VerdErg VETT Fish Testing Programme - 3rd Party Accreditation of Test on fish survivability of prototype VETT venturi

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Acknowledgements:

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University of Cumbria

CONTRACT RELATING TO THE SUPPLY OF CONSULTANCY SERVICES TO VERDERG RENEWABLE ENERGY LTD

DATE: 6th May 2013

Company details:

VerdErg Renewable Energy Ltd.
Lansbury Estate
Unit 5 & 6
102 Lower Guildford Road
Knaphill, Surrey GU21 2EP

The Work

The University of Cumbria agree to provide an academic to carry out fish testing activity in line with the project specification outlined below.
The work will be carried out by an academic over 5 days, who will have an additional half day to complete a report.

Project Specification

- Review the instrumentation and its calibration – pressure transducers, piezometers, sensor fish, data acquisition software and video recording equipment.
- Attend the Vis Advies test facility in Nieuwegein to witness test runs through the SMEC rig being conducted and post-passage fish welfare monitoring.
- Ensure the testing approach has been followed in accordance with relevant HSE and animal testing procedures.
- Confirm that the results of the tests were actually acquired.
- Validate the findings of the statistical analysis and research findings from Vis Advies.
- Produce an account of the fish friendly performance of SMEC technology in the form of a report and/or certification.

Timescale

Start date: May 2013 End Date: August 2013 (completion of report)

Cost
Verderg Renewable Energy Ltd will be invoiced for £5,000 plus VAT. This will include all travel and academic charges and will be collected in two instalments:

Payment terms will be strictly 30 days from invoice.

Intellectual Property
As per NDA agreement.

<u>Declaration</u>
I confirm that the above mentioned information is deemed correct and outlines the agreement made between Verderg Renewable Energy Ltd and the University of Cumbria

Verderg Renewable Energy Ltd agrees to pay £5,000 to the University of Cumbria

Verderg Renewable Energy Ltd agrees to pay the VAT element of the work undertaken

Signed for and on behalf of Verderg…………………………… ………………………… Date …………

Position……………………………………………………………………………… ……………………………

Signed for and on behalf of University of Cumbria………………………………………. Date … ………

Position……

University of Cumbria, Fusehill Street, Carlisle, CA1 2HH

Background:

The Venturi-Enhanced Turbine Technology (VETT) is a hydropower technology currently under development by VerdErg Renewable Energy Ltd, which is designed to produce electricity from low head drop sources of potential energy; typically over weirs or steep river courses. VETT is designed to amplify the low head drop source by up to five times such that a small conventional, high-speed turbine and generating equipment can be installed economically. 80% of the flow is passed through a venturi, creating a region of low static pressure, which draws the remaining 20% of flow via a turbine at an amplified head drop.

Most work in this area has focused on the pressure drop occurring 5-30m head drop of water and the potentially deleterious effects this may have on fish, providing they are not subjected to blade strike. Previous reports suggest fish are vulnerable to extreme pressure transients common in these systems as they pass through. The extent of the injury is dependent on the magnitude of the pressure flux in the system and the duration of acclimatization and exposure. This can cause barotrauma in fish with the type and severity of injury varying with fish species and life stage; such as the development of air bubbles in the tissues of fish. Potentially, one of the most damaging impacts would be to the air in the swim bladder and the buoyancy it generates for the fish. A drop in pressure may lead to a sudden expansion of the air in the swim bladder, causing it to rupture.

One of the main functions of this current testing process is to determine the functional implications for fish which pass through the VETT device. In so doing, this will provide evidence of independently observed testing to determine the impacts of passage through the VETT on a range of different test fish species. The results of these tests can then be used to help VerdErg address any concerns of the regulatory authorities regarding fish welfare in the future installation of a commercial VETT device in an open environment.

University of Cumbria Outcomes:

- **Review the instrumentation and its calibration – pressure transducers, piezometers, sensor fish, data acquisition software and video recording equipment.**

  VerdErg supplied a detailed outline of the VETT rig prior to departure to the test facility in Nieuwegein. This allowed a good examination of the equipment status and parameters prior to the testing being undertaken.

  On-site, further discussions were held throughout the duration of the testing period:

    Robert Kettle: the mechanical/structural engineer during the construction of the apparatus itself

    Jennifer Gomez-Molina: the project manager to review the bigger picture overview of the mechanism and the proposed testing regime itself

    Dr Paul Bird (ex-School of Civil and Structural Engineering at University of Plymouth), was on site to undertake all the electronic calibration and recording of flow, pressure and signal transduction data for the testing process

    Facility staff at VisAdvies (Dr Jan Kemper and his technical staff), who were aiding in the build of the VETT apparatus and were responsible for the sourcing, husbandry and physical testing/analysis of the impacts of the testing process on the different test species of fish.

- **Attend the VisAdvies test facility in Nieuwegein to witness test runs through the VETT rig being conducted and post-passage fish welfare monitoring.**

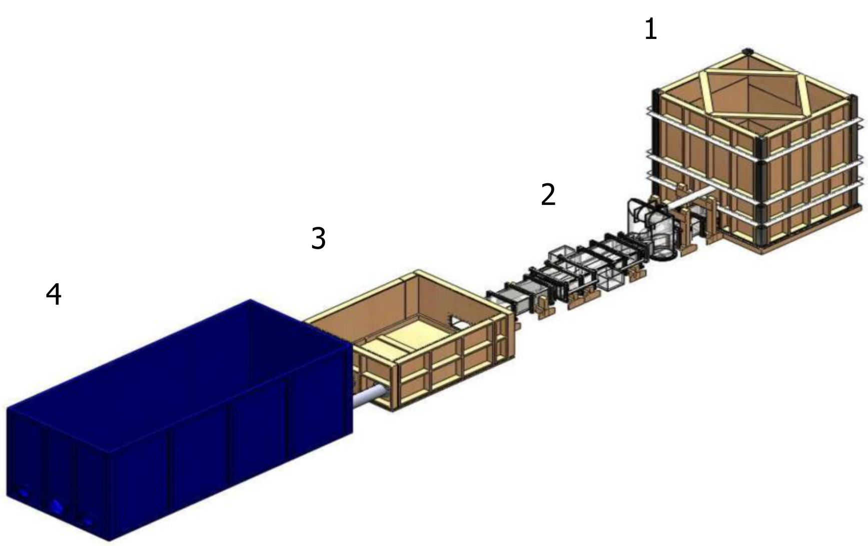
  Dr Billy Sinclair, Reader in Genetics and Conservation at the University of Cumbria attended the final stages of construction of the VETT apparatus during the week commencing 13th May 2013 at the VisAdvies facility in Nieuwegein, Holland.

The first of the test sample species arrived in the facility on the 14th of May, with others arriving the following day.

Live test runs on the VETT apparatus, with different fish species and different pressure head drops were completed on the 17th May 2013.

- **Ensure the testing approach has been followed in accordance with relevant HSE and animal testing procedures. Confirm that the results of the tests were actually acquired.**

Fig 1: The VETT prototype laboratory setup



1. Header tank (3m x 2m x 3m) to source water flow into the VETT device emulating upstream flow conditions
2. Rectangle culvert where power generation and pressure decompression occurs (VETT)
3. A sink tank (3.30m x 2.4m x 1.22m) to collect the fish;
4. Reservoir (6 x 2.5 x 3 m) to pump water back to the header tank, connected to the sink tank with 2x 10" and 1 x12" hoses

At the VisAdvies facility, the physical build of the test apparatus was undertaken:

Fig 2a: The 3m Header tank with associated water inlet pipe and connection to the VETT device.

Fig 2b: Sink Tank, showing connection to the Reservoir and the VETT device.

Fig 2c: Sink Tank, showing capture netting and internal baffle structures to provide calm areas for fish to rest in after passage through the VETT.

Fig 2d: Holding Tank and Entry Port for fish entering the VETT Apparatus

Fish were held in an elevated holding tank (top left), with constant fresh water flow (top right), a gravity fed process (above left and above right) allowed a controlled entry of the fish into the VETT apparatus via an open/closing mechanism on the entry pipe (right)

Fish Testing Authorisations:

In accordance with Dutch law, all licensing and regulatory approvals for the testing work were sought and held by VisAdvies prior to the experimental work being undertaken.

VisAdvies is licenced to perform experiments with animals. In addition, approval was sought from the appropriate "Animal experimental committee" for these particular experiments. All personnel involved in the experiments were authorized by the Animal Experimental committee (cf. Article 9 authorized officer WOD (J.H. Kemper) and cf. Article 12 authorized officer WOD (H. Vis and Robin Blokhuijzen) under the guidance of Drs P.S. Kroon of the Central Veterinary Institute (cf. authorized officer with Article 14 WOD). Dispensation was also received from the Ministry of economic affairs to catch and use fish that have a protected status in the Netherlands

Species selection

Tests were conducted using live fish to identify the effect of rapid pressure decompression over a range of different pressure transients. To maintain the integrity of the tests for future development and placement work within UK waters, a number of species were identified which are resident in the UK and therefore have direct relevance to future work.

It is fully recognised that there are many different types of fish present in UK waters which may come into contact with a functional VETT apparatus and that they are not all represented in this pilot-study suite of tests. The functionality of these tests in examining the impacts of passage through a VETT device on the general health and wellbeing on selected species is to provide representative empirical data. As a result, he research outcomes are valid as representative at this level. To include a comprehensive list of test species and comparable numbers of individuals would essentially be impossible and as such, representative species, with/without swim bladders and of different biological/conservation considerations have been chosen to provide relevant baseline data. The proposed species types and the size classes of the test fish are presented in table 1 below. Environmental legislation indicate it is a priority to cater for sensitive and protected species like eel (*Anguilla Anguilla*).

Table 1: Proposed test species of fish to be used in the testing process:

Latin Name	*Common Name*	*Swim Bladder*	*Size Class*
Oncorhynchus mykiss	Rainbow trout	Yes	15-20cm
Salmo salar	Atlantic salmon	Yes	15-20cm
Anguilla anguilla	Eel	Yes	≤ 45cm
			> 45cm
Cottus gobio	Bullhead	No	10-15cm

Salmon and Rainbow Trout

The Salmonids that were available for testing, salmon (*Salmo Salar*) and Rainbow Trout (*Oncorhynchus mykiss*), were sourced from a commercial supplier due to logistical availability and time of year. For salmon, the smolt developmental stage was considered the most appropriate for testing here as this represents the size and live stage at which salmonids migrate downstream. Of the 200 individual smolts which were received for testing, a subset, equivalent to 10% of the overall batch, were measured to provide an estimate of the average overall size in the test group. This was found to be 182mm ± 2.1 mm. Salmon smolts generally range from 100mm upwards in size, other salmonid species, such as sea trout (*Salmo trutta*) often reach closer to 200mm, therefore 182mm was considered to be a relevant, representative size range for this testing process.

For rainbow trout, of the 200 individual animals which were received for testing, a subset, equivalent to 10% of the overall batch, were measured to provide an estimated of the average overall size in the test group. This was found to be 166mm ± 1.9mm.

Ideally, it would be best to look at a spread of size ranges across the lifecycle of each of the species under investigation, such that any potential impacts of the VETT apparatus could be assessed, however this is not realistic in this context. The logistical challenges of such a regime are enormous, the availability of large numbers of animals at different life stages is highly constricted and the associated numbers of animals involved does not meet with the Animal Ethics Committee core theme of reducing the actual number of animals involved at each stage of an experimental process. By using an intermediate stage size group, a large number of test animals were not required and multi-species utility and extrapolation of results is a functional and relevant way forward.

European Eel

The European eel (*Anguilla anguilla*) is widespread in Europe, but world-wide, eel species are in decline, both in terms of juvenile stocks and adult catches. In 1998, ICES declared that "the European eel stock is outside safe biological limits and the current fishery is not sustainable." Since the eel grows very slowly in the cool, nutrient-poor waters of the UK, populations are highly vulnerable to over-exploitation.

As a conservation-relevant species, it is important to determine if the VETT apparatus would have any impacts on this species, when installed in a natural operating environment.

As the eels migrate from rivers to the sea (although many never actually leave the river systems), it is at this stage that they are likely to encounter the VETT apparatus. Size variation in eel populations is quite large, with many adults exceeding 450mm in length (males are usually smaller). The eels that were received for testing were divided into two size categories >450mm (as indicated above, this would most likely represent mainly female animals) and <450mm (a mixture of male and smaller female animals). As with the salmonids, a subset, equivalent to 10% of each batch, were measured to provide an estimated of the average overall size in the test group. This was found to be 320mm ± 3.9mm for the <450mm subset and 468mm ± 2.7mm for the >450mm subset.

Wild eel is not available at this time of year in Holland, so eels were obtained from a commercial eel farm in the Netherlands (Nijvis BV, Nijmegen). As with the salmonids, it is recognised that farmed animals will be subtly different from wild-caught individuals in terms of the different stresses and environmental factors which they are exposed to. While this is a relevant point to note, the animals themselves are fundamentally the same as wild-caught animals and have also been exposed to stress and challenge, making the baseline physiological and biochemical conditions essentially equal. It is not considered to be a significant factor in testing captive bred as opposed to wild-caught animals in this particular series of experiments

Bullhead

The Bullhead *(Cottus gobio*) is a small bottom-living fish that inhabits a variety of rivers, streams and stony lakes. It appears to favour fast-flowing, clear shallow water with a hard substrate (gravel/cobble/pebble) and is frequently found in the headwaters of upland streams. It is the only freshwater member of the family Cottidae that is native to the UK and is an SAC Annex II species.

For a number of logistical sourcing reasons, it was determined to use Round Goby (*Neogobius melanostomus)* in the test programme in place of the Bullhead (*Cottus gobio*), as they are comparable in many aspects of size, appearance and physiology. Round goby an introduced pest species in Holland and as such is easily obtained locally. For the Round Goby, a subset, equivalent to 10% of the overall batch, were measured to provide an estimated of the average overall size in the test group. This was found to be 134mm ± 3.8mm.

While the Round Goby is not identical to Bullhead in some of its behavioural characteristics, these are not considered to be significant for this suite of tests being undertaken in this trial.

Testing Protocols:

The test protocols employed developed by VerdErg after consultation with the Environment Agency in the UK and in discussion with staff at VisAdvies.

Using different water pressures in the header tank, 3 distinct loads were tested:

- Head drop of 1.0m
- Head drop of 1.5m
- Head drop of 2.0 m

Each species of fish to be tested would be broken down into different groups to facilitate these different head drops, for example:

- Salmon 1: 1.0m head drop;
- Salmon 2: 1.5m head drop;
- Salmon 3: 2.0m head drop;
- Salmon 4: control group

With 5 groups/size classes of fish Salmon, Rainbow Trout, Eel <450mm; Eel > 450mm and Goby, this meant a total of 5 VETT runs per head drop of water were conducted.

It had initially been proposed that each fish species which possessed a swim bladder would be acclimatized to the depth of the header tank for 3hrs prior to testing in the VETT apparatus. This system was undertaken in the initial testing runs but proved to be unworkable and was not continued in the testing process. Instead, an alternative entry protocol was developed for entry of the fish into the VETT apparatus. A holding tank containing the test samples was installed at a height elevated to that of the VETT system. Fish were taken from this holding tank and introduced via a gravity-fed, constant water flow system into the VETT apparatus.

Approximately ten minutes before the actual experiment the valve in the header tank was opened and the pump started to build up a steady flow of water through the system and develop a uniform pattern of flow. After each run, the pump was turned off as soon as possible, to prevent any incidental damage to the fish which were in the sink tank. After each run, the fish were removed from the sink tank by staff using catch nets and the placed into storage tanks (Fig 3 below) for observation during 72 hours.

Fig 3a: Test fish storage tanks at VisAdvies, showing individual holding/observation tanks for each test group during the trial.

Fig 3b: Test fish storage tanks at VisAdvies, showing the circulation water system which supplied fresh, aerated water to the system during the trial.

Observational assessments were carried out on the fish prior to their entry into the trial (to record the presence of any pre-existing damage) and after passage through the VETT apparatus.

In the observational assessment process, each individual fish was judged by the following criteria:

- Immediate external damage after the run, like scale loss, haemorrhage etc;
- Immediate mortality;
- Delayed mortality;
- Swimming behaviour;
- Internal damage for all fish that dies or otherwise gives rise to dissection.

It would be expected, in the case of significant trauma, that any casualties would present in the first period after the experimental treatment, therefore, observations in the first 12 hours were conducted at 2hr intervals. After this initial 12hr period, observational frequency was every 3hrs (as the expected incidence of significant impact was lessened) until the end of the 72hr observational period.

A full internal damage assessment was made for any experimental or control fish which died during the course of the experimental testing scheme, or for any which displayed signs of the criteria noted above.

Video Recording:

A Sony NEX-FS700 Full-HD Super Slow Motion camcorder, was used to make slow motion video recordings of the different fish passing through the VETT apparatus. This video footage was to form part of the analysis protocol, to observe the behaviour of the fish during and after the passage through the apparatus. The objective being to make footage during all the runs and of the different fish species.

Fish Entry into the VETT Apparatus

As indicated in Fig 2d, the fish were placed into an elevated holding tank prior to being introduced into the VETT. This mechanism introduced (via an open/closed valve) the fish through a connecting pipe which opened out into the VETT close to the point of entry of the water coming out of the header tank. A constant flow of water through the gravity-fed pipe system ushered the fish into the pipe and the VETT, as shown in Fig 4a and 4b

Fig 4a (left): Fish entry mechanism to allow the controlled entry of test fish into the VETT apparatus.

Fig 4b (below): Illustrating the entry of fish into the VETT apparatus

To minimise the chances of fish coming out of the acclimatisation tank and being caught/swimming around in the header tank, the connecting pipe from the acclimatisation tank passed through the header tank and it's exit was in the entrance of the Perspex culvert section of the VETT apparatus, as shown in Fig 5. This was done to ensure that the fish were introduced in such a way that they could swim as naturally as possible into the VETT apparatus and to minimise any potential for damage they may experience being released directly into the header tank.

Fig 5a (above): Entry pipe running from acclimatisation tank, which introduces the test fish into the VETT apparatus.

Fig 5b (Left): Illustrating the passage of the entry tube, through the body of the header tank and into the mouth of the VETT apparatus

Validate the findings of the statistical analysis and research findings from Vis Advies.

As indicated above, the tests undertaken were carried out at three specific head drops of water: 1m, 1.5m and 2m. For each water head drop, there were 4 species of fish tested (Salmon, Trout, Eel and Goby), with the eels being subdivided into two size classes.

In accordance with Dutch laws, all licensing and regulatory approvals for the testing work were sought and held by VisAdvies prior to the experimental work being undertaken. Discussions with the licensing authorities and the Animal Experimental Ethics Committee determined that for each test run, a maximum of 50 individuals per species and size group should be used. The committee determined this experimental number based on statistical grounds to limit the number of individuals, following the guiding principles underpinning the humane use of animals in scientific research - the three Rs (Replacement, Reduction, Refinement).

It was determined that, to minimise any unnecessary suffering, that 50 individuals per test should be enough to achieve auditable results from the tests and could be judged to satisfy any external agency/verifier beyond reasonable doubt that the outcomes from the tests would be valid both statistically and ethically.

From the 15 different test groups of animals and the control groups which were part of the overall process, there were no recorded incidences of mortality during the tests themselves. During the 72hr monitoring period post-testing, five Atlantic salmon smolts died. Specifically two fish from test scenario 2 (1.5m head drop of water), one from test scenario 3 (2.0m head drop of water) and two individuals from the control group.

All these fish showed signs of a fungal infection (non-specified species), especially on their fins (as shown in Fig 6).

Fig 6: Salmon smolt shown development of fungal infection around fins/gills during post-testing observation period.

Two of the fish which succumbed to fungal infection were from the control group and as such, the deaths were not considered to be due to the testing process or the passage through the VETT apparatus, but purely as a result of the infection itself.

Upon first observations of the fungal infection being recorded, approximately 20hrs into the 72hr post-testing observation, a small concentration of salt was introduced into the water and recirculated for 4 hours. At this point, the water was refreshed with clean, salt-free water. No further incidences of fungal infections were recorded.

All the individuals which died due to the fungal infection were autopsied to check for internal damage to susceptible organs which may have resulted from the VETT testing process – no damage to swim bladders etc. were found, as shown below in Figure 7

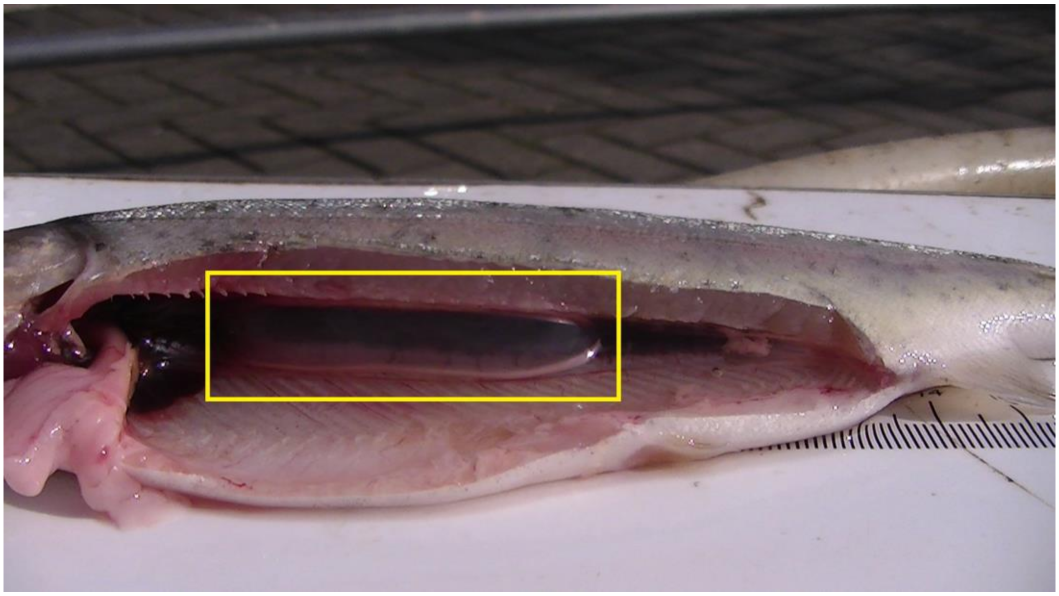


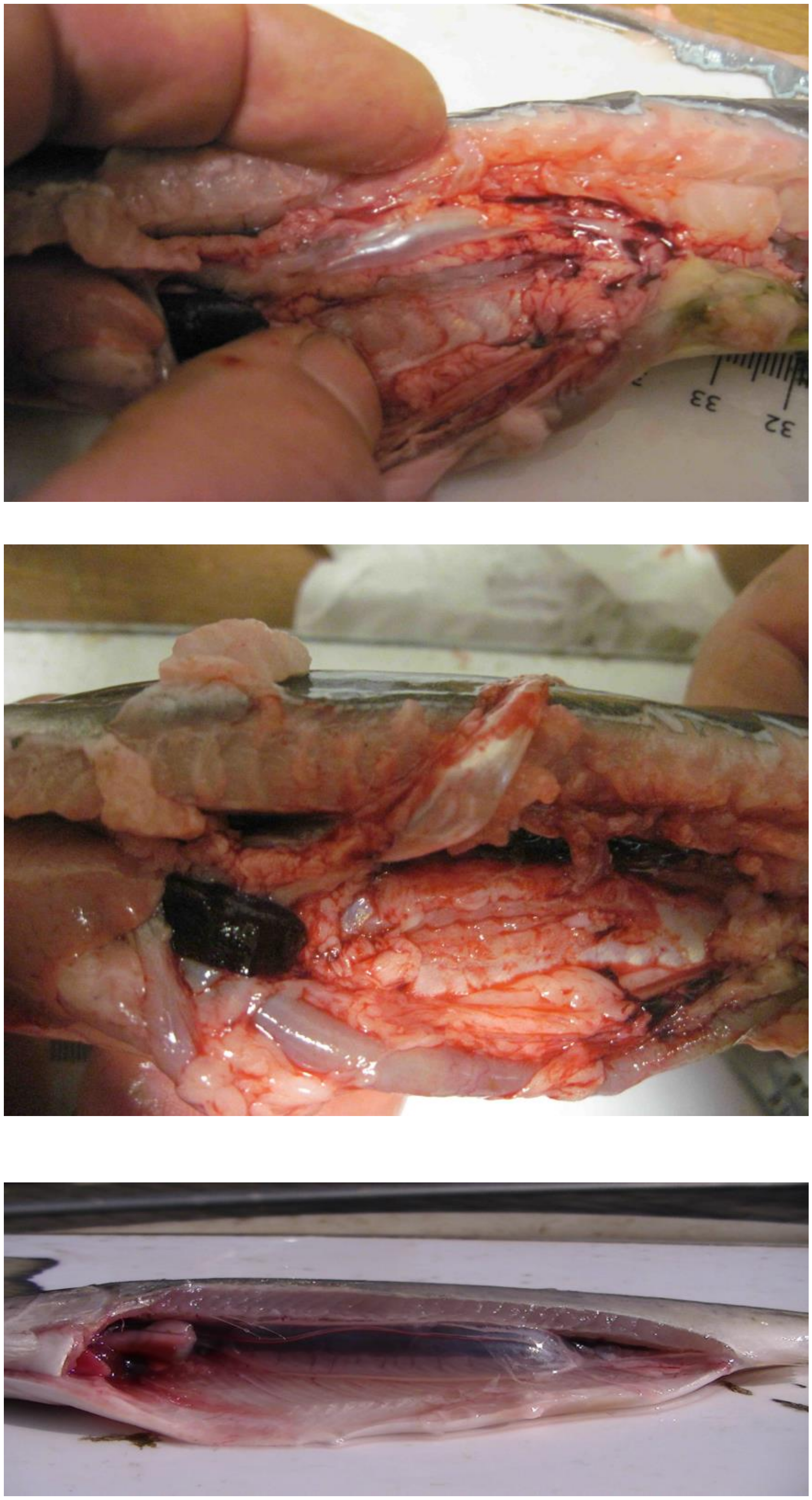
Fig 7: Autopsy of Salmonid smolt euthanized after fungal infection, showing no physical damage to susceptible internal structures such as swim bladder or blood vessels.

Qualitative physical assessments were also carried out on the fish (other than just observational recordings). In total, 10% of all eels tested were euthanized to assess the extent of any physical damage to susceptible structures (externally such as bubbles forming in the eye) and internally via autopsy, to check swim bladders and blood vessels. Numerically, 5 eels out of every group were assessed (3 head drop levels x 2 size classes= 6 groups).

For the salmonids (salmon and trout), a total of 25% of all animals (12 fish per group) were euthanized and autopsied. As the Round Gobies do not possess a swim bladder, no autopsies were carried out for this species, only external assessments.

During the autopsy process for each of the above, no physical damage or anatomical anomalies were recorded in the individuals examined, swim bladders were intact and there were no visible internal haemorrhages recorded, nor were there any physical signs of bubbles in the eyes (as shown in Figure 8).

Figure 8: Example autopsies showing undamaged susceptible internal organs and structures in test animals 72hrs after passing through the VETT apparatus



- **Produce an account of the fish friendly performance of VETT technology in the form of a report and/or certification.**

From the testing procedures and methods outlined above, I, Dr Billy Sinclair, Reader in Genetics and Conservation at the Centre for Wildlife Conservation, University of Cumbria, can confirm:

- The tests were carried out as outlined above and that all necessary licence and authorities were held at the time of the tests.
- Three different series of tests were conducted at 1.0m, 1.5m and 2.0m head drop of water and each of the 4 species of fish (n=50 per test) were tested at 1.0m, 1.5m and 2.0m head drops. A control group (n=50) for each species, which were not exposed to the VETT apparatus were also maintained for the duration of the tests.
- There were no recorded mortalities during the testing process itself, all fish which passed through the VETT apparatus survived without any visible injury. There were minimal casualties recorded after the testing process was competed and the fish were in the post-testing observation period. These were caused by the effects of a fungal infection, which is often seen when salmonids are being handled and kept in relatively high stock densities. This analysis was confirmed by the control group (not VETT exposed) where we also saw some infection and recorded two casualties.

While there is always the option for further testing, the use of a greater number of individuals or a greater range of individuals to provide much more detailed analysis of all the operational parameters of an experimental apparatus, in reality, is not feasible. Conducting a detailed pilot study, such as the one outlined here, provides a robust empirical dataset which can be used to develop and refine a stringent VETT testing programme as the prototype evolves from concept to fully active in the field. The tests carried out during the period commencing 13th May 2013 at the VisAdvies facility in

Nieuwegein, Holland represent such an opportunity, where important developmental and biological data were collected under controlled conditions.

The number of animals tested at each head drop of water was determined to be statistically robust and the outcomes generated, which represent nil-associated mortality and nil-associated physical perturbation lead to the conclusions that, within the parameters of the tests carried out that in the format tested the VETT is not harmful to passing fish and, in these experiments, could be considered a “fish friendly” device.