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DOWNSTREAM FISH MIGRATION ALONG THE LOW MEUSE RIVER

Action A3

Modelling of the passages through the hydraulic works in order to design the solutions

Deliverable – Behavioural study on smolts

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I. Introduction

The understanding of the behaviour of downstream migrating fish is mandatory in order to design properly effective bypass solutions based on hydrodynamic parameters. In situ surveys are the only way to assess real natural behaviour of fishes. However, such surveys are difficult to handle and rarely enable to control flow conditions. In addition, it is usually very costly to test varied geometric configurations on site.

To overcome some of the above-mentioned difficulties/limitations, physical modelling can be applied. It consists in reproducing real flow configurations in a perfectly controlled environment (a laboratory) in order to enable detailed measurements and to test varied geometries. Such physical models can be scaled in order to match limited dimensions of laboratories or on the contrary to enable an easier analysis of complex small geometries. In this case, dimensions of the real structure (the prototype) are (up or down)-scaled and similarity laws are used to scale laboratory results to prototype.

In the scope of the Action A3 of the Life for Fish project, it has been proposed to dedicate time during the second year of the project to carry on 1:1 physical model testing with real smolts. This phase of the Action A3 is presented in this report. It is more exploratory than the previous phase. Indeed, to our knowledge, no one has already conducted physical model tests with real smolts specifically focusing on the attractiveness of downstream migration structures. The relevance of such an approach has however already been proven by benchmark studies, particularly for designing upstream migration structures (fish passes).

We decided to focus on salmon smolts because

- such fishes are available thanks to the Salmon project and the SPW Erezée fish farm;
- some details of the pilot sites downstream passages still need to be defined but data are not available to make a decision (trash rack geometry and location for instance).

This report presents this behavioural study performed by ULiege-HECE team within Action A3 of the Life for Fish project during the second year of the project.

The experimental setup and the instrumentation are presented in details in section II. Section III presents the tests methodology and the method to analyse the results. Then, the results of the tests are presented and discussed in section IV, while section V summarizes the works and draws conclusions.

II. Experimental set up and instrumentation

II.1 General considerations

The aim of the physical modelling tests depicted in this report is to analyse the behaviour of downstream migrating salmon (smolts) approaching a downstream passage for varied flow conditions.

Fishes are living bodies whose behaviour is still poorly understood. In order to avoid bias in tests and results, tests have to be repeated with several different smolts batches and a single batch of fishes has to face different geometric configurations in the same conditions, i.e. at the same time.

Based on these considerations, the experimental set up consists in a single straight flume whose downstream extremity is split in two outlets. Both outlets can be identical or their geometry can be varied. Fishes will be placed in the flume and a discharge will be installed. Assuming that smolts will try to move downstream in the flume, i.e. will try to exit the system through one of the outlets, the experimental set up will enable to quantify the attraction/repulsion effect of different downstream passage intake geometries in the same approach flow conditions and with the same fishes.

II.2 Test flume

The test flume has been designed regarding downstream passage dimensions recommended in the literature, discharge capacity of the pumping system and space available in the laboratory.

Maximum discharge available in the laboratory is around 0.3m³/s. With such a discharge, a flume width of 0.8m enable to create a 1.5m/s flow velocity with a 0.24m water depth in critical flow conditions. These values enable to consider two parallel outlets 0.4m wide placed on the crest of a broad crested weir at the downstream extremity of the flume. Such dimensions and flow parameters are close to the minimal requirement for the outlet of a downstream passage as recommended in the literature (Larinier et al., 1992).

Upstream of the outlets, the flume width is kept constant but the water depth increases to 1m in order to reduce flow velocity. A ramp links the flume bottom to the outlets.

A wider area is build upstream to inject the discharge in the system while twin reservoirs are build downstream of the outlets to collect the fishes. The downstream reservoirs floor level is 0.6 m above the weir crest level to create a chute. A convergent section with a baffle wall and a rack links the upstream reservoir to the flume and create smooth and uniform flow conditions at the flume entrance.

The flume geometry is detailed on Figure 1 and on the pictures from Figure 2 to Figure 4.

Plexiglas walls have been built on both sides of the flume, just before the outlets, to enable fishes observation. Other walls of the flume are made of concrete blocks waterproofed by a mortar layer. White mortar has been used to make fishes visible by contrast. Mortar has been placed with a brush in order to get a rough surface.

During the tests, Plexiglas walls have been isolated from the laboratory using plastic sheeting (Figure 4). Indeed, movements in the laboratory from humans or machines could scare the fishes. Camera have been used to observe fish movements (see section II.5).

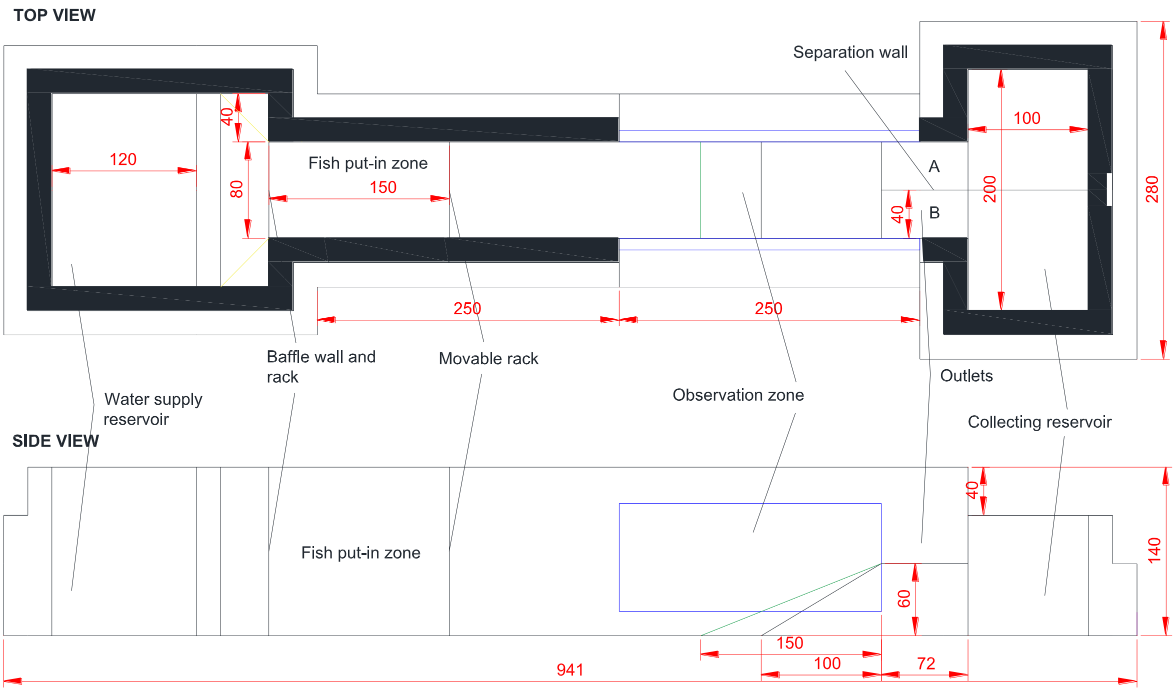

Figure 1 : Geometry of the test flume

Figure 2 : Side view of the test flume with the left Plexiglas observation sidewall

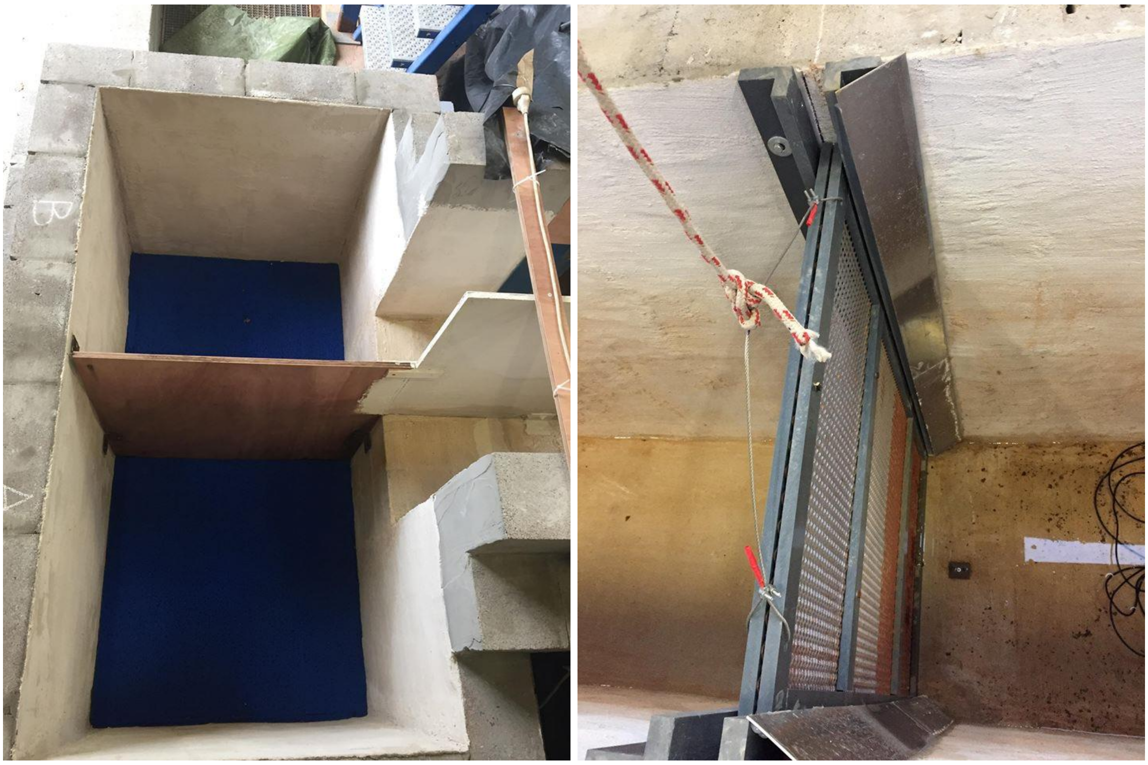

Figure 3 : Downstream collecting twin reservoirs (left) and movable rack downstream of fish put-in zone (right)

Figure 4 : Downstream view of the flume with plastic sheeting to hide observation sidewalls

II.3 Geometric parameters

The geometry of the downstream passage at both pilot sites has been designed during the first year of the project (Actions A3 + C1 and C2). However, questions still exist on specific parameters, and in particular about the trash rack geometry and location. That is why it has been decided to focus the behavioural tests on the effect of the trash rack geometry and location.

Besides, it is not possible to test a large number of parameters in the scope of Action A3 of Life for Fish project. Indeed, first, smolts are not available all the time and in unlimited number. Second, tests of a single geometry need to be repeated several times in order to provide a statistically meaning full result (see section III).

The study focused then on two parameters of a trash rack made of vertical round bars regularly spaced:

- The bars spacing along the outlet width;
- The rack location in the outlet.

In particular, it has been decided to test two bars spacing and to test two rack locations (Figure 6). A bars spacing of 20cm is recommended in the literature for downstream passages (Larinier et al., 1992). It is however quite large regarding floating debris dimensions in the Meuse river and a smaller spacing would then help in stopping more debris. A spacing of 10cm has then been tested. Regarding the trash rack location, it can be placed on the crest of the outlet (larger flow velocity area) or a the inclined ramp toe (smaller velocity area).

As all these tests went well and as time and smolts were still available, two slopes of the inclined ramp to the outlet have also been tested. Ramps slope is designed to control the velocity gradient. In our case, a steep ramp slope (60%) enables to get a velocity gradient just above 1m/s/m, i.e. just above the maximum acceptable value recommended in the literature (Larinier et al., 1992). A smaller slope of 40% has also been tested, i.e. a smaller velocity gradient.

Figure 5 : Upstream view of the flume with a 10cm spacing rack on the crest of the right outlet

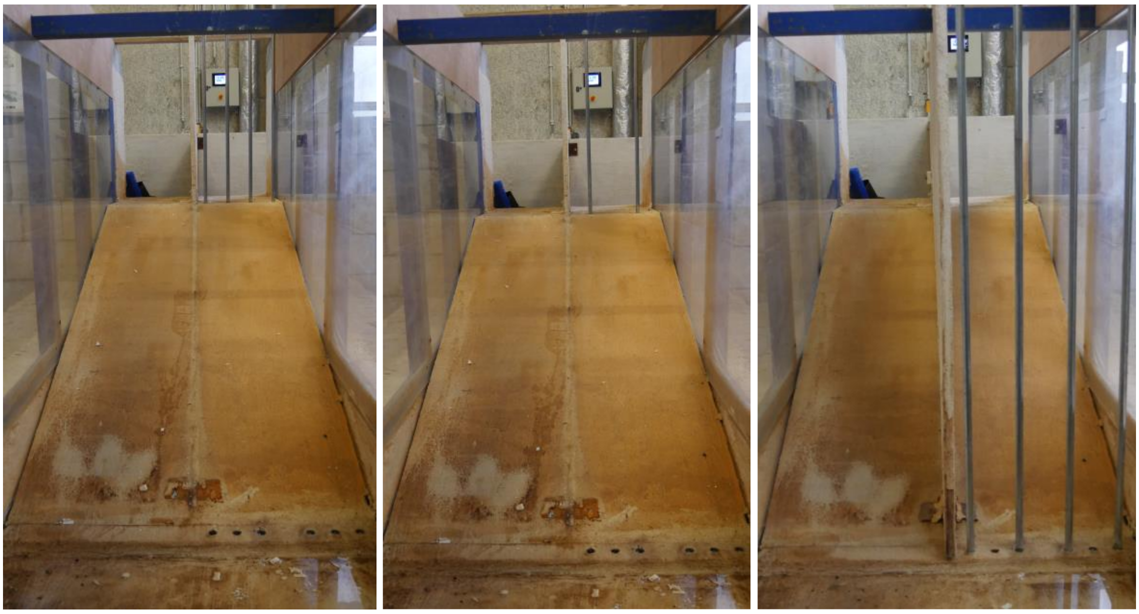

Figure 6 : Upstream view of the 10cm spacing rack on the crest of the right outlet (left), the 20cm spacing rack on the crest of the right outlet (center) and the 10cm spacing rack at the toe of the right outlet (right)

II.4 Fish related issues

II.4.1 Regulation

Tests with living bodies such as the ones depicted in this report fall within the Wallonia regulation regarding animals wellbeing. Thanks to the help of Prof P. Poncin and Dr M. Ovidio laboratory, accredited by SPW to perform experimentations with living bodies, the experimental procedure has then been submitted to the ethics Committee of Liege University. The Committee stated that the tests are observation tests (see Appendix 1) and, consequently, do not consist in “experimentation” in legal terms. This means that no specific regulation apply to the tests depicted in this report.

II.4.2 Availability

Smolts are not available every time. Indeed, such physiological status of one-year-old salmons exists only during spring. Tests with fishes have then been concentrated in March and April 2019.

This means that significant time has been dedicated before March 2019 to build the experimental facility, test the measurement devices, the experimental procedure and be sure that everything was ready before smolts were available. Similarly, most of the results have been analysed after the tests, i.e. from May 2019.

Smolts have been bought at Conservatoire du saumon mosan. Thus, the same smolts as the ones used by SPW to restore salmon in the Ourthe and Meuse Rivers have been used for the tests. These smolts were transported by ProFish from Conservatoire du saumon mosan to the Laboratory. After the tests, they were released by ProFish in the Ourthe River.

II.4.3 Storage

Prior and after the tests, smolts batches were stored in PVC tanks equipped with an aerator and a circulating pump.

Water temperature and oxygen concentration were monitored and controlled regularly to prevent decrease in water quality.

Water temperature evolution has been managed carefully as water temperature in Conservatoire du saumon mosan basins (5 to 10°C) and water temperature in the laboratory reservoir

(15-17°C) were not the same. In particular, special care has been taken to prevent smolts exposure to a water temperature gradient above 0.5°C/h.

II.5 Instrumentation

Aerators, circulating pumps, thermometers and oximeter have been used to control parameters in the storage tanks (see section II.4.3).

In the test flume, electromagnetic dischargemeters have been used to measure the water discharge supplied in the upstream reservoir by 2 conduits connected to the pumps of the pumping system of the laboratory. This pumping system is a closed loop, water exiting the flume going back to a 400m³ storage tank where the laboratory pumps are connected.

During the tests set up phase, a propeller has been used to measure flow velocity in the flume and a limnimeter has been used to measure water levels.

During the tests with smolts, 5 cameras have been used to monitor fish movements. 2 cameras were immerged in the flume, in the upstream section, and were looking downstream. One camera was placed in front of each Plexiglass sidewall and one camera was placed on the top of the model.

The primary goal of the test is to count how many smolts will choose outlet A or B. To know this number, a first step is to count manually how many fishes will be caught in the two downstream reservoirs after each test. However, it has been observed that some fishes may move upstream across the flume outlets during one test. Image analysis applied to camera recording is expected to provide additional information on how many fishes is choosing one outlet or the other. In addition, camera might provide useful information on fishes' behaviour when facing a downstream passage outlet.

III. Tests methodology and results analysis method

III.1 Statistics

Because of smolts availability at Conservatoire du saumon mosan, the number of fishes that can be used for the tests is limited. Initial number of smolts available for our tests was 226. At the end, it has been possible to get 120 more fishes, i.e. to use 346 smolts in total.

To study the influence of a parameter on smolts behaviour, it is necessary to repeat the tests in identical conditions. Indeed, fishes are probably not entirely rational living bodies, i.e. their behavior most probably depends on other variables than the ones fully controlled in the laboratory. On the other hand, it is known that smolts have a gregarious behavior. Tests on single individuals are then meaningless. On the contrary, tests should be done with several fishes at a time.

Finally, to avoid acclimatization or learning, fishes can go through the experimental set up only one time.

In order to assess the effect of as much parameters as possible while keeping statistically meaningful results, it has been decided to divide every group of smolts received in the laboratory into a minimum of four identical batches and to test each outlets configuration with two batches (repetition). For every configuration, one batch was tested on the morning and the other one in the afternoon. Prior to the start of the tests with most of the available smolts, 10 fishes have been used in a single batch to validate the experimental protocol (see section III.3).

Besides, smolts in the flume will have to choose between outlet A or B to move downstream. The idea of the tests is to assess positive or negative effect of an outlet configuration by comparing the numbers of smolts using outlet A or B, each outlet being geometrically different. To get meaningful results, “choice” of each outlet, if identical, has to be 50%. Such a symmetry has to be confirmed by testing (see section IV.3).

III.2 Smolts batches

During the tests, groups of 72 to 120 smolts were received every week in the laboratory. Each group has been divided into 4 to 6 batches of 18 to 20 smolts. Each batch was “tested” only once to prevent “fish learning” or acclimatization. Smolts biometry performed at fish arrival in the laboratory enabled to create batches with homogeneous fish content in terms of smolts weight.

As an example, Table 1 presents the smolts repartition in 4 batches for group 1.

Batch number	M< 30g	30g≤M≤40g	M> 40g
1.1	6	9	3
1.2	6	10	2
1.3	6	10	2
1.4	6	10	2

Table 1: Smolts weight distribution for group 1

III.3 Preliminary tests

A first group of 10 smolts (group 0) has been used during 2 weeks prior to main fish groups arrival in order to test and optimize the tests methodology. Indeed, has already mentioned, main smolts groups have been received on a limited period of time and no adjustment of the test protocol was possible during this period.

This period of preliminary tests enabled to

- Verify that it was possible to keep alive smolts batches in the laboratory during at least one week;
- Show that smolts were moving downstream when placed in the experimental flume and that they were moving whatever the day period (day or night);
- See that after 10min in the put-in zone of the flume, smolts were calm enough to open the downstream rack and let them move freely in the flume;
- See that the period of time needed to have all the fish going through one outlet varies a lot (from 1 h to more than 4 hours);
- Confirm the gregarious behavior of smolts: when a first fish moves across one outlet, several others usually follow it.

Following these tests, it has been decided to test each outlet configuration with 2 smolts batches and to place each batch in the flume during 4 hours: one batch in the morning and one batch in the afternoon. At the end of each period of 4 ours, the number of smolts in each downstream reservoir is counted to know how many fishes used outlet A or B. Then, smolts still in the flume are expelled from the flume and forced to choose one outlet. This enable a second counting.

Despite the preliminary test period, it has been necessary to adjust the test protocol when using the large group 1. Indeed, it appeared that 4 hours was too long for smolts exiting early from the flume to stay alive in the downstream reservoir, probably because of too much energy dissipation in the reservoirs (too small reservoirs volume). Figure 7 shows flow conditions in the downstream reservoirs.

Figure 7 : Upstream view of the flume during a test with a rack bars spacing of 10cm in right outlet – Downstream reservoirs at the front

In addition, even a very long period at constant discharge may lead to a very small number of passages. It has however been found that creating several short periods (30min) at constant discharge enable to observe more passages.

III.4 Tests methodology

The final tests methodology, applied to groups 2 to 4 (14 batches), was as follows:

A) Placement of the smolts in the set-in zone and acclimatization during 10min;

B) Opening of the downstream rack and set up of a constant 0.265m³/s discharge during 30min;

C) Decrease of the discharge to 0.116m³/s and removal of the smolts caught in the downstream reservoir;

D) Increase of the discharge to 0.265m³/s and new constant discharge period of 30min;

E) Repetition of steps C and D four times;

F) If no smolt exited the flume during the fifth constant discharge period, extension of the constant discharge period during 30 more min before ending the test. If smolts exited the flume during the fifth constant discharge period, repetition of step C and D a sixth and a seventh time before ending the test;

G) After removing of all the smolts in the downstream reservoirs, expulsion of the fishes still in the flume (forced selection of an outlet) and last counting.

In addition to manual counting of the fishes caught in each of the downstream reservoir, it was expected to be able to develop a method to count fishes choosing outlet A or B from image analysis, using the data from the camera placed on the top and sides of the flume. The development of the algorithms necessary to do has not yet been successful, despite significant time has been devoted to its development (see section III.5).

III.5 Smolts counting and observation

Main results expected from the tests depicted in this report are a quantification of the effect of varied downstream passage geometrical parameters on fish attraction. Such quantification has been primarily done considering the number of smolts caught in the downstream reservoirs during each tests, i.e. the number of smolts exiting the flume through outlet A or B. Such counting is easy to do manually by catching the fishes in the downstream reservoirs with a net.

It has been decided to film the tests with several camera in order to provide additional data thanks to post images analysis. Such data could be time evolution of smolts movement, smolts trajectories, gregarious behaviour or number of fishes crossing the outlets “going and coming”.

Significant time has been devoted to developing tools for analysing images from the top view camera in order to count fishes going and coming through the outlets and thus enriching the quantification of outlets attraction. Such tools have to be able to detect fishes on an image and to follow them along time. Considering images decomposition and application of correlation techniques, it has been possible to get encouraging results, such as depicted on Figure 8 and Figure 9. However, strong problems have been encountered with light reflexion at outlets location. These problems have not yet been fixed and reliable results from image analysis will not be available.

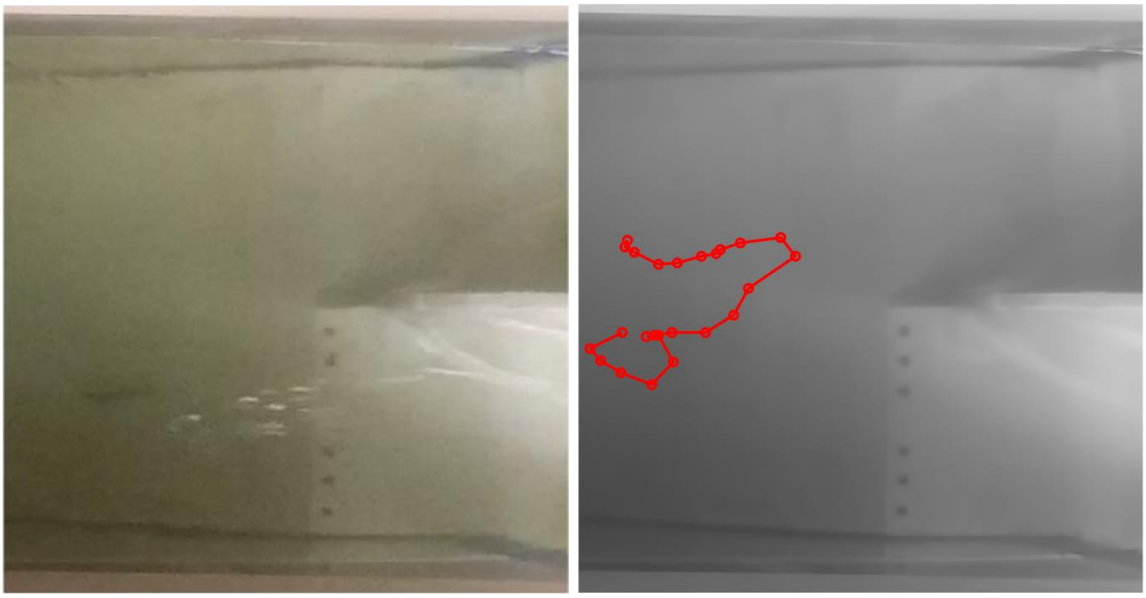

Figure 8 : Example of an image from the top view camera (left) and smolt trajectory extracted from the analysis of a succession of images (right)

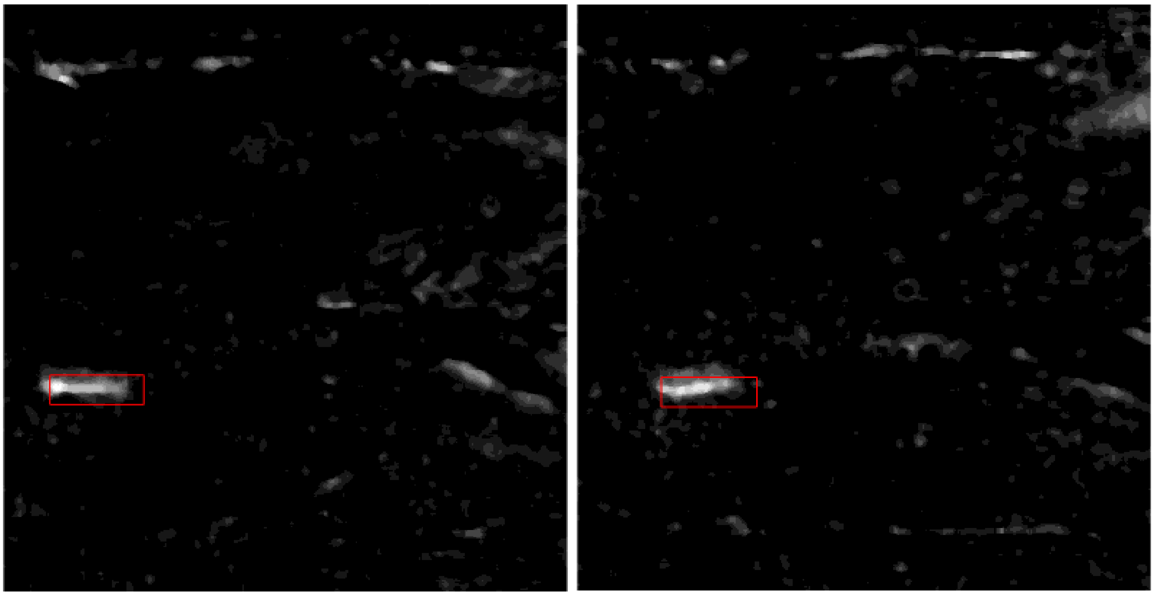

Figure 9 : Example of automatic fish detection on two successive images from the top view camera transformed to highlight fish location

IV. Results and discussion

IV.1 Geometric and tests configurations

As mentioned in chapter III, 346 smolts have been used for the tests. 82 (10+72) of them have been used to verify and optimize the experimental protocol. 264 smolts have then been used to assess the effect of the geometrical parameters defining the outlets. These 264 smolts have been divided into 3 groups (Groups 2 to 4: 2x72smolts +120 smolts) used to test 7 geometric configurations of the oulets. Table 2 presents the groups division into batches and all the geometric configurations tested.

Test n°	Group n°	Batch n°	Number of smolts/batch	Ramp slope	Rack bars spacing	Rack location
1	2	2.1 and 2.2	18	60%	No rack	
2	2	2.3 and 2.4	18		10cm	Weir crest
3	3	3.1 and 3.2	18	40%	No rack	
4	3	3.3 and 3.4	18		10cm	Weir crest
5	4	4.1 and 4.2	20		20cm	
6	4	4.3 and 4.4	20		No rack	
7	4	4.5 and 4.6	20		10cm	Ramp toe

Table 2: Tested geometric configurations of the outlets

The difference between tests 3 and 6 is that the separating wall between outlets A and B has been extended from the weir crest to the ramp toe, as required to place the rack at the ramp toe. Main geometric configurations are sketched on Figure 10 to Figure 13).

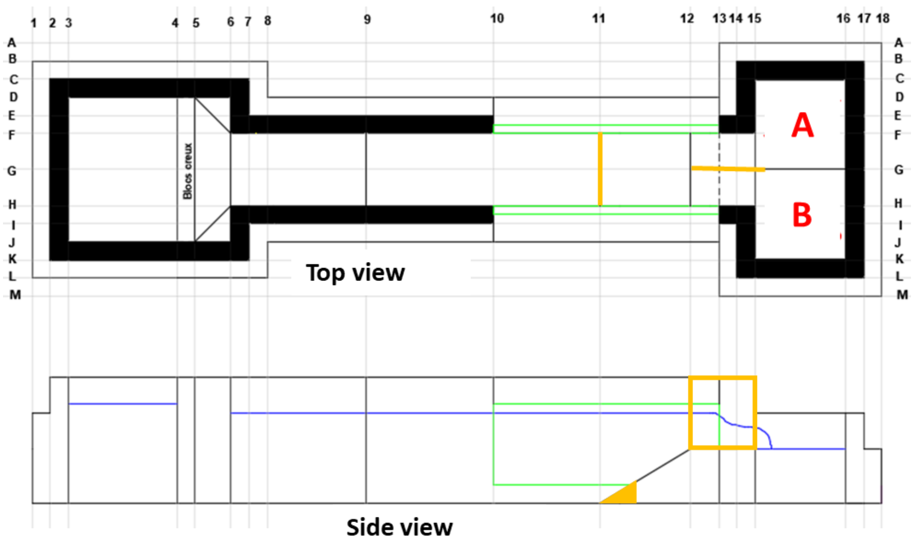

Figure 10 : Sketch of flume configuration for test 1 (60% ramp slope)

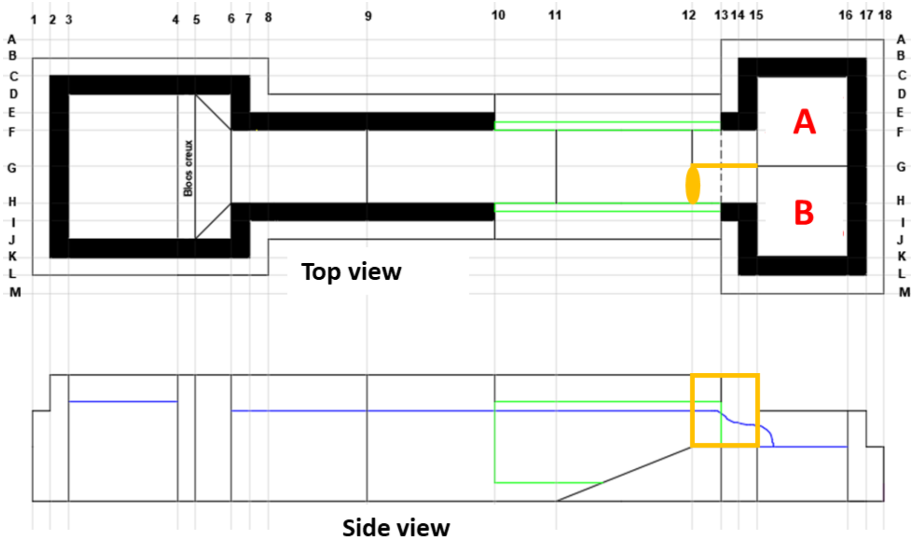

Figure 11 : Sketch of flume configuration for tests 4 and 5 (40% ramp slope, rack at weir crest)

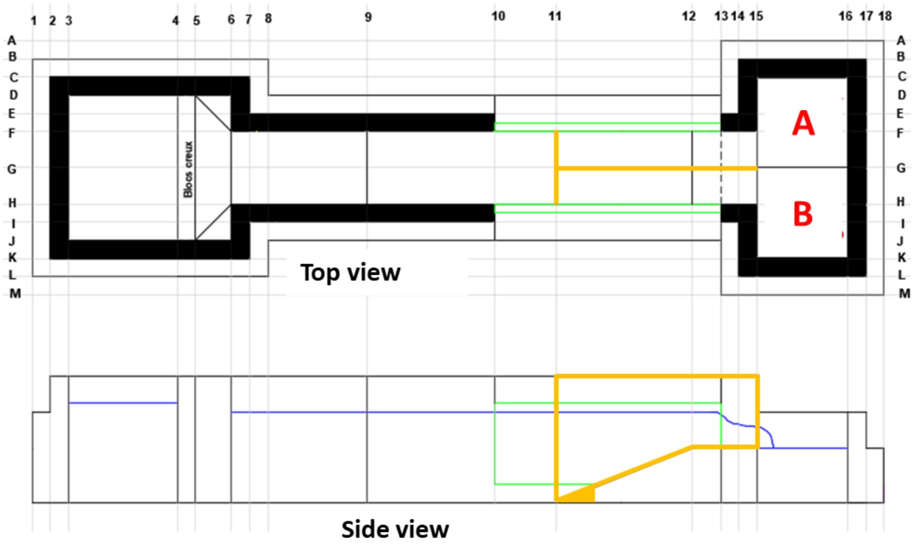

Figure 12 : Sketch of flume configuration for test 6 (40% ramp slope, separating wall extended to ramp toe)

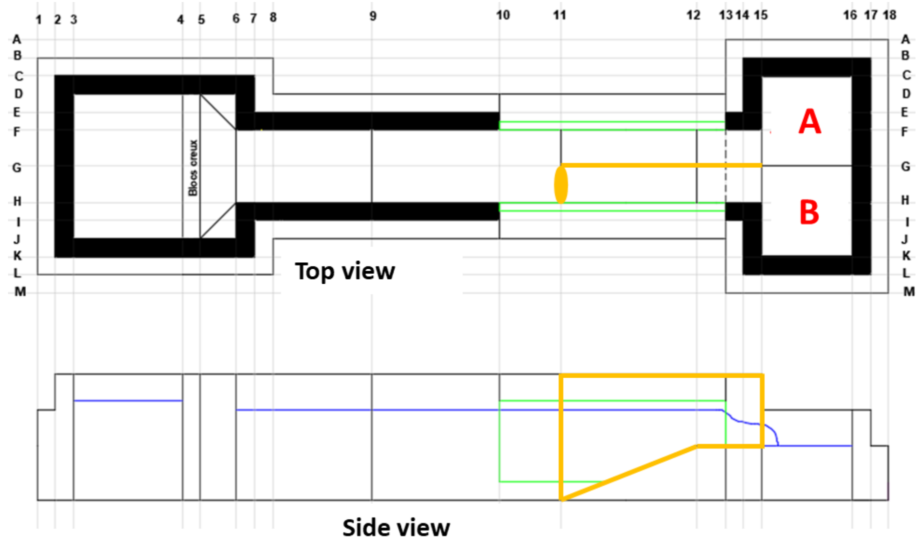

Figure 13 : Sketch of flume configuration for test 7 (40% ramp slope, rack at ramp toe)

IV.2 Global results

Bars on Figure 14 show the number of smolts choosing outlet A or B during each test. The graph shows fishes choosing outlet A or B "naturally" as well as the number of fishes choosing outlet A or B when forced to exit the flume. When a rack has been placed, it was always in outlet B, i.e. outlet A is always free of rack.

It is interesting to notice that forcing the smolts to make a choice never change the most chosen outlet during a test. Proportion of forced passages varies from 5.5 to 38.9% of a batch during a test, with an average of 19.4%. However, in the sequel, forced passages have not been considered to analyse the effect of the tested parameters.

Repetition of the tests for each configuration has been done to overcome the effect of the gregarious behaviour of the smolts and to minimize the effects on outlet selection of parameters not controlled in the study such as lighting for instance. In this respect, each test has been down one time in the morning and the other time in the afternoon. Results analysis in the following has been performed considering aggregated results per configuration. These values are given in Table 3.

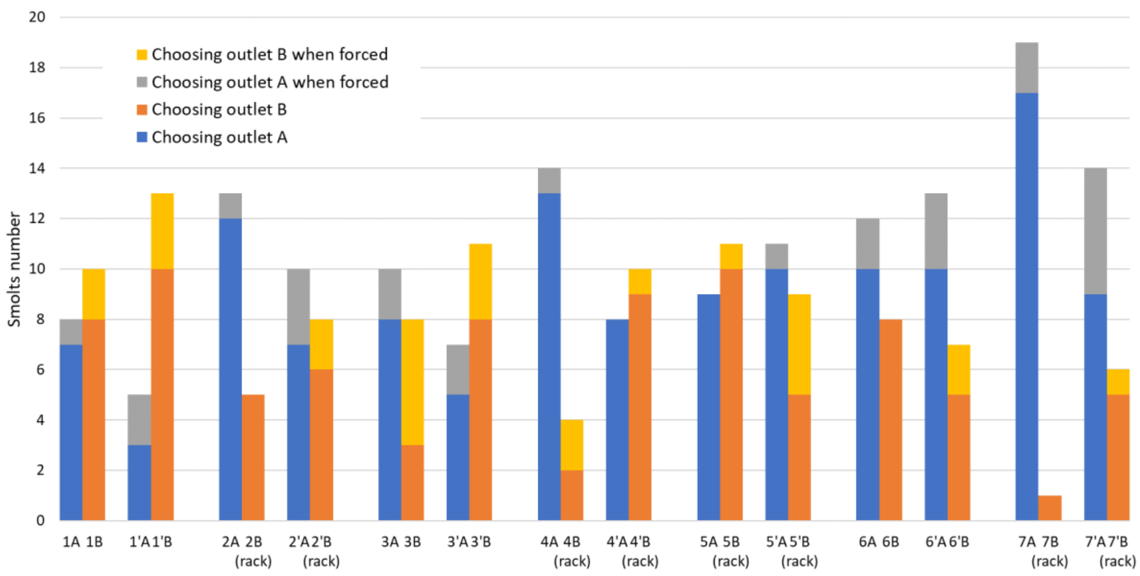

Figure 14 : Global results in terms of number of smolts for each test

Test n°	Group n°	Batch n°	Choosing outlet A	Choosing outlet B	Choosing outlet A when forced	Choosing outlet B when forced
1	2	2.1 and 2.2	10 (27.8%)	18 (50%)	3 (8.3%)	5 (13.9%)
2	2	2.3 and 2.4	19 (52.8%)	11 (30.6%)	4 (11.1%)	2 (5.6%)
3	3	3.1 and 3.2	13 (36.1%)	11 (30.6%)	4 (11.1%)	8 (22.2%)
4	3	3.3 and 3.4	21 (58.3%)	11 (30.6%)	1 (2.8%)	3 (8.3%)
5	4	4.1 and 4.2	19 (47.5%)	15 (37.5%)	1 (2.5%)	5 (12.5%)
6	4	4.3 and 4.4	20 (50%)	13 (32.5%)	5 (12.5%)	2 (5%)
7	4	4.5 and 4.6	26 (65%)	6 (15%)	7 (17.5%)	1 (2.5%)

Table 3: Global test results aggregated per configuration in terms of smolts numbers and percentage of batch

IV.3 Attraction symmetry

The attraction symmetry can be assessed considering results of tests 1, 3 and 6 (Figure 15). Indeed, both outlets were identical for these tests, despite the ramp slope and the separating wall length were different.

Test n°	Choosing outlet A	Choosing outlet B
1	10 (36%)	18 (64%)
3	13 (54%)	11 (46%)
6	20 (61%)	13 (39%)

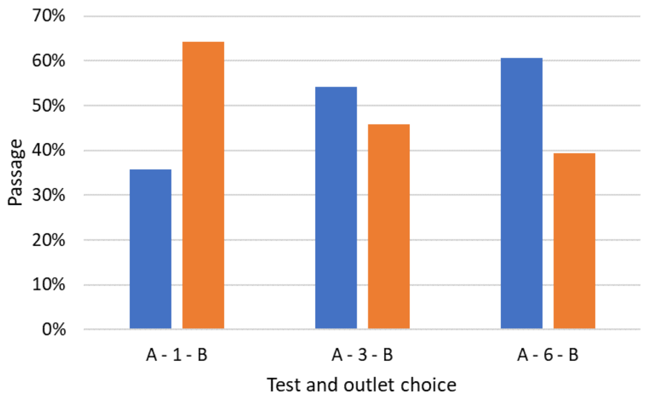

Figure 15: Results for tests 1, 3 and 6 – Unforced choice – Outlet selection

It appears that attraction of the outlets is not perfectly symmetric. In addition, it is not always the same outlet that is more attractive than the other one. As already mentioned, smolts are not fully rational bodies and have a gregarious behaviour: once a fish make a choice, some others will follow. This is probably the main reason why both outlets are not chosen at 50%. Maybe that with more tests, the tendency will be to a more even repartition.

In any case, it is interesting to notice that average selection of each outlet among the 3 tests with identical outlets (1, 3 and 6) is exactly 50%... On the contrary, average selection for all the tests with non-symmetric outlets is 67% for outlet A and 33% for outlet B. Racks were only placed in outlet B while outlet A was the same for all the tests. This suggests that identical outlet are equally attractive while an outlet with a rack, whatever its position, is less attractive than the same outlet without rack.

IV.4 Effect of rampe slope

The effect of the ramp slope can be assessed considering the same test as for attraction symmetry. Indeed, test 1 considers a 60% slope while tests 3 and 6 consider a 40% slope. Difference between test 3 and 6 is the length of the separating wall. As the outlets are identical in these cases, the effect of the ramp slope can be quantified regarding the number of smolts exiting the flume without being forced (Figure 16).

Test n°	Unforced choice (outlet A & B)
1	28 (78%)
3	23 (67%)
6	33 (83%)

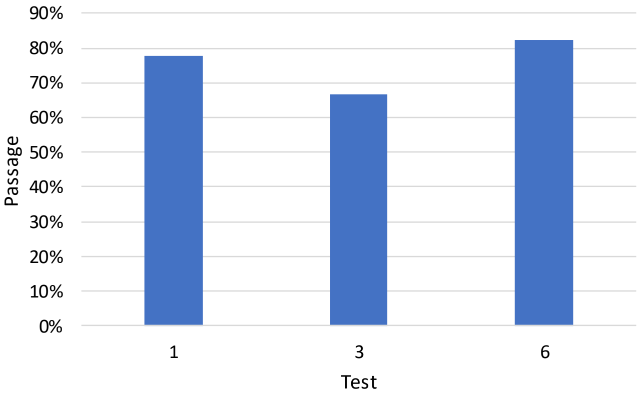

Figure 16: Results for tests 1, 3 and 6 – Unforced choice

60% slope is more attractive than 40% one when the separating wall is placed only on the crest. Extending the separating wall to the ramp toe increases drastically the percentage of fishes exiting "naturally" the flume for a slope of 40%.

Tests 2 and 4 can also be used to compare the ramp slope effect (Figure 17 and Figure 18). Both tests consider a rack with 10cm bars spacing on the outlet B crest. Test 2 was with a 60% slope ramp while it was 40% for test 4.

Comparison can be done considering the number of smolts choosing an outlet without being forced (Figure 17) and also the repartition between both outlets (Figure 18). Whatever the way to compare the results, they are very similar. 40% slope is a little bit more attractive in terms of global passages (Figure 17) but 60% slope shows a smaller effect of the rack (Figure 18).

In both cases, the presence of the rack in outlet B decreases significantly its attraction.

Test n°	Unforced choice
2	30 (83%)
4	32 (89%)

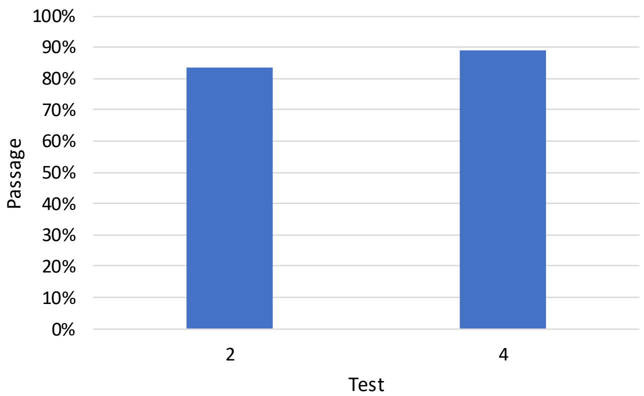

Figure 17: Results for tests 2 and 4 – Unforced choice

Test n°	Choosing outlet A	Choosing outlet B
2	19 (63%)	11 (37%)
4	21 (66%)	11 (34%)

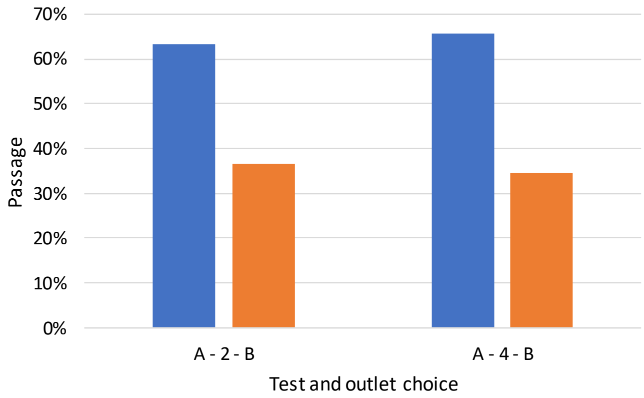

Figure 18: Results for tests 2 and 4 – Unforced choice – Outlet selection

Looking more in details to the results shows that time for smolts to move downstream is shorter with the 60% slope than with the 40% slope. After 65 min of test, 90% of the smolts have already make a choice with the 60% slope while such a percentage is reached only after 135 min of test with a 40% slope.

60% slope is thus better than 40% slope, despite the steep slope does not respect the criteria of a velocity gradient below 1m/s/m.

IV.5 Effect of rack bars spacing

The effect of rack bars spacing can be assessed considering results of tests 4 and 5 (Figure 19). Bars spacing is 10cm for test 4 and 20cm for test 5. Results of test 3 (same ramp but no rack) is also presented for comparison.

Test n°	Choosing outlet A	Choosing outlet B
4	21 (66%)	11 (34%)
5	19 (56%)	15 (44%)

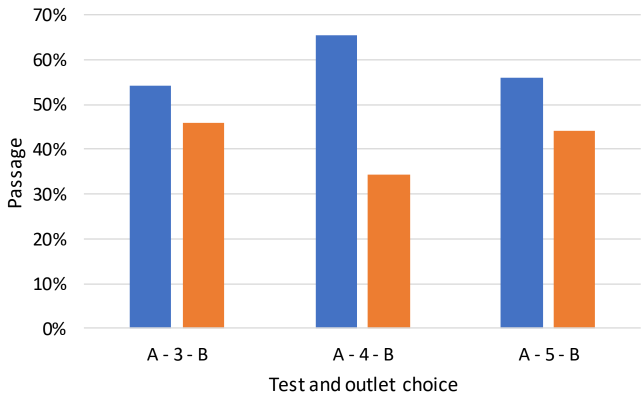

Figure 19: Results for tests 4 and 5 compared to test 3 – Unforced choice – Outlet selection

Again, it can be seen that a rack decreases outlet attraction. 20cm bars spacing has however a smaller effect than 10cm one.

IV.6 Effect of rack location

The effect of rack location can be assessed considering results of tests 4 and 7. The rack is located on the crest for test 4 and at the ramp toe for test 7. The ramp slope is 40%. Tests 3 and 6 are the reference tests without rack but with the same length of separating wall. Results of these tests are presented in Figure 20.

Test n°	Choosing outlet A	Choosing outlet B
3	13 (54%)	11 (46%)
4	21 (66%)	11 (34%)
6	20 (61%)	13 (39%)
7	26 (81%)	6 (19%)

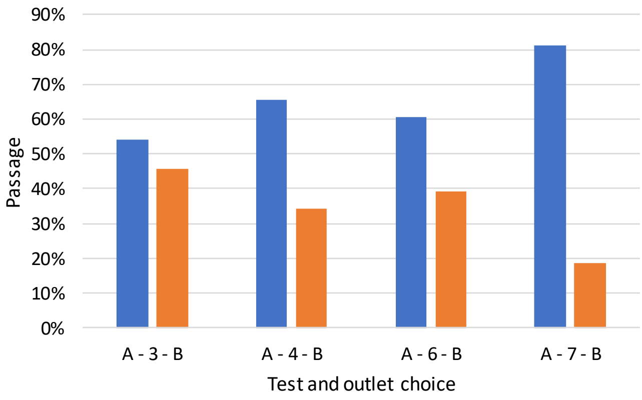

Figure 20: Results for tests 3, 4, 6 and 7 – Unforced choice – Outlet selection

In both cases of rack location, the presence of the rack decreases significantly the attraction of the outlet B. Extension of the separating walls also decreases the attraction of outlet B, with and without rack. But the most important result is that rack location at the ramp toe as a strong negative impact on outlet B selection.

V. Conclusions

1:1 physical model testing with real smolts has been performed in the laboratory of Engineering Hydraulics – HECE of the University of Liege during the second year of the Life for Fish project in order to test the influence of several geometric parameters of a downstream passage on fish attraction.

To our knowledge, such tests are original. Significant time has thus been devoted to design the experimental set up and to tune the test methodology. Tests have been performed in a straight flume whose downstream extremity represents a downstream passage with its acceleration zone, a weir to control the flow conditions and a downstream basin. This downstream part was divided in two passages, either geometrically similar or different depending on the configuration.

As much fishes as available during a single season from the Conservatoire du saumon mosan have been used to assess the effect of varied geometrical parameter on oulet attraction. The parameters whose effect has been analysed are the presence of a rack made of vertical cylindrical bars, the location of the rack and the bars spacing. Two ramp slopes have also been tested for the acceleration section.

Each test has been repeated twice with smolts batches from 18 to 20 individuals. Each smolt was placed only once in the experimental set up (no acclimatization).

Tests have been performed with salmon smolts from the Conservatoire du saumon mosan. After the tests, the smolts have been released in the Ourthe river.

Regarding the experimental set up, tests showed that the downstream reservoirs such as presented in this report are too small. Consequently, the test procedure had to be adapted to prevent the death of fishes exiting the test flume. It was expected to perform image analysis from camera recording in order to get insights into fishes movement along time during a test. Further developments are needed to get these results as strong problems emerged for fish detection because of light reflexion on the free surface.

Counting of the number of smolts exiting the flume through an outlet or the other during a test enabled to assess the effect on fish attraction of each of the parameters tested. In particular, the tests showed that

- A test facility such as considered in this study is suitable to observe downstream movement of salmon smolts, i.e., globally , the smolts were moving downstream naturally when placed in the flume, within at period of a few hours;
- A rack with vertical round bars in a downstream passage always decreases its attraction compared to the same geometry without rack;
- Vertical bars spacing of 20cm reduces less fish attraction than a bars spacing of 10cm. With a 20cm bars spacing, the negative effect of the rack is limited;
- A rack placed in the low velocity zone (toe of the acceleration ramp) reduces more the passage attraction than the same rack placed in the high velocity zone (control section);
- A ramp slope of 60% in the acceleration zone is more attractive than a ramp slope of 40%.

The conclusions of this study have been considered to design the downstream passage at Grands Malades pilot site, and in particular the trash rack design.

VI. Appendix

VI.1 Notification of Animal Ethics Committee of ULiege

DOCUMENT A CONSERVER
PAR LE SERVICE

Commission d'Ethique Animale

Dossier n°: 18-2086 **Date de réception: 10012019**
Catégorie et évaluation rétrospective :
Date de l'avis: réunion 23012019
Avis : prise d'acte : pas une expérience au sens légal du texte.
Rappel : (AR 29052013)
-toute personne impliquée doit être certifiée légalement AVANT d'intervenir
-les animaux doivent être contrôlés 7j/7
ACTIONS À MENER PAR LE CHERCHEUR :
-RÉPONDRE AU COURRIER SI NÉCESSAIRE
-LA COMMISSION ENVOIE LE NTS ANONYME au SPW
- **EVALUATION RETROSPECTIVE OBLIGATOIRE** A L ECHEANCE FIXEE : aucun rappel ne sera envoyé et cette formalité est légale (AR 29052013)

Codes et significations
Avis « favorable » : Vous pouvez débuter le protocole.
Avis de report : la Commission ne rend pas d'avis à ce stade : Le protocole ne peut PAS être mené. Vous devez/pouvez répondre aux questions posées par la Commission. Vous devez attendre son avis AVANT de débuter le protocole.
Avis défavorable : la Commission refuse le protocole expérimental

Liège, le 31012019
4000 Sart Tilman
Pr. P PONCIN
Dr Sc M Ovidio
Dr Sc S Erpicum

Chers Collègues,

Votre dossier intitulé «**L4F-Etude comportementale de smolts de saumon atlantique**» a été examiné en date du 23012019 par la Commission et a reçu le numéro **2086.**

La Commission a classé ce dossier comme n'étant pas une expérience au sens légal du terme (observation simple).
Elle en prend acte.
-Elle vous demande de continuer à lui soumettre ce genre de demande à l'avenir.
-En cas de nécessité pour une publication scientifique, elle confirmera être informée de vos travaux.
-Il vous revient de respecter les règles légales éventuelles en termes de transport et origine des poissons (déjà en captivité).
-Il vous faudra informer l'Expert bien être des dates de réalisation de l'expérience avant leur réalisation afin qu'il puisse passer durant le protocole.

Nous vous prions de croire, chers Collègues, en l'expression de nos sentiments les meilleurs et vous souhaitons plein succès dans vos recherches.

Pour le Pr. J. Balthazart, Président,
Pr. P. Drion, Secrétaire

ULG – Comité d'éthique - Secrétariat - Sart-Tilman, bât. B23 – Tour de Pathologie - 4000 Liège – Belgium
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