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Water quality - Guidance for assessing the efficiency and related metrics of fish passage solutions using telemetry

Wasserbeschaffenheit - Anleitung zur Beurteilung der Wirksamkeit und zugehöriger Kennwerte von Fischaufstiegshilfen mittels Fernmessung

Recommandations pour l’évaluation par télémétrie de l’efficacité des dispositifs de franchissement piscicole et d'indicateurs associés

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (prEN 17233:2018) has been prepared by Technical Committee CEN/TC 230 "Water analysis", the secretariat of which is held by DIN.

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Introduction

to Fish Pass Monitoring.

Fish passage solutions (FPS) are measures to help fish pass a cross-river obstacle or impediment in upstream and/or downstream directions. The ideal solution – from a global-ecological perspective – would be to re-establish natural river connectivity by decommissioning or removing the obstacle which would at the same time eliminate or reduce any impounded section and allow unimpeded sediment transport. In the last two decades or so, the number of constructed upstream FPS has increased significantly at least in some parts of the world, and the range of proposed FPS designs has also increased. However, despite careful control of FPS design both pre-and post-construction, the performance of fish passage solutions need comprehensive field monitoring for the following reasons; FPS designs globally rely on laboratory experiments that need validating *in situ*; the efficiency of initially well-designed FPS may be modified by changes to the environment (e.g. discharge, river morphology) and require improvement; and the efficiency for new target species or life stages that were not considered during the initial design process may be necessary. In addition, the design and implementation of downstream migration facilities is still lagging behind, with the associated evidence gap in our knowledge of performance. Only systematic, reproducible monitoring studies assessing the performance of fish passes will enable us to improve and develop current fish pass designs.

In general terms, fish pass monitoring is the activity of assessing by all appropriate means the degree of success (or failure) of fish dealing with the conditions of an implemented fish passage solution.

Comprehensive fish pass monitoring serves several purposes. Firstly, it helps determine the appropriateness of the chosen design of a FPS by providing data about the effectiveness (number of fish, size classes and species passing the obstacle, sometimes related to spawning success upstream, or species compositions and abundances of the river section down- and upstream of an impediment) and/or the efficiency (proportion of fish passing the impediment in relation to the number of fish actually trying to pass) for fish that have to cross the impediment. As a result, a documented well-functioning solution can serve as an example for a solution in a similar river type with a similar fish community; any reduction in performance should be carefully analysed, and the reasons for failures identified and addressed through adjustments, i.e. by structural changes (e.g. modifications of the design of [different parts] the pass) or by operational solutions (concerning the pass itself, e.g. by optimizing the attraction to the entrance or by adapting the discharge through the pass; or concerning turbine management). Secondly, technical information which is indispensable for the design development or optimization of future fish passage solutions can be gathered along with the observations of fish behaviour. Thirdly, provided that appropriate methods are used, fish pass monitoring can support informed management of fish populations upstream or downstream of the impediment, e.g. supporting EU eel regulations, EU Water Framework Directive or direct management of freshwater fishery resources, and the general biodiversity in the river.

Frequently, however, due to non-standardized choice of monitoring methods and protocols adopted, data from fish pass monitoring studies across Europe are not directly comparable. Fish trapping usually works only in the upstream direction, is quite costly and does not provide information on the numbers of fish that approach the impediment to pass. The same is true for other capture-independent methods like video monitoring. However, methods such as acoustic or radio telemetry or PIT tags that enable estimation of a percentage of fish that passed the obstacle in relation to the number of fish approaching the obstacle to pass usually look only at a single species and fish of a particular size range (e.g. adults, sub-adults), and are therefore unsuitable for small and young fish existing in the area of the FPS. A comprehensive monitoring programme should ideally target the whole range of species and fish sizes present, therefore requiring a multi-method approach.

As described above, different monitoring methods will provide different insights. There exist capture-dependent methods (e.g. trapping; pooling in a counting basin; capture–mark-recapture [CMR]; monitoring based on tagging with transmitters or transponders [telemetry]) and capture-independent methods (e.g. visual observations [and counting] or by video recording; resistivity counter; hydroacoustics). Detailed descriptions of these methods can be found in the relevant literature and are not repeated here.

All aforementioned methods — with the exception of telemetry — provide data that benefit primarily the assessment of the effectiveness of a FPS. If efficiency needs to be addressed, measures of the proportion of fishes passing successfully, relative to those attempting, is crucial, together with evidence concerning passage-related delay, mortality or other health impacts (Cooke and Hinch, 2013). For this purpose, telemetry (acoustic, radio and PIT tagging techniques) have major advantages over the other methods. In the following, only telemetric methodologies are addressed and standardized as efficiency estimates are considered to be the best and most relevant metrics of FPS performance.

1 Scope

This document provides guidance for assessing the efficiency and related metrics of fish passage solutions using telemetry methods that allow fish approaching an impediment to be monitored.

It provides recommendations and requirements for equipment, study design, data analysis and reporting. A selected literature with references in support of this standard is given in the Bibliography section.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

Not all definitions listed below are necessarily applicable to all studies. Only those which are relevant to the aims and objectives of the study in question are required.

This standard defines efficiencies related to sampled fish as follows:

3.1
fish passage solution
FPS
any device, structure or mechanism which is designed or operated to facilitate the safe movement of fish in an upstream and/or downstream direction past one or several impediments

3.2
FPS performance
overall capability of the FPS to meet its design objective

Note 1 to entry: The design objective will include objectives related to the target fish community, target species, attraction and passage efficiencies and effectiveness.

3.3
available fish
number of tagged fish approaching the impediment

Note 1 to entry: The approach distance will be site specific and fish are assumed to be motivated to pass.

3.4
overall FPS efficiency
percentage of available fish attempting to pass an impediment(s) that find, enter and successfully negotiate, the FPS

Note 1 to entry: Encompasses attraction, entrance and passage efficiencies.

3.5
FPS attraction efficiency
percentage of available fish that are attracted to the FPS entrance

3.6
FPS entrance efficiency
percentage of fish attracted to the FPS entrance that subsequently enter

3.7
FPS passage efficiency
percentage of fish entering the FPS that successfully negotiate and exit the FPS

3.8
overall FPS passage time
time from first approach of fish to an impediment to exit from the FPS

3.9
FPS attraction time
time from first approach of fish to an impediment to arrival at the entrance area of the FPS

3.10
FPS entrance time
time from first arrival of fish at the FPS until first entrance

3.11
FPS passage time
time from first entrance of fish to FPS until exit

3.12
FPS effectiveness
assessment or count of the number and type of fish successfully negotiating the FPS in relation to the fish community present

3.13
number of attempts
count of the number of times each tagged fish entered the FPS until successful negotiation and exit from the FPS

3.14
fall-back
percentage of fish that move back downstream/upstream after ascending/descending an impediment (whether by FPS or other route)

3.15
impediment passage efficiency
proportion of fish attempting to pass an impediment that successfully negotiate it, by any route

3.16
overall impediment passage time
time from fish first approach to an impediment to successful passage, by any route

3.17
telemetry
use of electronic tags such as radio and acoustic transmitters, data storage tags, pop-up satellite archival tags and PIT-tags to obtain information on free-ranging fish

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

FPS	Fish Passage Solution
PIT	Passive Integrated Transponder
CART	Combined Acoustic Radio Transmitters
CMR	Capture Mark Recapture
CPUE	Catch per Unit Effort
EMG	Electromyogram
eDNA	Environmental Deoxyribonucleic Acid
WFD	Water Framework Directive
3R’s	Replacement, Reduction and Refinement as per DIRECTIVE 2010/63/EU (European Union, 2010):

Replacement — Methods which avoid or replace the use of animals.

Reduction — Methods which minimize the number of animals used per experiment.

Refinement — Methods which minimize suffering and improve animal welfare.

5 Principle and field of application

The purpose of a fish passage solution is to allow the free passage of relevant developmental stages of endemic species. This enables fish to complete both diel and seasonal movements such as accessing foraging, resting and reproductive habitats, and includes both upstream and downstream pathways.

Whilst the design of fish passage solutions for some species and life stages is well advanced (e.g. adult migratory salmonids), the requirements of other species and for downstream migration are not fully understood. FPS monitoring studies can provide several layers of information: For example, appropriately sited fish counters (e.g. cameras, resistivity, multibeam sonar) and trapping can provide a relatively simple demonstration of FPS use, however, despite these being non-invasive, these approaches provide no estimates of the population attempting passage.

This standard covers studies using fish tagged with acoustic, passive integrated transponder and radio tags to provide a variety of defined passage efficiency metrics and facilitate comparisons between fish passage solutions. Guidance is provided on the selection of appropriate monitoring equipment, the experimental design of FPS monitoring studies and data collection (Clause 7), data processing procedures (Clause 8), quality control and assurance (Clause 9), and presenting the results in a standard reporting format (Clause 10) to provide essential fish passage efficiency and delay metrics.

Methods for monitoring other aspects of the performance of FPSs that are **not** covered and related to the assessment of effectiveness by this standard include; trapping, video, acoustic cameras, direct observation/online surveillance, catch — mark — recapture (CMR), physiological telemetry (e.g. EMG (electromyogram), accelerometry and heart rate), eDNA (environmental Deoxyribonucleic Acid), Catch Per Unit Effort (CPUE) and flume studies. See Lucas and Baras (2000) and Kemp and O'Hanley (2010) for further information about these methods.

6 Valid methods for assessing efficiency and related metrics

Fish passage efficiency encompasses attraction, entrance into, and successful passage through, the FPS. In order to evaluate the efficiency of FPSs, it is necessary to be able to identify individual fish that are available to pass so that the success or failure of each fish is known. Individual detection is best provided by telemetry.

Valid methods for assessing the efficiency of FPSs are:

— acoustic telemetry;

— radio telemetry;

— Combined Acoustic Radio Transmitters (CART);

— PIT telemetry;

— permutations of the above.

The suitability and limitations of these methods are summarized in Clause 7.

7 Equipment

7.1 General

In order to provide near-continuous detection performance and precise detection times, telemetric determination of FPS performance is likely to involve the use of automated receiver systems and antenna/hydrophone arrays. The choice of telemetry method and associated equipment is based on many factors, including study objectives, environmental factors such as channel depth and width, target fish species and size and sample size. Annex A (Table A.1) summarizes the suitability and limitations of telemetry methods for assessing the efficiency of fish passes.

7.2 Calibration and system checks

7.2.1 General

Thorough calibration and tuning of the receiving equipment is crucial to ensure the collection of good quality, accurate data. It is essential that the detection range of the receiving equipment is fully mapped and understood. Regular system checks should be performed to take into account changing conditions that can modify receiver detection ranges; for example temperature, entrained air and electromagnetic fields. Data on tag failure rates should be obtained from the manufacturer or, better, tested for a subset under experimental conditions; this enables one variable for tag loss during tracking to be quantified. Similarly, careful quality controls need to be placed upon false positive records of tags, due to signal processing errors and code collisions.

Tagged fish should be scanned prior to release to confirm that the tags are functioning; this is true for all telemetry tag types. The likely effects of code collisions, or cycle period between reception frequencies (used in some radio applications) relative to antenna range, on tag detection probability shall be considered and incorporated into experimental design. The percentage period during the study for which the remote array was functioning effectively should be recorded; this is particularly important for PIT stations since tag range is low, and in all but small streams, manual tracking to determine the fate of PIT tagged fish is difficult (cf. radio, acoustic with battery-powered transmitters).

7.2.2 Acoustic telemetry

— A detailed detection efficiency test should be performed at the beginning of the study with test tag(s) of the power output to be used and repeated where possible during the study. Detection ratios of test tags within the hydrophone field should be recorded. Actual detection efficiency of tagged fish should be back-calculated from known routes and reported.

— Reference acoustic-transmitters should be placed at several depths in known locations under typical experimental conditions and the accuracy and precision of reported transmitter positions calculated. It is a good idea to retain one or more reference transmitters ('sentinel' tags) for the duration of the study.

— The detection range of each hydrophone should be determined under the range of experimental conditions likely to be experienced.

— 'Tag drags' (moving a tag within the array) should be conducted to test the tracking capability of the system.

7.2.3 Radio telemetry

— A detailed signal strength map around antennas should be generated at the beginning of the study for the tags to be used. Logger data should be analysed and signal strengths from several loggers (if present) used to create a signal strength map that enables the position of the fish to be pinpointed. The same approach should be used where one receiver is multiplexing multiple antennas.

— Detection ratios of test tags within the antenna fields should be recorded. Actual detection efficiency of tagged fish should be back-calculated from known routes and reported.

— Radio-transmitters should be placed at several depths in known locations during known periods of time and the accuracy and precision of reported transmitter positions calculated.

— Reference transmitters can be used to compensate for variations in disturbance and the resulting signal strength recorded. It is a good idea to retain one or more reference transmitters ('sentinel' tags) for the duration of the study.

7.2.4 PIT telemetry

— Because of the small range of PIT antennas, thorough testing with tags of the size and type to be used is vital. Range and detection efficiency tests should be conducted over the possible extent of experimental conditions for all tag orientations and for multiple as well as single tags (tag proximity can block detection of other tags). This should include testing of tags passed at the same speed for which fish passage through the detection field may be expected.

— Regular tests of antenna efficiency should be carried out by manual checks or by automated sentinel (check) tags and recorded. Actual detection of tagged fish should be back-calculated from known routes and reported.

7.2.5 Multiple tagging scenarios

— To overcome limitations of individual telemetry methods fish could be tagged with multiple tags, provided fish welfare is not compromised. For example, both acoustic and PIT tags could be used for fish moving through a wide and deep river and a narrow and shallow FPS. Acoustic telemetry will enable fish approach to the obstruction be studied while PIT telemetry will enable movements inside the pass to be studied.

7.3 Experimental design

7.3.1 Pre-planning

The following points should be considered prior to conducting a study:

— **Aims and objectives** shall be clearly defined, as these will determine the study design. These could be partially pre-determined by a request to monitor a particular location, species, age/size class or catchment.

— **Potential collaborative partners** should be identified at an early stage in the planning process in order to maximize the value and outcomes of the study.

— **The study site** may be predetermined at the outset of the study. If not, then the most strategic or important site should be identified.

— **Site logistics**. The operational and physical aspects and limitations of the site should be identified. This should include:

— safety of operators and equipment;

— potential for vandalism;

— impacts of flooding;

— availability of a power supply;

— access conditions;

— predator numbers/density;

— local sources of noise or other potential interference.

— **The discharge variability of study site** should be assessed in advance to ensure that the study objectives are achievable and that the target metrics can be measured across the range of interest.

— The range of **environmental conditions** over which the efficiency of the FPS will be assessed e.g. discharge, temperature, should be selected.

— **Ownership of the site** shall be determined and the relevant access permissions obtained.

— **Approvals.** Relevant approvals for the work shall be obtained from the appropriate authorities.

— **The time and spatial scales** of the study should be determined e.g. single year/many years; single site/whole catchment.