smaller and less efficient species and individuals, the hydraulic conditions are particularly decisive, while the passability for larger specimens depends primarily on the size of the migration corridor. [2] Overcoming a fish passages is a considerable challenge and results in the fish swimming upstream being exhausted by the time they reach the headwater. The area should therefore be free of strong turbulence and high flow velocities. [2] The principle states that functionality is only guaranteed if it is regularly maintained. Proper maintenance includes weekly checks of the system and the occasional removal of floating debris and other faults. In addition, the lift should be taken out of service at least once a year to identify and rectify debris, potential damage to the bottom protection and problems in the areas below the water surface. [2]

4.2 Criteria from the guidelines for the construction of fish passage

The following general criteria are listed in the guidelines for the construction of fish passages:

- Ensuring findability [7]
- Ensuring passability [7]
- Sufficient service life throughout the year [7]
- Ensuring operational safety [7]
- Appropriate accident prevention [7]
- Size-determining fish species [7]

Criteria such as ensuring detectability, ensuring passability, passability of the facility, functional acidity, operational safety and the general criteria for fish

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species were explained in the chapter above. To prevent potential disturbance, measures must be taken to protect the facility in the event of flooding, driftwood or other forms of destruction. It is important to establish an appropriate procedure for any necessary fishing operations. In the event of a damming or low water levels, an emergency supply should be guaranteed. In the event of a failure of the regular water supply, defined minimum quantities of water must be statically available. [7]

4.3 Determined criteria for the selection of special solutions for fish passage

If there are specific conditions at a site that cannot be met by conventional fish passage, a special solution must be found. Factors such as the height to be overcome, space requirements, complex estuary and entry situations, high water velocities, water level fluctuations and financial resources are the criteria according to which special solutions for fish passage can be selected. By simultaneously considering the general requirements for conventional fish passage and the combination of site-specific requirements for special fish passage solutions, a list of criteria for the selection of special fish passage solutions can be drawn up.

5 Summary of the criteria in a criteria catalog

The requirements listed in chapter three are summarized in this chapter and formatted in an evaluation catalog for use in selecting a suitable special solution. A selection of criteria was chosen based on the general criteria listed and the criteria for the construction of special solutions for fish passages. As the general criteria must also be observed when constructing special solutions, these play a less important role in the catalog. There are general criteria and decisive ones for the choice of special solutions. For example, the target fish species is a strong criterion when choosing a special solution. In the case of passability, it is assumed that these criteria are prerequisites and do not need to be evaluated separately in a catalog for special solutions. The same applies to the operating time, which is defined in accordance with DWA-M 509, the migration corridor, findability and the design of the exit. At this point, it should be noted that criteria such as passability, maintenance and operation should be assessed in a different way. For example, the criterion of the number of structures already built by the special solutions plays a role here. The number of realized locations of special solutions and their evaluation can be used to draw conclusions about passability, maintenance and operation. As the disadvantage of the special solutions is the limited number of individual locations, the existing locations of the special solutions are included as a criterion. In addition, the decisive factors for the need for a special solution (see section 3.3) are also taken into account. In summary, the following criteria form a possible catalog for the selection of special solutions for fish ladders:

- Target fish species
- Height difference
- Space availability
- Costs
- Realized locations
- Maintenance and service life

5.1 Presentation of the criteria catalog

The figure 4 shows a possible representation of the criteria mentioned in sections 4.3 and 5. Further criteria can be added in the columns if necessary. The respective special solutions for fish migration can be evaluated in the rows.

	Criteria						
special solution	Target fish species	Height difference	Space availability	Costs	Realized locations	Maintenance	Service life
Fischlift							
Bristle ramp fish lock							
Two-chamber fish migration aid							

Fig. 4: Presentation of the criteria in a catalog

5.2 Evaluation of the criteria catalog

The evaluation of the criteria catalog can be filled out site-specifically for a special case in order to be able to select a choice of special solutions for the fish ladder or generally in order to compare the special solutions with each other (see fig. 5). For a site-specific evaluation, the evaluation catalog can be used as follows:

- ++: fully applies
- +: applies
- O: neutral
- -: does not apply
- –: does not apply at all

After the site-specific assessment, the special solution with the most positive results can be selected with ease.

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special solution	Criteria						
	Target fish species	Height difference	Space availability	Costs	Realized locations	Maintenance	Service life
Fischlift	+	++	++	--	++	--	-
Bristle ramp fish lock	+	--	-	+	o	-	+
Two-chamber fish migration aid	++	--	--	+	o	++	++

Fig. 5: Exemplary evaluation form of the catalog for a special case

special solution	Criteria						
	Target fish species	Height difference	Space availability	Costs	Realized locations	Maintenance	Service life
Fischlift	Depending on the built-in catch chamber	10 m	low	Depending on circumstances: between 100.000 € and 30 Mio. €	Many and well-documented locations	Comparatively higher	Rather lower in comparison due to many fittings and moving parts
Bristle ramp fish lock	Also for weak swimmers	/	Small and customizable	Comparatively low	Pilot plant on the Aare	Low due to few fittings and moving parts	High due to few fittings and moving parts
Two-chamber fish migration aid	sole migrants, weakly swimming fish species	1,5 – 6 m	Very small due to compact design	Cost-saving investment	Very many locations	Resistant	High due to few fittings and moving parts

Fig. 6: Exemplary evaluation form of the catalog for various special solutions

In a comparison of the special solutions for fish migration without site-specific conditions, which can be included in the criteria, the evaluation may be as the follwing figure 6.

For example, two types of application and forms of evaluation of the established criteria catalog could look like this.

6 Conclusion and outlook

The investigation of special solutions for fish ladders has shown that the importance of the continuity of water bodies for aquatic ecology is crucial. Standardized fish ladders reach their limits when it comes to adapting to site-specific conditions. The development of special solutions has proven to be an effective alternative to meet these requirements. A set of criteria that takes into account both general and site-specific requirements can optimize the selection and implementation of tailor-made fishways and thus promote the ecological sustainability of watercourses. It should also be noted that the established list of criteria is only one possibility for evaluation and can be supplemented by further criteria. Furthermore, a list of criteria for general consideration should always be updated, as new findings will emerge in the future. It was also not possible to provide a meaningful answer to every criterion in the evaluation examples, as some information was missing. The work on a catalog of criteria for special solutions for fish ladders represents an important step in supporting the field of aquatic ecology. Future research could focus on validating and expanding this catalog by applying it to different sites and new technologies. It would also be interesting to conduct case studies to verify the practical application of these special solutions and evaluate their effectiveness in different environments. This could help to identify best practices and enable the development of even more effective special solutions for fish migration.

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