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A Stock Assessment of Atlantic salmon in Large Riverine Catchments

A thesis submitted to The National University of Ireland in fulfilment of the requirements for the Degree of Doctor of Philosophy

By

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Appendix

Glossary of Terms

BS	Background Subtraction
CL	Conservation Limits
CSOT	Convolved Sample Over Threshold
.csot files	Name given to DIDSON files after CSOT processing
.ddf file	Name given to DIDSON files
DEP	Digital Echosounder Processor
DES	Digital Echosounder
DIDSON	Dual Frequency Identification Sonar
DIDSON-LR	DIDSON Long Range
DIDSON-SR	DIDSON Short Range
EA	Environment Agency
EPA	Environmental Protection Agency
FC File	Name given to files of data saved from the DIDSON
ICES	International Council for the Exploration of the Sea
IFI	Inland Fisheries Ireland
IM	Image Mode
LF	Low Frequency
SED	Single Echo Detection

Section I

CHAPTER 3a

Direct Counting – Initial Methodology Tested

Resistivity (Logie), Infra-red (Vaki) and three types of hydroacoustic technology HTI (split-beam), Simrad (split-beam) (both dealt with here) and DIDSON (Dual-Frequency Identification Sonar) (Chapter 3) were assessed as part of this project to find a reliable and cost-effective method of enumerating salmon in large rivers in Ireland. The existing Logie and Vaki counters on the River Moy were initially tested, and an assessment made of the HTI hydroacoustic equipment previously tested in 1999 (Good, 1999). Alternative hydroacoustic technology used in other countries i.e. other types of split-beam eg. Simrad, was also assessed.

3a.1 Materials and Methods

Resistivity and Optical Counters – Moy River

An assessment was made of the IFI, Ballina, existing fish counters on the River Moy at the traps at Ballina, Co. Mayo on the 10th August 2006. This was to facilitate the testing of existing counter technology on the River Moy. Three Vaki infra-red counters (Trap 2, Trap 3 and Trap 5) were assessed (Section III: B). Adjustments were made to the counters regarding settings and their positioning in the traps. The panels of both counters were cleaned and a new naming system was set up for data processing. The problems previously encountered by the IFI regarding the downloading of data were resolved but very little data collected for 2006, prior to the assessment on the 10th August 2006, was found to be valid due to these downloading issues. The positioning of the Vaki counter in Trap 3 was adjusted. Data collected from Trap 2 for 26th July – 14th November 2006; from Trap 3 for 8th August – 12th December 2006 and from Trap 5 for 22nd – 30th September 2006 were analysed for fish movement. A new Logie (Resistivity) counter was installed in Trap 7 on 20th September 2006 and data collected from 20th September to 15th November 2006 were analysed to determine the run of fish on the left bank of the river. As part of the study, a protocol was established whereby a weekly counter download and maintenance schedule was carried out

to assess the counters and data output.

Data obtained from the Vaki counters were processed after each download. Cameras had not yet been installed for the Logie counter on Trap 7 during its operation as part of this study and so validation of the counter was not possible.

Historical Commercial Salmon Catches – Ballina Traps, River Moy

To establish fish movement in the traps and to assess the counter location of the Ballina trap counters, historical commercial salmon catch data was assessed from 1987 to 1989 to determine which traps had the greatest quantity of fish movement. This data was acquired from an historical data set collected over the above time period by Mr. Billy Thornton, IFI and entered into an Excel spreadsheet for analysis. Yearly total catches from trap 1 to trap 7 were collated.

Split-Beam Hydroacoustic System – Moy River

The system tested at Hollister's, Ballina, Co. Mayo, on the River Moy was a HTI Model 241 Split-Beam Hydroacoustic system. The acoustic system included three dimensional target tracking software, a 22 kHz Model 240 Digital Echosounder (DES), 100 ft cable (30.48 m), oscilloscope and a PC monitor and keyboard (Fig. 3a.1). The DES generated sound pulses for transmission by the transducer and received the returned echoes. The Digital Echosounder Processor (DEP – V.3.54) processed the acoustic information returned to the transducer from targets in the water and analysed the returned echoes which allowed visualisation of the echoes on an echogram (Enzenhofer 2000; Hydroacoustic Technology 2000). Data from HTI's software was stored on the DEP's hard drive in the form of five types of computer data files. As per Good (1999), only raw files (.raw) were collected for the purpose of this assessment.

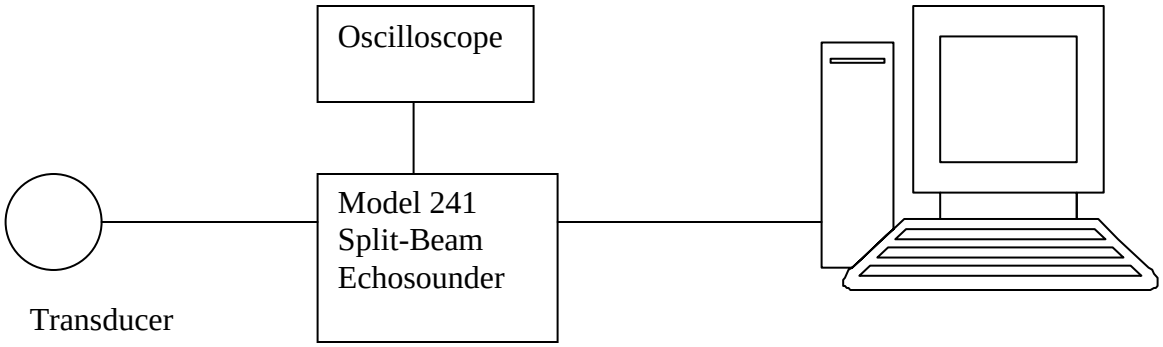

***Figure 3a.1: Schematic of the HTI 241 Split-Beam Hydroacoustic System*.**

Assessment of the HTI Counter Site and Existing Equipment, River Moy

The initial site structure constructed in 1999 was used again for the re-trials of the HTI split-beam counter (Plate: 3a.1 & 3a.2; Section III: B). The walkway and mounting frame required modification. The transducer was attached to a secure walkway with movable rotating lifting system which was used to adjust the transducer position to obtain maximum river bed to surface coverage. For the purpose of this project the counter was assessed on the 4th and 5th April 2006. The transducer most suited to the site, a low side-lobe transducer with elliptical-beams, a 4 x 10° beam was not operational due to in-river damage from the 1999 trials. A replacement transducer, a 15° beam, was put in place for training purposes until the 4 x 10° transducer beam could be repaired. The 15° beam was a wider beam and more suitable for lake monitoring and thus more reverberant noise was detected, causing the system to continually crash. The repaired 4 x 10° beam transducer was returned at the end of August 2006 and installed on the River Moy at Hollister's on the 1st September 2006. A pan and tilt mechanism was fitted to enable better movement of the transducer in the water. New processing software was also installed and parameter settings adjusted. The software was also updated from Windows 95 to Windows XP when the site was made operational for training purposes. Training and testing of the equipment was given priority during the initial assessment.

Plate: 3a.1: HTI Site on the River Moy at Hollister, Ballina, with Pully System in place for Beam Mapping and Calibration. Hut in background for storage of PC and Echosounder (Louise Brennan, 28/09/06).

Plate: 3a.2: HTI Site on the River Moy at Hollister, Ballina, with tungsten sphere for Beam Mapping and Calibration (Louise Brennan).

Initial operations consisted of self training using the 15° beam transducer to become familiar with split-beam operations and data processing. The beam was aimed close to the river bed to ensure adequate coverage of the water column to determine where fish passage occurred and

to ensure that no fish migrating upstream would go undetected. The aiming of the beam using split-beam was very important to prevent reverberant noise from the river bed. Initial settings of parameters for the Hollister's site (each set of parameters are site specific) were assigned and the best fit for the transducer selected with equipment available; initially the 15° beam and then the 4 x 10° beam after repairs. These settings were adjusted to suit the selected beam being tested and were changed over the course of the trials to determine the best parameter settings for the system. Calibrations were carried out every time the transducer was adjusted. Bottom profiling and beam mapping were carried out at low water levels to determine bed coverage with the beam.

Bottom Profiling of the River Moy – Hollister's and Mount Falcon

Bottom profiling was carried out in June 2006 at both Hollister's and Mount Falcon, Moy River (Plate: 3a.1 & 3a.2). Mount Falcon was profiled as a possible alternative site, as previous reports from the operation of HTI split-beam at the Hollister's site had shown potential problems (Good, 1999; Fewings & Gregory, 2000). Water depths were recorded at one-metre intervals across the width of the river and the nature of the riverbed substrate noted.

Detailed Settings for the Model 241 System

Details of the settings trialled on the Moy River using the split-beam Model 241 System are described below.

Echo Sounder Settings

The echo sounder settings were changed to produce the best results using the HTI equipment when monitoring adult salmon for the River Moy (Table 3a.1 & Table 3a.2). . The parameters were set to control the transmit and receive components of the hydroacoustic system used to collect the data. Increases to the pulse duration were undertaken with caution, as an increase to the pulse width limited the ability of the system to detect fish in close proximity to one another (Enzenhofer & Cronkite, 2000). Changes were made to the echo sounder settings as advised by HTI:

Table 3a.1: Changes made to echo sounder settings, from Original start up settings.

Sounder Settings	Original	New
Transmit Power	8	20
Pulse Width	2.5	1.25
Time Varied Gain, Gain	0	-6
Time Varied Gain, Start	2	1
Receiver Gain	0	-12

The transmit power and gain values were changed, thus, threshold values (minimum voltage signal levels that would be accepted) in the defined strata were altered.

Table 3a.2: Changes made to Threshold values, from Original start up settings.

Strata Definition				Original	New
Number	**Start**	**End**	**Size**	**TS Threshold (v)**	**TS Threshold (v)**
1	1	3	2	1	0.275
2	3	5	2	1	0.275
3	5	7	2	1	0.275
…20	39	41	2	1	0.275

Strata and Bottom Settings

Initially one metre strata were used to cover the maximum distance across the river and to extend slightly beyond the bank. The bottom was extended when water levels changed. The same voltage threshold (TS threshold, not density) of 0.275 was initially applied. The transducer was then aimed to achieve the best coverage of the area where the fish migrated. The bottom was originally fixed at 36 m but was changed on the 20th October 2006 to 35 m, as beyond this the transducer was picking up reverberant noise from the river bed and right bank.

Aiming the Beam

The acoustic beam was equivalent to aiming an acoustic flashlight of sound that is shaped like an elliptical cone. The beam was aimed perpendicular to the flow so that fish were viewed in side aspect at their largest target strength. The beam was aimed by observing the target in real-time on the PC. The software displayed the target's vertical/horizontal position

(XY) on-screen (Fig. 3a.12). . The return signals from the target allowed the beam to be aimed in relation to the river bed and water surface. Where smaller rocks were in the way (not larger rocks that block the beam totally) the voltage threshold was increased for just that strata so that the rock no longer showed on the echogram. This allowed fish detection beyond the rock but only when they were out from behind the rock. The transducer was adjusted slightly during different water levels to align the horizontal axis to the river bottom.

Echo Selection

For riverine salmon monitoring the upstream/downstream criteria were set to exclude returns from outside the nominal beam width. The horizontal was set at a minimum (- 5°) and the maximum (- 5°) for 10° total. The vertical was set to include as many objects near the bottom as possible, but to exclude objects near the surface such as debris and wind waves. The vertical was set at a minimum of – 2.5° and a maximum of 2.5° total.

Calibration

The counter at Hollister's was calibrated on the 15th September 2006 on return of the 4 x 10° beam from HTI (previous calibrations were unsuccessful). HTI's standard method was used for monthly calibration (Hydroacoustic Technology 2000). Improvements were again made to the counter settings to reduce noise levels and improve detection for adult salmon prior to calibration. Prior to receiving the pan & tilt mechanism adjustments were made manually, making it difficult to achieve best fit for beam coverage. The pan & tilt received required further alterations before deployment as it was not received to specifications from HTI and was thus not available for testing during the Moy River split beam trials. Standard target calibration required different settings, to pick up the standard target, the tungsten carbide sphere (-38.5dB). A different minimum threshold was needed as the standard target was smaller than the size of salmon being detected. A new configuration file was created, a standard target configuration file named Moy_Cal_15-09-06.cfg, to make it easier to switch between standard target work and fish counting. The tungsten sphere of known acoustic size (-38.5dB), was held in a fine nylon mesh bag and suspended in the beam about 5 m from the transducer (Enzenhofer & Cronkite, 2000; Hydroacoustic Technology 2000). A period of approximately 5 minutes constant echo collection from the sphere was gathered and/or 1000

echoes. This quantity of data was required for accurate calibration.

Beam Mapping

Beam mapping was undertaken to provide details of the section of river counted and the location of the beam in relation to the river bed. A standardised method was developed as advised by HTI (Hydroacoustic Technology 2000) and using the EA, UK operational manuals (Gregory 2002a; Gregory 2002b). The transducer coverage was mapped in the centre of the beam due to the lobed nature of the acoustic beam. A pulley system was developed and installed across the width of the river on the 28th September 2006, to facilitate beam mapping (Plate 3a.3 above & 3a.4). It consisted of two ropes extended across the river, with the rope marked at meter intervals. The rope with the experimental target of -30 dB attached was marked with black tape every half meter (the tungsten sphere was too light to hold in position in the water column). Beam mapping was carried out on the 20th October 2006, when the water level had subsided (OPW flow records were not available for this period). The standard target was trialled for this purpose but due to the flow on the main channel, the target was pushed downstream out of the beam. For this reason the experimental target was developed using a 500 ml plastic bottle with a wide top to allow for the addition of sea angling weights. The experimental target was developed with the guidance from HTI, to make a target similar to the tungsten sphere but that would hold better in the water column. Weights were added to the bottle until the new target had a target strength (TS) of -30 dB (Plate 3a.3). The sonar detects fish echo tracks from reflections from its air bladder and the experimental target behaves in a similar way as it detects air in bottle. The experimental target was held in the cross-hairs of the beam as seen in the output. The methodology was similar to calibration methodology.

Plate 3a.3: Experimental target developed in conjunction with HTI (Louise Brennan, 28/09/06).

Plate 3a.4: Nigel Bond (MI) operating the pully system for beam mapping and calibration, Hollisters Site, Ballina, River Moy (Louise Brennan, 28/09/06).

Validation

The river was split into cells of approximately 5 m widths and the area assessed for fish movement (Gregory et al., 2002a; Gregory et al., 2002b). A camera array was designed and installed on the 28th and 29th June 2006. The array extended for 4 m out from the transducer looking back towards the river bank and the transducer (Section III: B). The purpose of the

camera array was to determine fish movement and behaviour in the first cell (5 m) of the transducer where fish could not be counted using the transducer as the beam width was too narrow in this area. This zone of no detection included the first 1 m using a 15° beam and the first 3m using a 4x10° beam. The camera array was ready for use in validation across the width of the river. The camera array designed was heavier than the structure used by the EA (Gregory et al., 2002a; Gregory et al., 2002b). A sample of the digital video recordings of the first 5 m (first cell) were reviewed and data entered onto an Access database for comparison with HTI data.**Data Analysis**

Data was collected from June to November 2006. A sample set of data collected in October 2006 was processed using HTI upgraded Echoview software. Only *.RAW files were saved and tracked manually. Each *.RAW file produced summary data files for processing in Echoview or Echoscape (V.2.12) HTI software. Each file was viewed using HTI Echoview software during processing and the direction of each track was observed to determine and established if the track was a fish or debris. The tracks identified were studies to determine the angle at which the track moved. Each detected possible fish/track was book marked and allocated a direction of travel or description of track. Processed files were saved in an Access database containing information on all traces which were accepted as an upstream fish or a downstream fish or target. Each trace was book marked as one of the following: U = Upstream; D = Downstream: Mill = Milling and DEB = Debris. The range, target strength, and angle of movement were used to determine if the track was a fish or debris. Data for the 2nd October 2006 was processed using Sonar 5 software to determine if this software made it easier to select fish tracks from debris and reduce processing times.

Split-beam Trails at Mount Falcon, River Moy

The HTI split beam sonar was transported to Mount Falcon to determine if a better beam fit could be achieved for the river bed at this site. The HTI was operated from a car battery which lasted for approximately 40 min. The beam was not mapped in relation to the river bed or calibrated during the trials, due to staff constraints and a location to mount the rods to extend the target across the first 5 m of the river. From the above findings a decision was made to trial alternative hydroacoustic equipment, the Simrad EK60, which was obtained for

testing from the manufacturers. This allowed for the testing of the most up to date split-beam sonar on the market. Trials using the Simrad EK60 were carried out on the 13th December 2007 at Mount Falcon, River Moy, using a mobile aluminium tripod to deploy the EK60.

Trials of Alternative Split-beam Hydroacoustics – Simrad EK60: Moy Tributaries – Deel and Clydagh

Due to the problems encountered at operating split beam in the main River Moy channel at the Hollister's site, alternative sites and split-beam equipment were assessed. Bottom profiling was carried out on four tributaries of the River Moy for the purpose of locating suitable profiles for a new site to deploy Simrad EK60 split-beam hydroacoustic equipment as part of trialling the EK60 and to determine if a better profile could be located for split-beam. These tributary were selected due to their discrete genetic salmon stocks (Dillane et al., 2007).

Bathymetry was carried out using the Lowrance: LMS – 334 CiGPS provided by the IFI, Ballina, for the initial surveys. Profiling was carried out on the 27th and 29th November 2006, from Muckanagh Bridge at the mouth of the Clydagh system where it enters Lough Cullin. Profiles were taken from the mouth of the river to approximately 100 m upstream of the bridge, profiling from bank to bank to obtain maximum bottom bathymetry. The Tormeen River was also assessed but this area was liable to flooding and therefore unsuitable for the deployment of equipment. The Deel River was profiled on the 29th November 2006. The boat was launched approximately 200 m from the river mouth, where the River Deel enters Lough Conn. Bottom profiles attempted on the Gweestion River, upstream of Scarrownageeragh Bridge were unsuccessful. Further profiling using the Simrad EK60 and testing of Simrad's EK60 was carried out on the River Deel from the 5th - 12th December 2007.

3a Results

Existing Direct Counting Methodology in Ireland

An assessment of the existing counter technology was essential to determine the best methodology for direct stock assessment prior to the testing of new hydroacoustic technology.

Resistivity and Infra-red Counters

After the initial assessment of the Vaki and Logie Counters at the traps, Moy River, Ballina, Co. Mayo, problems were discovered with the data regarding the downloading of data from the two Vaki counters. Once established and resolved very little data collected for 2006 (prior to the operation of the counters for the purpose of this study) before the 10th August was found to be valid due to the downloading issues. As the Vaki counter in Trap 3 had been fitted incorrectly all upstream moving fish had been counted as downstream moving fish and vice versa, thus making the data collected prior to the 10th August 2006 invalid. Operational needs of the counters increased during flood conditions. The traps and Vaki panels required cleaning more regularly. Debris was noted to build up, even within a 24 hour period, which was affecting the counters performance. The performance of these counters up to the summer of 2007 was limited. Most of the recorded images captured by the Vaki were not fish but rather water turbulence and interference from debris (weed growth becoming trapped around the counter and large branches etc.). A large number of 'no images' were recorded on Traps 2 and 3, again thought to be due to water turbulence. All fish identified ≥ 40 cm were recorded as salmon and fish < 40cm were recorded as sea trout. This was in line with the methodology used nationally, where all Vaki and logie counters are deployed.

The Vaki counter at Trap 2 was operated for this study from the 26th July to the 14th November 2006. There were 2, 504 events recorded in 113 days of counting: 177 salmon; 85 trout, 380 No Image, 1852 Not Fish, Eels 2, and 8 Other Fish Species (Fig. 3a.2). The daily maximum and minimum number of events recorded during the operation of the Vaki at Trap 2 was 345 and 1 respectively. As 89 % of the recorded events were not fish, the operation of the Vaki in Trap 2 proved unsuccessful given that only 11 % of fish were identified and the

man power and maintenance required to obtain these data. The peak maximum daily events recorded in October 2006 were all classified as Not Fish and No Image and due to increased water turbulence in the traps which interfered with the counter performance. These data from the 10th to 23rd October were logged as downtime. Large gaps in the data were due to downtime of the counter on the 18th to 20th, 23rd and 24th August; the 13th to 25th September and the 10th to 23rd October 2006 (Fig.3a.3).

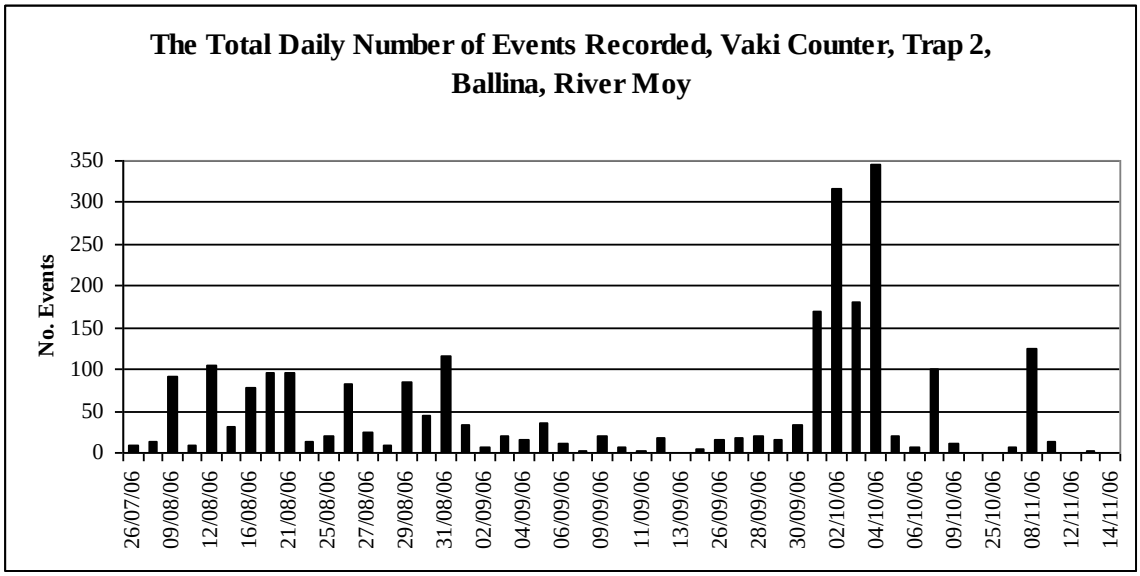

Figure 3a.2: The total daily number of events recorded, Vaki counter, Trap 2, Ballina, River Moy.

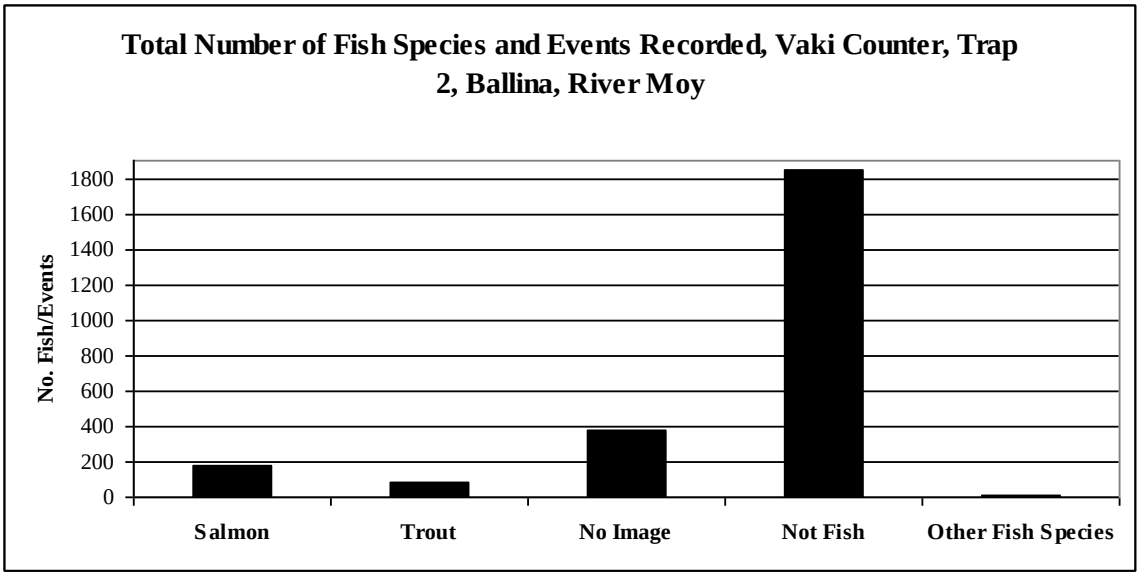

Figure 3a.3: The total number of fish species and events recorded, Vaki counter, Trap 2, Ballina, River Moy.

The operation of the Vaki counter on Trap 3 was more successful than that at Trap 2 or 5. The trap was operated for assessment for 112 days and data was collected from the 8th August to 12th December 2006. A total of 1,843 events were recorded, with a maximum and a minimum of events of 281 and 1 respectively. A total of 293 fish were identified, 219 salmon, 58 trout and 16 other fish species. Large gaps in the data were due to downtime of the counter on the 18th to the 21st August; the 13th to 25th September and the 10th to 23rd October 2006 (Fig. 3a.4). A total of 936 'No Image' and 614 'Not Fish' events were recorded, again these were indicative of the counter picking up false counts from water turbulence in the trap in October 2006 (Fig. 3a.5).

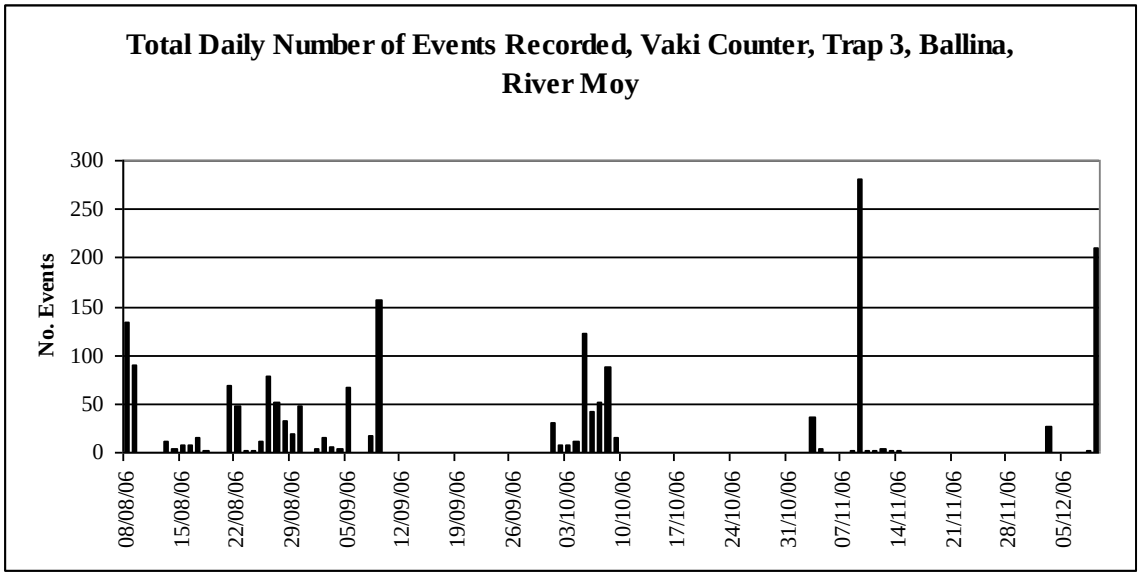

Figure 3a.4: The total number of events recorded, Vaki counter, Trap 3, Ballina, River Moy.

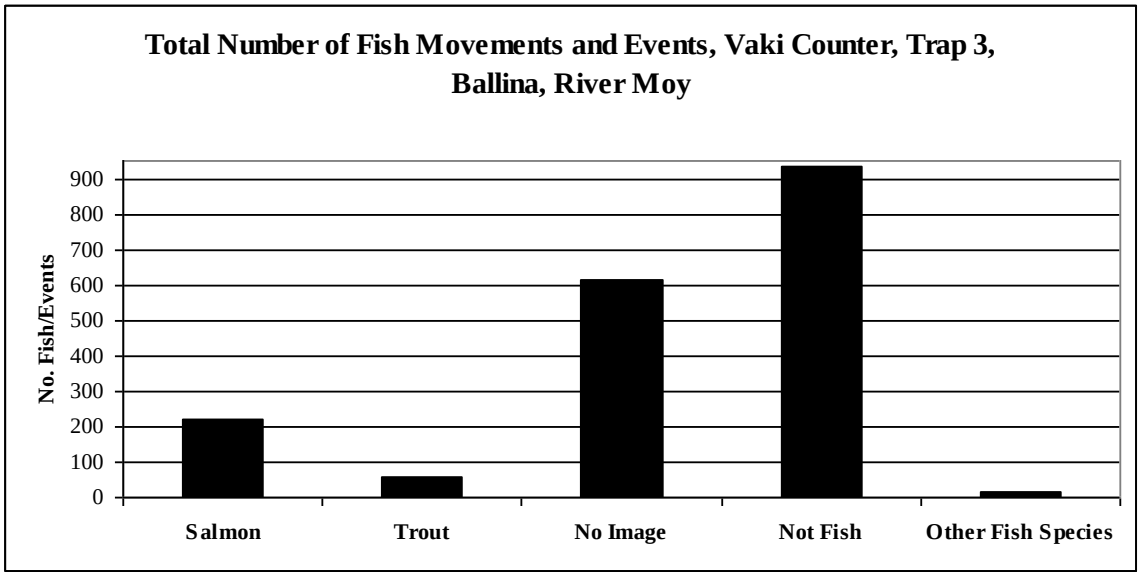

***Figure 3a.5: The total number of fish movements and events, Vaki counter, Trap 3, Ballina, River Moy*.**

The Vaki in Trap 5 did not produce count estimates and was producing images that were indicative of the panels not being clean (there was no mechanism in place at that time, on that trap, to lift the counter for the purpose of cleaning) and water turbulence. Vaki 5 was operated from the 22nd to 30th September 2006 but no fish were confirmed from the images obtained. 718 events were recorded with 680 and 38 classified as Not Fish or No Image

respectively; classic signs of interference from water turbulence. This trap was washed downstream during flooding in spring 2007, showing the difficulty in maintaining this counter type in a large river, even when attached to a solid structure. The new Logie counter installed in Trap 7 operated more successfully than the Vaki counters producing the first estimate of fish runs in the main river (Fig. 3a.6 to 3a.8).

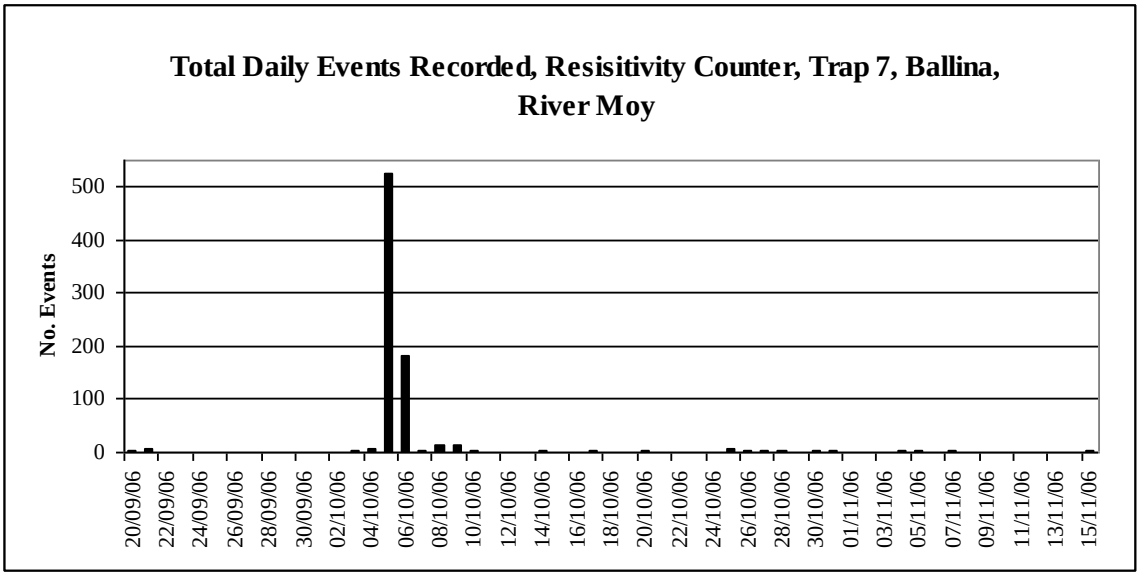

Figure 3a.6: The total daily number of fish migration upstream, downstream and events logged, Resistivity counter, Trap 7, Ballina, River Moy, 20th September to 15th November 2006.

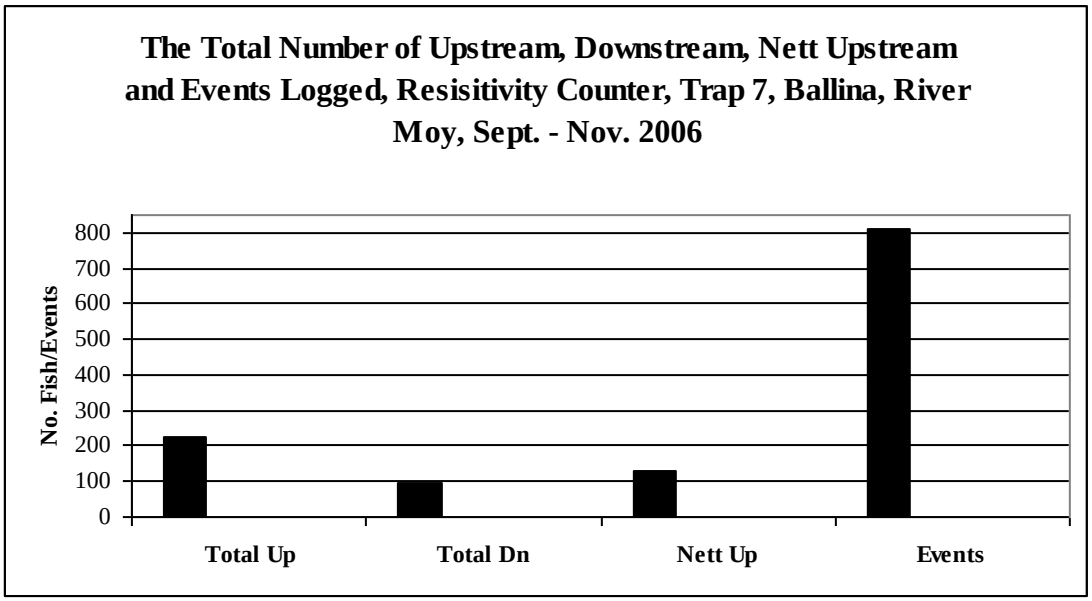

Figure 3a.7: The total number of fish migration upstream, downstream, nett upstream and events logged, Resistivity counter, Trap 7, Ballina, River Moy, 20th September to 15th November 2006.

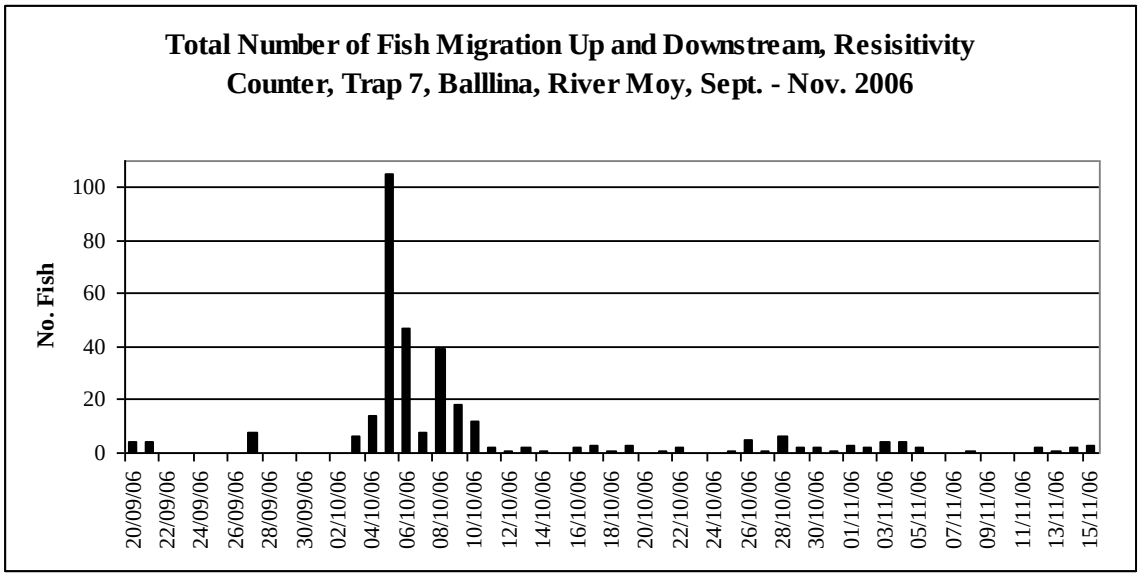

Figure 3a.8: The total number of fish migration upstream and downstream, Resistivity counter, Trap 7, Ballina, River Moy, 20th September to 15th November 2006.

Split-beam Hydroacoustic

A HTI split-beam hydroacoustic counter was operated on the Moy over a five month period from June to November 2006. Over this period a substantial amount of downtime was logged, making enumeration of salmon population in the river impossible using this technology at this site. A conservative estimate of downtime was calculated at approximately 25 days.

Initial Trials

Data collected during the re-installation, training and operation of the HTI split-beam echo sounder using the 15° beam from May 2006 to September 2006 on the River Moy at Hollister's was limited. This was due to the continuous crashing of the system due to the Ethernet connection (Windows/Network communication problem) and this delayed training in the optimum use of the equipment and data processing software. Calibration trials were unsuccessful in June 2006 as the 15° beam made successful calibration almost impossible due to excessive reverberant noise picked up by the wider beam which continually crashing the system. The 15° beam, a weaker beam than the 4X10° beam, had a wider area to spread beam energy across the river and this was believed to be the cause of the target not being detected during calibrations. Transmission settings were increased to try to improve detection using the 15° beam but these were relatively unsuccessful. Adjustments to the fixed bottom tracking, pulse width criteria and the receiver gain were made to improve calibration attempts but background noise was still an issue. To allow some data to be gathered for the training in processing echo data in the post-processing software; the bottom tracking was adjusted to 8 m to allow an assessment of only the first 8 m across the river. This reduced reverberant noise from the river bed at > 30 m and from the right bank. The system was upgraded to a new PC with Windows XP and this caused initial connection problems with the memory allocation between Windows XP and the echo sounder, adding to the connection problems.

The repaired 4 x 10° beam was returned at the end of August 2006 and installed on the Moy river at Hollister's to replace the 15° beam on the 1st September 2006. The same procedures

were repeated regarding setting changes until the split-beam counter was operational at the site using the 4 x 10° beam transducer. Sample data collected was used for training in post-processing software, to determine the technical requirements and timeframes for data processing from a HTI split-beam.

Site Limitations and Operational Issues

The pan and tilt had not arrived during the testing of the HTI split-beam system, all adjustments to the transducer position had to be made in-river, by physically moving the transducer by hand. This made it extremely difficult to know the precise transducer location and thus beam angle in the water column before and after each adjustment. No large boulders were present that fish could hide behind but the bed substrate did interfere with fish detection from 24 – 32 m due to the rise in the river bed (Fig. 3a.9 & 3a.10 below). Winter flooding from November 2006 onwards increased reverberant noise in the beam and the system continually crashed for this period. The water level in November 2006 was just under the walkway, making re-positioning of the transducer beam impossible. From November 2006 onwards the counter continued to crash making sustained periods of data collection un-attainable. Large amounts of siltation in the water column increased noise detected by both beams tested and this also increased system failures. From approximately 30 m to the right bank of the river, the beam was hitting the river bed making it difficult to select fish echoes in that area. Problems encountered with the system crashing may also have been a result of excessive background noise from the river bed. Both site limitations and operational issues were the reasons to cease the use of split-beam hydroacoustics on the River Moy.

Bottom Profiling

Profiling was successful at both the Hollister's and Mount Falcon sites on the River Moy (Fig. 3a.9 & 3a.10 below). Previous bottom profiling of the Hollister's site could not be located for comparisons with the 2006 profiles, to determine if there had been any substantial changes in the river bed over time and to determine if the river bed was stable at the site for split-beam acoustics. The river bed profile at Hollister's site was canal like due to dredging and not the most suitable profile for acoustic deployments. The rise in river bed at 9 m and 32 m created blind spots in the beam that could not be counted for fish movement and these

increased reverberant noise picked up by the beam during operations. The profile at Mount Falcon was much more suitable to the use of hydroacoustic deployment. The Mount Falcon site had a sloping bed and a sharp rise in bank on the opposite side of counter deployment. The bed substrate was made of sand and gravel, which is more suitable for acoustic deployments. Less reverberant noise was picked up at this site using both HTI and Simrad split-beam counters.

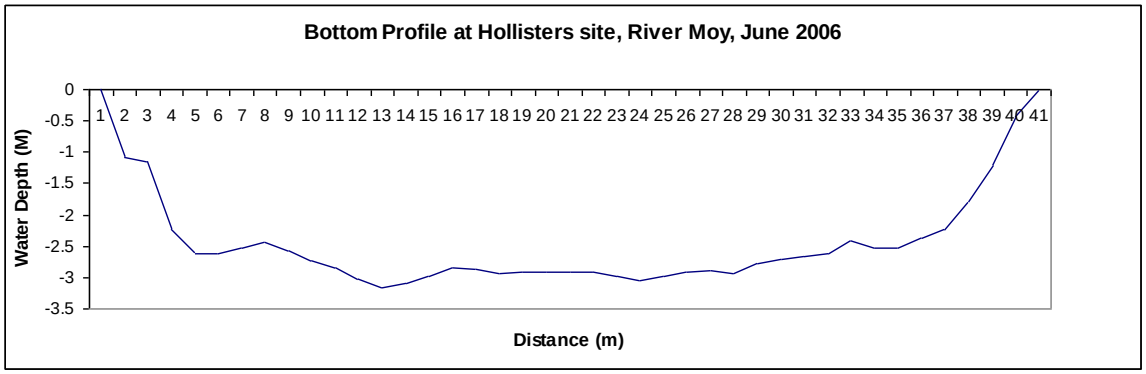

Figure 3a.9: Bottom profile at Hollister's, River Moy, Ballina, Co. Mayo.

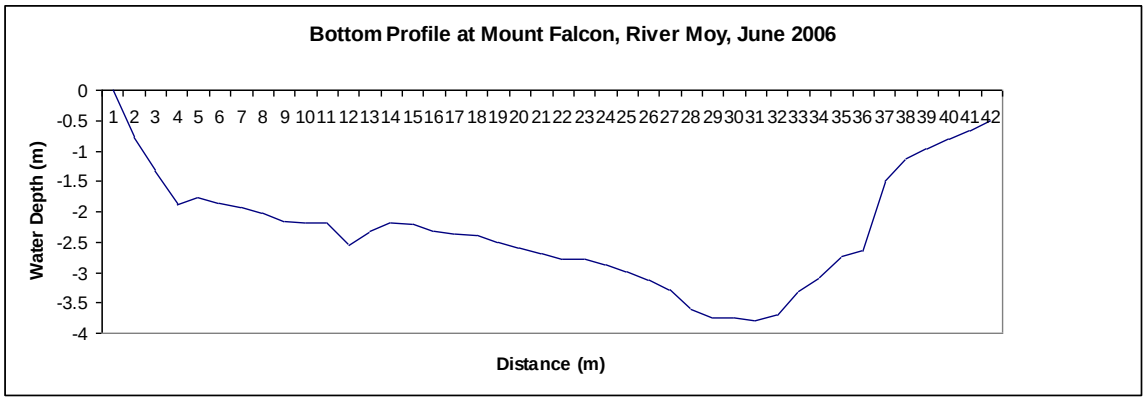

Figure 3a.10: Bottom profile at Mount Falcon, River Moy, Co. Mayo.

Echo Sounder Settings

The echo sounder settings were changed to produce the best results using the HTI equipment to monitoring adult salmon for the River Moy. The parameters were set to control the

transmit and receive components of the hydroacoustic system. The Sum Detected Voltage vs. Power and Gain, was used to determine that with a transmit power of 20 and a gain of -18, a fish with a target strength of -40 dB (approximately 19 cm in length) would be detected exactly on the transducer axis, with a voltage threshold of 0.275 volts. Thus for fish of 19 cm in size the transducer would only detect it when it was exactly on axis. To ensure that fish throughout the entire beam width were detected the target strength needed to be 6 dB larger, or -34 dB in size (a fish of approximately 36 cm in length). This represented the smallest fish that would reliably and without bias be detected. Smaller fish may have been seen with these settings but would only appear when in the very narrow cone near the transducer axis (less than the 4 X 10° beam width over which larger fish would be detected). A 6 dB change in the target strength represented a two time's difference in voltage, and (roughly) a two time's difference in length. As advised by HTI a lower threshold was thus required to collect the data, thus smaller fish could be removed in post-processing. Where these settings caused the system to pick up too much noise from surface reflections and/or the river bed, the threshold was increased from 0.275 to 0.350 volts for all strata. This increased the minimum fish size to about - 32 dB (approximately 45 cm in length). The thresholds were increased for some of the strata to reduce noise from the bed from 26 - 35 m across (Fig. 3a.9 & 3a.10). Calculations were made using a standard Target Strength to Length formula (Love, 1971). The formula is for fish in dorsal (from above) aspect, and the fish being detected in the River Moy were ensonified in side aspect, which caused the fish to have a slightly (maybe 2 - 3 dB) higher target strength. Therefore length data would have been conservative even if good quality data was collected.

Beam Mapping

Knowing the precise aim of the beam was essential. This provided details of the section of river that was being counted and the location of the beam in relation to the river bed. Beam mapping was required every time the transducer was adjusted but this was not possibly due to the lack of man-power. The transducer required adjustment with changes in water level; this ensures consistent best fit and reduced surface noise. After heavy rain the water level at the transducer at Hollister's increased approximately 1 m in a 24 hour period in August 2006. This was a particularly fast increase in flow for the main channel of a large Irish river system.

The beam was mapped on the 19th and 20th October 2006. Fig. 3a.11 shows the large area of the river that was not ensonified below the beam from 0 - 20 m. The beam was not a perfect 'flashlight' in shape, as it is 'lobed' at its edges. The transducer was also directed at an angle downstream which made it difficult to map further along the beam, with the 'pulley system' used to move the target across the width of the river.

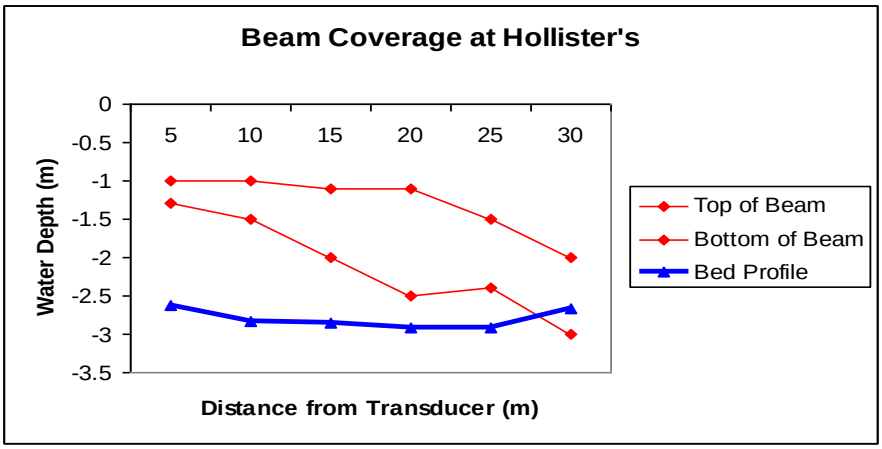

Figure 3a.11: Beam coverage at Hollister's 20-10-06 using experimental target.

It was easier to map using the tungsten sphere up to approximately 15 m, but greater than 15 m too much background noise at the selected TS threshold of 0.05 was detected. The TS threshold of 0.05 was used to detect the sphere. Problems with the 'pulley system' were aggravated the further across the width of the river as the beam was pointed at an angle downstream and the 'pulley system' was straight across the river, pulling the target along the edge of the beam.

Calibration

The counter at Hollister's was successfully calibrated using the 4 x 10° beam on the 15th September 2006 (Fig. 3a.12). Calibrations using the 15° beam were unsuccessful. Calibrations were carried out where staff were available to assist in the field. The initial set-up using a galvanized steel pole was unsuccessful as it wobbled every time the sphere was moved up and down in the water column. Weather conditions had an effect on the calibration procedure as even light winds caused the sphere to move in the water making it more difficult to find the sphere in the visual out put on-screen. The 'pulley-system' design made

moving the sphere up and down in the water to align it in the 'cross-hairs' of the visual out put on-screen easier (Fig. 3a.12). No records were located of calibrations at this site from previous operations.

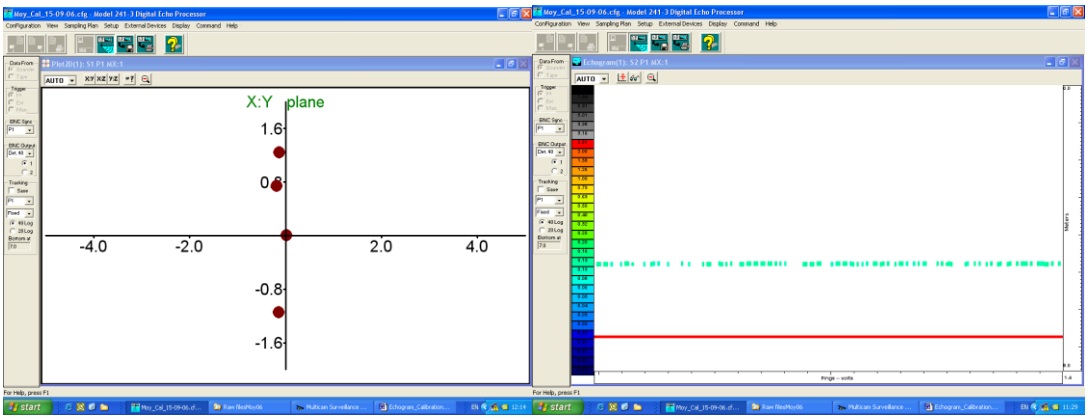

Figure 3a.12: DEP output of 2D plot and Echogram during calibrations, with sphere at 5 m out from the head of the transducer, at approximately 1.5 m depth, on the 15th September 2006 (Louise Brennan).

Validation

Video cameras were not successful for their use on a large Irish river for the purpose of validating split-beam hydroacoustic data at this site. The lifting system used was successful but this was attached to the solid structure of the walkway and only an area of 5 m could be covered, as extending the array made it too heavy to lift for installation and cleaning. Methodology used by the EA (Gregory et al., 2002a; Gregory et al., 2002b) for camera deployment were not successful in the River Moy as they would not stay in place on the bed of the river due to water flow. Camera siltation was continuous and weed growth collected on and around Cameras 2 and 3 which constantly triggered the motion detection settings despite routine weekly cleaning. The cameras were cleaned 29 times during operation. The change of settings to continuous video data collection meant that more data was recorded, stored and processed to determine fish movements in the first 5 m from the river bank. This increased the operational needs to validate the counter. Eight days of digital video data were viewed but no confirmed identification of salmon were made, due to the quality of the image obtained, however, non-target species were abundant. From the initial camera trails which commenced in June 2006, it was noted that several non-target species frequent this stretch of

the channel. Milling behaviour and camera avoidance was identified. Species such as pike, roach and perch were identified. The hydroacoustic data could not be compared to video footage for validation for the same period. The area of river bed covered in the first cell by cameras is not ensonified in the first 3 m using a 4 x 10° beam and this was the beam most suitable for the Hollister's site. The cameras were successful in showing that no salmon were moving near the left bank around the transducer. This showed that salmon were not missed swimming behind the transducer and must be migrating further out across the width of the river. The successful collection of split-beam data was not obtained to warrant validation. Vandalism in early November 2006 prevented the lifting system from operating and the cameras could no longer be cleaned.

Data Analysis

Data processed using HTI EchoView software was very laborious and difficult to interpret without specialized technical training. Processing times were too slow for real time analysis and one day of data took three days to process using EchoView software. The poor quality of the data and need for greater processing experience accounted for the long processing times It should be noted that limit training in the use of the software was received due to lack of acoustic experience in Ireland. It was extremely difficult to determine fish from background noise (Fig. 3a.17). Echo tracks that were detected were recorded and direction allocated (Fig. 3a.13 to 3a.16 below). It was very difficult to determine if downstream moving tracks were fish or debris. These data were not sufficient to provide an accurate fish stock assessment from the HTI split-beam counter at Hollister's site (Fig. 3a.18).

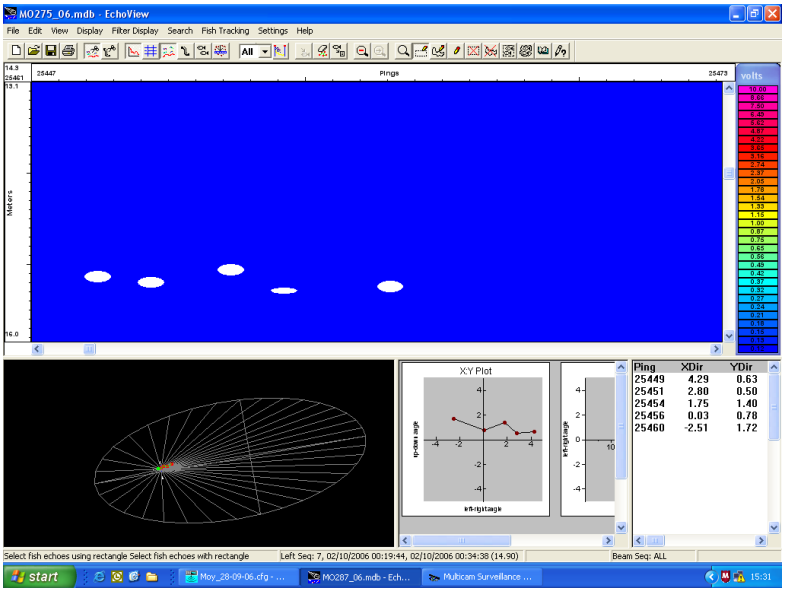

Figure 3a.13: Downstream moving fish detected on the 1st October 2006 in EchoView (Louise Brennan).

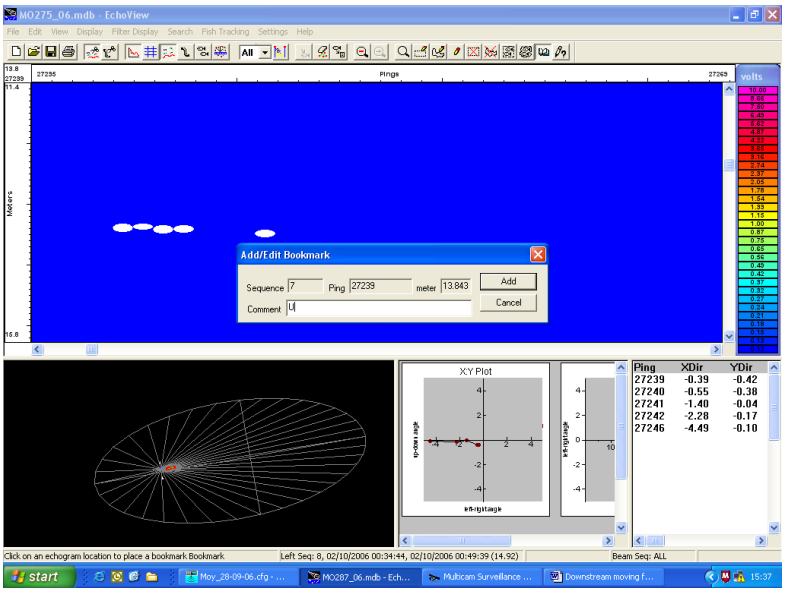

Figure 3a.14: Upstream moving fish detected on the 1st October 2006 in EchoView, showing 'Bookmark' for allocating movement type (Louise Brennan).

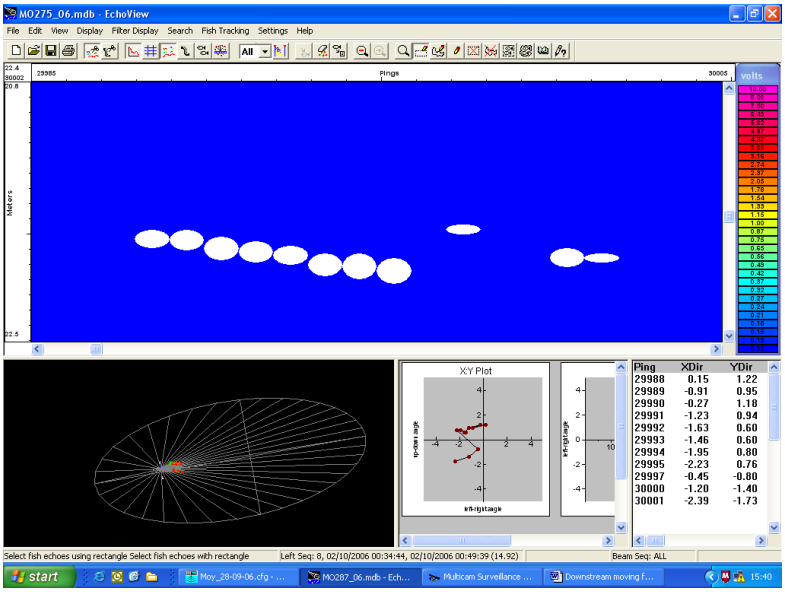

Figure 3a.15: Unknown movement on the 1st October 2006 in EchoView (Louise Brennan).

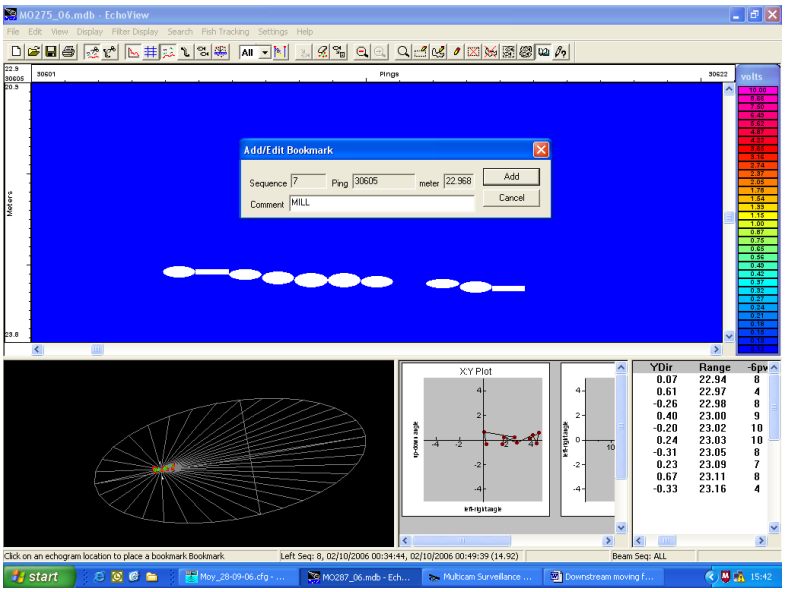

Figure 3a.16: Milling fish on the 1st October 2006 in EchoView, showing 'Bookmark' for allocating movement type (Louise Brennan).

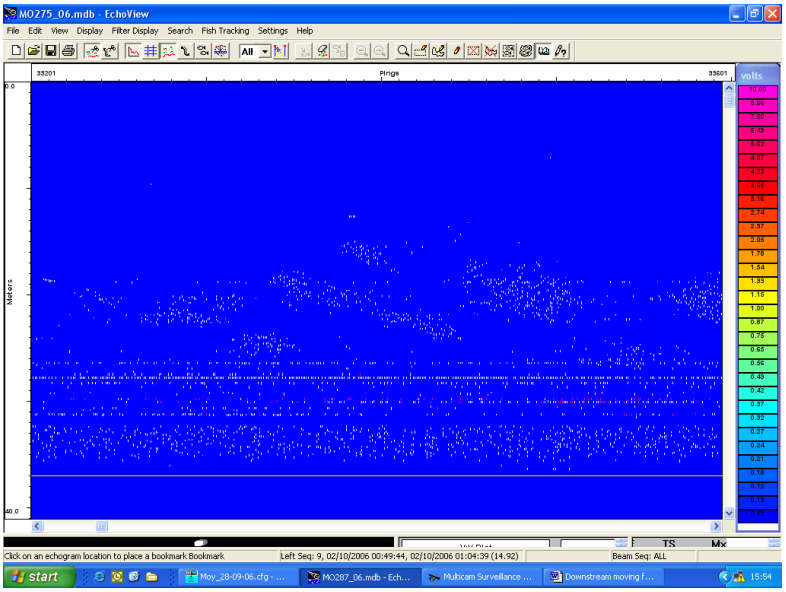

Figure 3a.17: The effects of surface noise on the 1st October 2006 in EchoView (Louise Brennan).

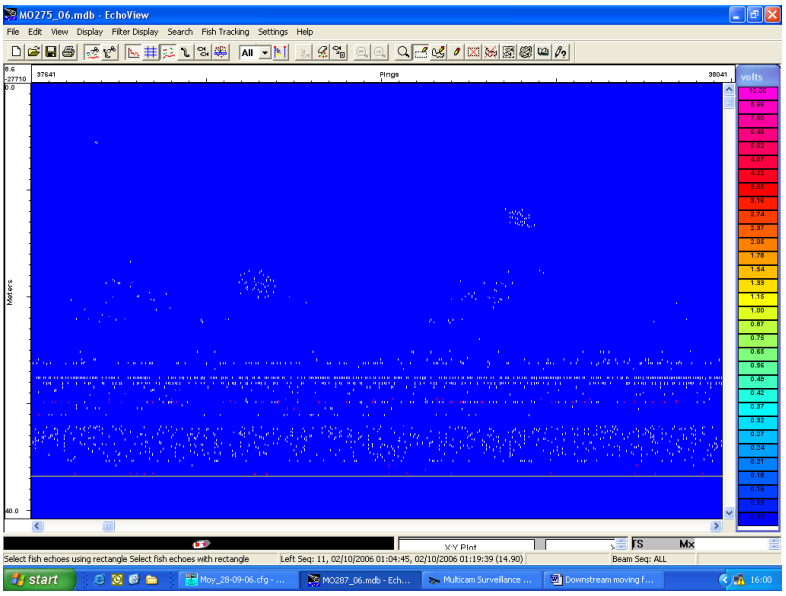

Figure 3a.18: Possible shoals of non-target species on the 1st October 2006 in EchoView (Louise Brennan).

Testing of Alternative Software

Sonar 5 software was used to process a sample data set from the 2nd October 2006. The software allowed background noise to be removed using single echo detection. A minimum target strength of – 50 dB was applied with a maximum phase deviation of 5 (Std. dev). The mean target strength detected was - 19.8 dB, at a mean range of 26.95 m. The minimum

target strength was - 41.89 dB and the maximum -13.75 dB, at a range of 0 to 36.73 m. Returning echoes were continuously from the same range where the beam was hitting the river bed. No fish images were confirmed as fish in these files due to the erratic nature of the echo tracks received (Fig. 3a.19). However, processing times were reduced, taking 2.5 hr to process one day of data. All aspects of the software were not tested due to the poor quality of the data collected. Sonar 5 (Balk & Lindem, 2004) was easier to use and the Single Echo Detection (SED – allowed for the removal of background noise) made the interpretation of echo data easier.

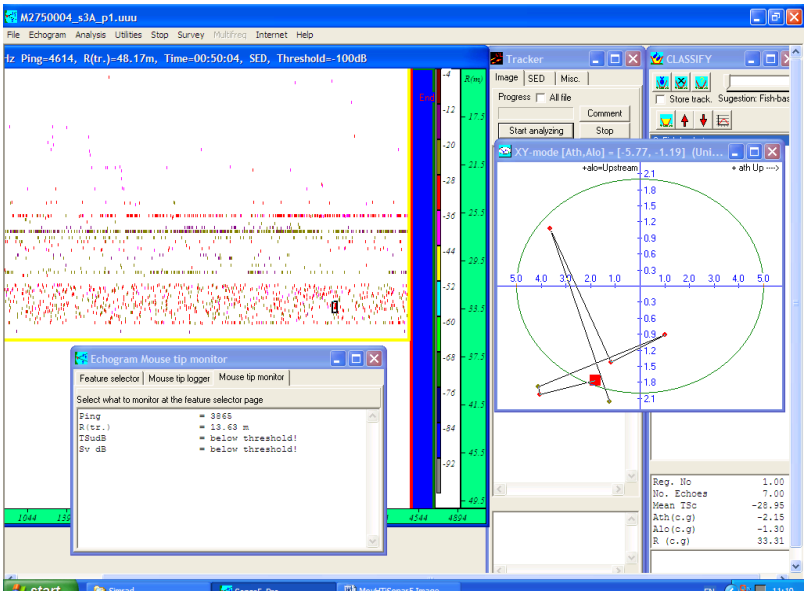

Figure 3a.19: Single Echo detection using Sonar 5 software with HTI split-beam acoustic data collected from the River Moy, 2nd October 2006.

Alternative Site Locations for Split-beam Hydroacoustics

The most suitable profiles found were located on the meanders of rivers. On the Clydagh, the river bed was canal like near the mouth of the river but favourable profiles were noted just upstream of Muckanagh bridge. However, the close proximity to the lake may have caused problems for counting using split-beam, due to the milling in and out of the lake of non-target species. The upper reaches of the Clydagh were too shallow for split-beam acoustic deployment and the Tormeen river, a tributary of the Clydagh, was prone to flooding and unsuitable for the deployment of split-beam hydroacoustics. During profiling on the River

Deel, it was noted that during winter flooding the river is encroached by Lough Conn and backwatering occurs upstream to Knockadangan Bridge. The river profile was canal like near the mouth. Suitable profiles were noted near Deel Bridge but the summer water level in this area was below 1 m, too shallow for split-beam acoustics. The river here displayed varying water depths and was not suitable for split-beam deployment. Bottom profiles attempted upstream of Scarrownageeragh Bridge, Gweestion River, were unsuccessful due to the strong current and loss of satellite connection. Summer water levels were noted < 1 m and would be unsuitable for split-beam counter deployment. The site also consisted of a rocky bed which would cause problems for split-beam deployments.

Simrad EK60 Split-beam Hydroacoustic Assessment

The Simrad equipment obtained on the 28th November was successfully used to carry out bed profiles for site selection on the Rivers Deel and Clydagh, providing an alternative, easy to use method for profiling. An assessment was made of the equipment during the site selection to determine if the Simrad technology had advantages over the HTI unit. The EK60 was intuitive, provided better visual output and did not have the same Ethernet connection problems as the HTI spilt-beam system. The testing of the Simrad EK60 sonar for fish counting was made very difficult due to winter flooding. Again the varying water levels and flows at the Deel Bridge made deployment almost impossible. Data that was collected showed a high degree of siltation present in the water column and the effects of wave motion on the surface. No fish images were observed. Thus the EK60 would not have operated well for fish stock assessment in flood conditions, thus concluding that split beam technology was unsuitable for Irish rivers. Surface debris was seen in the beam during deployment at Mount Falcon but no fish were detected from the data collected during the 40 mins deployment.

Overall Assessment of Split-beam Acoustics

Aiming the transducer was the most difficult part of using the HTI split-beam counter. From the data collected it was difficult to determine if fish were travelling close to the riverbed and moving in and out of the beam. If this behaviour was happening then these fish tracks would be counted several times. The target strength of fish increases the further away a fish lies from the transducer but data collected was not sufficient to determine the target strengths of

fish species in the River Moy system. The continuous crashing of the HTI system made it impossible to obtain good quality data for processing and an adequate fish stock assessment of the river for 2006. Data that was collected required long processing times using Echoview to interpret the echoes received from the river and a high degree of technical training was required to install and operate the system. Sonar 5 made the process easier with the removal of background noise but again the data collected was not of sufficient quality to detect fish tracks. As part of the training schedule a site visit was undertaken in June 2006, to the EA in Wales. Four sites with HTI hydroacoustic counters were visited. The purpose of the visit was to see HTI counters operational in other catchments and discuss parameter settings, calibration and beam mapping methodologies. The counters visited were not functioning during the visit due to high water levels but site logistics were noted and problems regarding site operations in flood conditions, data processing and downtime were observed. This was vital as part of the initial assessment of the HTI equipment for use in large river catchments for Ireland. This also emphasised the need for the testing of alternative split-beam systems and the DIDSON. It was clear from the data analysis that this split-beam system was not adequate for salmon stock assessments in Irish rivers and this move to alternative acoustics was already being made by US, Canadian and UK split-beam operators. During screw trap operations on the River Deel in the spring of 2007 several areas were noted for possible deployment of a hydroacoustic counter and for the possible testing of the DIDSON counter.

Recommendations were presented to the IFI, Ballina, regarding the location of the Vaki, infra-red counter within the traps to potentially improve counter performance. Limited good quality data was recorded during the operation of these counters. The counter performance and the quality of data obtained were constrained due to the counter position of the Vaki counters, due to water level and water flow in the traps. The performance of the two Vaki counters in their present position in Traps 2 and 3 was unsatisfactory during the testing period. As fish passed through the Vaki counters no image or spurious counts were recorded. Turbulence was believed to be the cause of the spurious counts and the tidal nature of the river at the traps made it difficult to ensure that the counter was submerged at all times. The need to reposition the counters in the traps was being assessed by the IFI, Ballina, in 2007. The IFI, Ballina Logie or resistivity counter installed in trap 7 performed relatively well in trap 7 but no validation was carried out during the 2006 trails. Video cameras were installed

above the trap to validate the counter and validation was carried out by the IFI, Ballina since 2007. Since the assessment undertaken in this study, a new Logie was installed by the IFI, Ballina in Trap 1. This would give a good estimate of the salmon run in the main River Moy at Ballina if the counter's performance improved. However, consist poor performance of these counters, particularly during periods of flooding has limited there use on large rivers and again solidifies the need for an alternative counter, hydroacoustic for large Irish rivers.

Section II - ICES Papers

NOT TO BE CITED WITHOUT PRIOR REFERENCE TO THE AUTHORS

International Council for
the Exploration of the Sea

Working Group on
North Atlantic Salmon
Galway, Ireland
Working Paper 2008/16

Atlantic Salmon Stock Assessment using DIDSON (Dual-Frequency Identification Sonar)

Authors :

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Abstract

Split-beam hydroacoustic technology has been used to monitor adult salmon migration since 1992. These technologies were first used in Ireland in 1999 on four Irish rivers with limited success, one of which was the Moy system, Ballina, Co. Mayo. The trials of these hydroacoustic counters were part of an initiative to overcome the problem of counting salmon in large rivers where conventional counters (resistivity and infra-red) were not feasible options. A Doctorate study was initiated in 2006 to review these technologies further and to examine any new technologies including the DIDSON (Dual-Frequency Identification Sonar). The aim of the project is to establish a baseline salmonid stock assessment approach for large riverine catchments using these new technologies and existing survey methods.

Conservation limits have already been established for all Irish salmon rivers but the size of migrating populations needs to be quantified to evaluate the status of these stocks relative to their conservation limits and this is particularly challenging in large rivers with numerous or important tributaries possibly containing sub-populations or stocks. The harvestable surplus available for fisheries after the conservation limits have been met must also be estimated and advised to fishery managers and local interest groups. In order to develop such stock assessment methodologies in large rivers, the River Moy, Co. Mayo, which is one of the most prolific salmon producing rivers in Europe was chosen as a suitable experimental river due to its large catchment size, prolific salmon run (rod catch approximately 10 to 15,000 salmon annually) and well established fisheries management infra-structure. For similar reasons, the Eagle River, Labrador, Canada has also been chosen as an experimental site for an initial installation of this new counting technology in a Canadian river.

Migration data from a range of indices, generated by the counter and also based on mark and recapture experiments using smolts caught in screw traps (smolt wheels) and adult salmon caught and released will be used to establish a relationship with other physical, chemical and biological data to determine the timing of migrations and will provide more valuable information on the distributed of salmon throughout the system, and to allow managers to protect these fish at critical stages during the freshwater migration and residency. Salmon stock data obtained from the Deel River, Moy Catchment will be used for the purpose of establishing the count using genetic identification, through research already carried out to determine the relative abundance of the four discrete stocks in the River Moy Catchment.

Study Areas

River Moy, Ireland Catchment

The Moy is the third largest catchment in Ireland and has an area of 2,108 km^2. The system has a very complex drainage pattern with the majority of the system still maintaining a good water quality. The salmon population in the Moy has the potential to produce 700,000 smolts and adult fish returning to the coast have been estimated at approximately 70,000. Recent historic levels of adult fish to the coast were estimated at 150,000 (Ken Whelan pers comm.). Historically the Moy has produced up to 10,000 salmon on the rod alone in some years. The

commercial fishery (draft net and trap) which operated until 1998 took up to 15,000 fish in a given year. Despite these large annual catches, the Moy consistently produces the largest salmon run in the country (Ó Maoiléidigh, 1992). The Deel River is the largest tributary of the Moy Catchment, with an area of 234.31 km^2 and is the most productive tributary of the Moy Catchment in terms of smolt production (McGinnity et al, 1999). Earlier genetic work has determined the relative abundance of the four discrete stocks of salmon in the River Moy catchment, Cloonacool, Manulla, Deel and the Main Moy genetic management units (Dillane et al, *Submitted*). Genetic sampling of the main stem run of salmon at Ballina, to confirm the relative abundance of the River Deel stock in this run, combined with a direct estimate of the Deel stock using the DIDSON counter, will facilitate an estimate of the total Moy salmon run.

Three types of split-beam hydroacoustic technology have been tested during the course of the study: HTI, Simrad and DIDSON. Two exploratory trips were undertaken to obtain training and operational functionality of alternative hydroacoustic counters in Norway (Simrad manufacturers) and Alaska (DIDSON – used by the Alaskan Department of Fish and Game who have been using DIDSON since 2003). The purchase of a DIDSON, which offers near video imagery and an easier counting method, has allowed for the testing of the most up to date technology as this is the first DIDSON to be used in Ireland. The DIDSON counter is reported by the EA, UK to be easier to install, operate and obtain count data (Hateley, J and Gregory, J, 2006). The DIDSON counter and fish fence on the Deel River, will be used to estimate the stock on the system and to examine at fish migration and behaviour relative to river flow and rainfall patterns.

Eagle River, Labrador Catchment

The Eagle is the third largest catchment in Labrador and has an area of 10,824 km^2. The system has a very complex drainage pattern with the majority of the system still maintained in a pristine natural state. The Eagle River drainage has no habitations within it and no industrial development. There currently is a road being constructed from Cartwright Junction to Goose Bay about 265 km distant. The salmon population in the Eagle has the potential to produce 35,000 adults.

DIDSON – Initial Installation, Operation and Data Analysis for the Deel River, Moy Catchment

The standard DIDSON operates best at a frequency of 1.1 MHz - 1.8 MHz, allowing a maximum operating range of 40 m. Counts can be obtained by reviewing computer images on-screen (Image Mode Analysis) or by using the DIDSON SMC processing software (eg. CSOT Analysis). DIDSON counters are rapidly replacing split beam HTI counters in Alaska and the UK.

The H-frame constructed for initial trails on the Boyne River, Blackcastle, Navan, Co. Meath, was used to mount the DIDSON and deploy on the Deel River, just upstream of Knockadangan Bridge. During the trials on the Deel which commenced on the 18th October 2007, the counter position was moved and the standard tungsten target and a second experimental target design were used to map the beam and ensure that the beam was covering the whole bed across the river. The beam location was also determined in relation to the water surface at different water levels. The transducer was located 11 m out from the left bank, directed across to the right bank at a range of 10m using the higher frequency of 1.8 MHz, to allow the DIDSON to be tested at its optimum performing frequency and range. A temperature data logger was installed in November 2007 and attached to the fish fence beside the DIDSON. Flow data will be taken from the (EPA) Environmental Protection Agency's data logger at Knockadangan Bridge.

Fish Fence Installation

Installation of a fish fence and deployment of the counter was only possible this time of year due to the lower water levels and low rainfall level during autumn/winter 2007. The fence was constructed to act both as a walkway out to the transducer location (11m from the left bank) and to guide fish to pass in front of the beam. Fence construction commenced on the 24th October 2007 and was completed to the point where fish could only pass upstream in front of the transducer on the 7th November 2007; fence construction continued until the 17th December 2007, when repairs were carried out due to flood damage in early December 2007.

The walkway still requires completion. Materials have now been obtained and work will be completed when the water levels drop and man-power is available in spring 2008.

To ensure that debris did not gather on the fish fence and walkway, another fence was put in place at an angle from the end of the walkway, to the rivers left bank (water level across the river has not been affected by the installation of this fence). A deflector fence was installed on the 27th November 2007, to guide fish moving upstream further out from the transducer and into the wider part of the beam. This deflector fence is approximately 2 m long and positioned downstream from the transducer.

Operational needs

- Initial use of a power generator required refueling every 24 hrs when running equipment connected to a PC and every 48 hrs when connected to a laptop. The power drain using the PC meant that once the generator stopped running the batteries lost power within approximately one hour. Full mains supply was connected on the 17th December 2007 which allowed the DIDSON to be operated on a 24 hour basis with a much reduced man-power requirement and downtime.
- The fish fence was cleaned as necessary and depending on the water level for safe access. The most common debris was leaves caught in the fence and these were easily removed using a garden rack. The angle of the deflector fence allowed larger debris to pass safely in front of the DIDSON, even at flows just below the top of the fence.
- A system check was carried out to ensure the DIDSON was running and recording data accurately.
- Changes in the transducer position were required periodically especially after flood events. In such situations, the force of water moved the pan and tilt or moved the cable of the DIDSONs transducer or pan and tilt, which in turn may have moved the transducer or pan and tilt. Every time the transducer is moved the profile must be determined to ensure that the beam is covering the whole bed of the river.

Initial DIDSON Data Analysis

The initial assessment of data obtained from trials on the Deel River were used to determine the best site profile, counting zone and to assess fish behavior in the counting zone. Once fish behaviour was established and target work completed, the fish count became the focus of data analysis. Any abnormal behaviour was noted if it deviated from the initial assessment. All files analysed concentrated on obtaining the fish count, measurement and the time that fish movement occurred. Fish counts are obtained for every 15 minutes, to compare salmon counts with water level data recorded every 15 minute (obtained from the EPA data logger on Knockadangan Bridge). This initial assessment will be used to determine when the bulk of fish are moving.

The accuracy of counting was tested using different data analyser's to count fish by 'tallywacking' (counting fish using a tallycounter to obtain a total count every 15 mins); to determine the best, most accurate method for counting DIDSON data using the SMC software, with the smallest file size. The following methods have been tested:

1. Image mode analysis.
2. 'Tallywacking'.
3. Mark Fish Option.

A method incorporating both methods of Image Mode analysis and the SMC software Mark Fish Option is now being used on data that is saved in continuous mode, i.e. 24 hours per day, 7 days per week. Motion Detection is not recommended as a data collection method even though it does offer a reduction in file size. Collecting data continuously and then using the CSOT motion detection option to 'pick' out fish movements and reduce file size is used to establish a baseline of the run in the Deel River, to determine fish sizes and therefore indirectly estimate numbers of fish and species in the river (where possible). It is also easier to obtain fish measurements from counting using this method and each full file is available for validation of counts from files processed using the CSOT option. These count data require processing regarding downtime and beam coverage with various flow levels. Alternative processing software is available for testing and the processing option used will depend on the site and the run of fish being assessed.

Advantages of DIDSON over other Hydroacoustic Counter

- Marine, estuarine and freshwater applications.
- Easy to install, operate and collect data.
- Provides a full fish image rather than an acoustic signal.
- DIDSON systems are easy to transport and can thus easily be moved from river to river enabling counts on other systems from one year to the next.
- Debris moving downstream – is easier to distinguish than when using other hydroacoustic counters.
- Fish behaviour observations: fish avoidance to debris, fish predation, fish movement with different flows and sections of the river that the fish prefer to migrate upstream and downstream.
- Easier to distinguish some species.
- Fish measurements can be estimated directly from screen measurements.
- DIDSON can count fish in flood conditions.
- Very little downtime.
- On-going development of software to reduce file processing times eg. SMC processing, Sonar 5, Echoview etc.

Disadvantages of DIDSON over other Hydroacoustic Counters

- Initial cost (€75,000 / €100,000 inc. Irish Taxes).
- Data storage: Large file sizes e.g. 15 min files are 292 MB resulting in daily sizes of ~45 GB.
- Initial data analysis time: at low fish movement a 15 minute file counting in image mode will take approximately 2 minute 30 secs to analyse. At high fish movement, a 15 minute file counting in image mode will take approximately 7 minutes to analyse. Therefore, 24 hr of data will require 12 hrs of analysis, including the entry of records onto an Excel spreadsheet using image mode analysis.
- Automated counting using software can improve processing times but this will depend on the site selected and species being counted.

- Does not give location of the fish within the water column. Provides information on the distance the fish moves from the transducer.
- Cannot download data remotely due to the large file size.

Discussion

The DIDSON has proved to be a valuable tool for the assessment of salmon stocks on the Deel River, Moy Catchment. To date, the migration patterns of salmon and trout have been observed and initial analysis has shown that run timings are coinciding with a rise and fall in flood waters. However, fish have been seen to move upstream even in heavy flood conditions. Fish behaviour can now be seen directly using a DIDSON whereas this is not the case with resistivity or infra-red counters which provide only static images of the fish. Similarly, visualising the movements of salmon using other hydro-acoustic counters was much more difficult. The DIDSON has proved affective in the Deel River since its installation to test suitable site locations for counting. Once a suitable site was located, data collection and counting commenced. The DIDSON is portable and fence installation is only recommended when a suitable more permanent site has been located. Therefore, the DIDSON can be used as an investigation tool initially for numerous applications for counting adult salmonid migrations, smolt migration, eel migration and observations have been seen of predation by otter, mink, pike and possibly cormorant.

Counters such as the Resistivity and Infra-red counters used widely in Ireland, require a weir or narrow channels for installation making them very difficult and costly to install on large rivers. The standing wave of a resistivity counter is affected by flood conditions. Once the wave creeps over the electrode of the counter it becomes inefficient. These counters can also interfere with fish migration, as the Vaki (infra-red) counter requires the fish to pass through a narrow channel of 40 cm wide X 60 cm deep. The DIDSON beam is not known to deter salmonoid migration. The infra-red beam in the Vaki counters will not penetrate heavily silted water and thus ineffective at counting in such conditions. DIDSON can operate in turbid water conditions even in heavy flood conditions.

DIDSONs are used extensively elsewhere as follows:

British Columbia

- Counting sockeye salmon in Fraser River
- Extensively tested for accuracy and precision
- Counts as good as at a counting fence
- Counts easily repeatable by different viewers with little training required

Alaska

- DIDSON used extensively for counting salmon on various rivers in Alaska
- Counting Dolly Varden, chinook, sockeye and chum salmon in various rivers

Washington State

- Tested for species identification
- Works well easily differentiating various species/debris due to high quality of video

Red River, Manitoba

- Successfully used to evaluate fish passage at dam
- Showed about 50% of 10,000 fish successfully passed through spillway

Teifli River, Wales

- Counted 23,000 fish moving upstream
- Used to post-correct previous year counts

Holmes et al. (2006) extensively ground-truthed counts from the DIDSON by installing it downstream from traps in counting fences and other assessment facilities on four different rivers in British Columbia, Canada. They found the counts at the fence and the DIDSON corresponded on a one for one basis. They also examined the precision of DIDSON counts by having four different readers count salmon from the same sonograms from the four test rivers. Once again the counts so obtained corresponded with each other suggesting that the DIDSON is easy to use and the counts precise. There are about 75 DIDSONs currently in use for fisheries assessment mainly on the west coast of North America. Some have been in use for up to 5 years and have proven to be reliable and simple to use. In Alaska, DIDSONs are replacing HTI and Biosonics sonars previously used. DIDSONs are also in use in the United Kingdom and both Norway and Finland have purchased units for testing in 2008. The

disadvantages of the DIDSON are its high initial cost and its inability to distinguish species of salmonids when of a similar size; although frequently species can be separated on the basis of run timing or different migration characteristics, i.e. movement upstream near to the bank as opposed to mid-stream as noted in Pacific salmon for sockeye and chinook. Projects are also soon to be underway to demonstrate the DIDSONs utility for counting salmon smolts as they descend rivers in the spring of the year. If successful this would add much to the usefulness of the DIDSON systems.

Burwen et al. (2007) conducted calibration experiments with a DIDSON system to evaluate the potential for estimating fish size from images of tethered and free-swimming fish in two Alaskan rivers. In the first experiment, DIDSON images were collected from ten Pacific salmon that were tethered and in the second 130 salmon were allowed to swim freely through the DIDSON multibeam array after being released from a trap. Length estimates from DIDSON images of tethered fish were subject to a positive bias that increased with range of the fish from the transducer. Measurements from free-swimming fish did not demonstrate the same size bias with range. Possible causes for the differing results are discussed in their paper, as well as the performance of the DIDSON with respect to detecting fish, determining direction of travel, and tracking fish at high densities which proved to be highly accurate.

The aim of using the DIDSON in Labrador and Irish waters is to develop methodology that is easy to operate, maintain and obtain accurate count data. Furthermore, it is intended to extend the technology to large rivers where it is currently not feasible to enumerate upstream migrating salmon by any other known method. For this a large river in Labrador, Canada was chosen viz. the Eagle River, Labrador where experiments will be conducted during the summer of 2008. Processing methods will be used to count and trace the migration pattern of salmon in the Deel and to establish a total count for the Moy catchment. Testing of the DIDSON is on-going and it is hoped to develop a method that will be easy to use for both field staff and scientists.

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Atlantic Salmon Stock Assessment using DIDSON in Ireland and Newfoundland/Labrador – Development of a Semi-automated Counting Technique

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Abstract

A DIDSON (Dual-Frequency Identification Sonar) was operated on the Deel River, Moy Catchment, to obtain salmon counts by reviewing fish images on-screen using the DIDSON SMC processing software (eg. CSOT Analysis). DIDSON counters are rapidly becoming an alternative to split beam HTI counters in the US, Canada and the UK. A baseline of the salmon run in the Deel River was made by the continuous collection of data (Image Mode (IM)) and the use of the CSOT motion detection option to 'pick' out fish movements and reduce file size to facilitate post-processing. These data were used to determine fish sizes and indirectly estimate numbers of fish and species in the river. The process described facilitated the acquisition of fish measurements and counts and each full file was available for the verification of all counts from files processed using the CSOT option. It was noted that the processing option used will depend on the site and the size of the run of fish being assessed. The accuracy of counting was tested using three separate analysts who counted fish in image

mode and after CSOT processing using the manual Mark Fish Tool in SMC software. CSOT was also tested as a semi-automated processing method to determine the best, most accurate method for counting salmon using the SMC software and provided the smallest file size and fastest processing times. The method proved to reduce the time and effort of counting with DIDSON as well as providing fish length data and an insight to fish behaviour.

Introduction

The project was initiated to assess salmonid stock size on large rivers in Labrador and Ireland. DIDSON sonar was highlighted as a viable method of counting salmon based on accuracy (Holmes et al. 2006) and ability to size fish (Burwen et al. 2007). The purpose of this paper is to provide information on the application and integration of DIDSON sonars into assessments of salmon stocks in Ireland and Newfoundland and Labrador, Canada.

Methods

Study Area - River Moy Catchment

The Moy is the third largest catchment in Ireland and has an area of 2,108 km^2. The system has a very complex drainage pattern with the majority of the system still maintaining a good water quality. The salmon population in the Moy has the potential to produce 700,000 smolts and adult fish returning to the coast have been estimated at approximately 70,000. Recent historic levels of adult fish to the coast were estimated at 150,000 (ICES 2008). Historically the Moy has produced up to 10,000 salmon on the rod alone in some years. The commercial fishery (draft net and trap) which operated until 1998 took up to 15,000 fish in a given year. Despite these large annual catches, the Moy consistently produces the largest salmon run in the country (Ó Maoiléidigh, 1992) and ranks in the top three of rivers wit the highest productive potential in the country (McGinnity et al, 1999). The Deel River is the largest tributary of the Moy Catchment, with an area of 234.31 km^2 and is the most productive tributary of the Moy Catchment in terms of smolt production (McGinnity 1999). Earlier genetic work has determined the relative abundance of the four discrete stocks of salmon in the River Moy catchment, Cloonacool, Manulla, Deel and the Main Moy genetic management units (Dillane 2007). Genetic sampling of the main stem run of salmon at Ballina, to confirm the relative abundance of the River Deel stock in this run, combined with a direct estimate of the Deel stock using the DIDSON counter, will facilitate an estimate of the total Moy salmon run.

DIDSON Setup

During trials on the Deel river, which commenced on the 18th October 2007, the transducer was located 11 m out from the left bank, directed across to the right bank at a range of 10 m using a standard DIDSON operating at a frequency of 1.8 MHz. This allowed the standard DIDSON to be tested at its optimum performing frequency and range. The initial assessment of data obtained from trials on the Deel River was used to determine the best site profile, counting zone and to assess fish behavior in the counting zone. Once fish behaviour was established and target work completed, the fish count became the focus of data analysis. Any abnormal behaviour was noted if it deviated from the initial assessment. All files analysed concentrated on obtaining the fish count, measurement and time the fish movement occurred. These data were saved continuously in 15 minutes files, to 500 GB removable hard drives for processing.

Data Processing

Sound Metrics SMC software was used to develop a semi-automated processing technique. Continuous DIDSON .ddf files collected 24/7, were processed using CSOT processing tool to identify fish > 30 cm. CSOT only saved the frames in each file where the targets meet the criteria selected. This reduced the size of the file for ease of processing subsequently. These shorter CSOT files were viewed in image mode and analysed using the manual Mark Fish Tool in the SMC software and fish counts and measurements were collected. These data were automatically registered as upstream, downstream or unknown movement depending on the direction the measurement was taken. Fish length data from the DIDSON were used to determine the proportion of Atlantic salmon migrating past the DIDSON counter in the Deel River. The Mark Fish Tool included an arbitrary quality system for rating the quality of each measurement. The analyst rated each measurement and assigned a Q of 1-5.

The migration patterns of salmon and trout were counted over a 14 month period and their run timings examined. Increased turbidity and the use of the silt box was noted to reduce the range of the DIDSON on the Deel River site. Ground-truthing assessment of the auto-measuring tool in DIDSON SMC software, showed that auto estimates were more variable and underestimated length more frequently than manual measurements (Baumgartner 2006). Thus, the manual measuring tool was used for the Deel River stock assessment.

Verification of DIDSON data processing

Initial testing of the semi-automated processing method using CSOT was carried out on 73 test files. These files were assessed using data collected from October 2007 to June 2008, and included twenty-three 10 minute .ddf and fifty 15 minute .ddf files. Each file was processed using CSOT and both .ddf and .csot files were viewed. Background Subtraction (BS) was not used during the test. Three analysts viewed the files in image mode using the manual Mark Fish tool, at a maximum frame rate of 20, counting only fish > 30 cm and recording other events of importance i.e. otter/mink, lamprey/eel and the presence of shoals. The file size, total number of frames per file and processing times of each file were recorded by each analyst for data comparisons. Analyst 1 and 2 had three weeks previous DIDSON training and processing experience.

Validation of DIDSON

Validation was carried out using DIDSON for two purposes. Firstly, to validate that the DIDSON was recording all fish movements in the beam and that the whole of the counting zone was being observed**.** Secondly, to validate the use of DIDSON for length measurements taken during the processing of DIDSON data using the SMC software. The validation was carried out on the 16th and 17th October and the 6th and 26th November 2008, using fish of known length passed through the DIDSON beam. Coho salmon (*Oncorhynchus kisutch*) have been used successfully as a test target from a tethered line to validate the DIDSON-LR (Long Range), (Galbreath 2005). The data was collected at a frame rate of 7 and a range of 10 m, settings as per operations carried out over the 14 months of data collection. This simulated the daily counting conditions at the site. The total fish length (cm) was measured prior to the fish entering the water. The total fish lengths and DIDSON recorded lengths were analysed and to determine the relationship between these length measurements. DIDSON fish lengths were taken using the manual mark fish tool in the SMC software, using the 'zoom' tool for ease of measurement.

Data Analysis -Verification

In previous tests to verify DIDSON data processing, holding and milling fish were not counted (Cronkite 2006; Holmes 2006; Maxwell 2007). These fish movements were counted in the Deel River verification tests. To compare the efficiency of counts between IM and

CSOT methods to verify the use of CSOT, Analyst 3's data were referred to as the *reference data. Therefore, Analyst 1 and Analyst 2 CSOT counts were compared to the reference data, i.e., the true count. The reference data was used to calculate the percentage accuracy for the upstream, downstream and nett counts for each analyst (Table 1-3 and Figs. 1-3). The semi-automated processing (CSOT) efficiency was 99% for the Analyst 3 for the nett count. The percentage accuracy for the downstream counts were much lower than that of the upstream counts and the nett upstream counts. This was most evident for analysts 1 and 2, highlighting the importance of user experience. The close proximity in the percentage accuracy of Analyst 1 and 2, may be due to the fact that both were trained together and had the same length of user experience. This also showed that training provided was probably transferable to two different users.

Analyst 3's processing showed very little difference between counts when the net count was determined. Direction was easily determined when analysing CSOT files if fish were not milling. Milling created error with some analysts counting fish going upstream and downstream when the fish turned back downstream in the beam, prior to leaving the beam. The difference in gross fish count between analysts may also be due to the counting of milling fish if the same fish is moving up and downstream continuously. This made very little difference to the nett upstream fish count. A greater number of fish were counted using the CSOT method when compared to total net upstream count for image mode.

During the processing of autumn/winter 2008 data the method was changed and Background Subtraction (BS) was used making it easier to identify and measure fish. Site improvements were made to the counting zone with the installation of a deflector fence and the removal of a fallen tree, on the right bank. This increased fish detection and reduced the number of fish holding and milling in the beam allowing easier determination of the direction and a reduction in milling fish behaviour. There was a vast reduction in processing times after CSOT processing due to the reduction in file size.

In-attention has been described as a factor contributing to the variation in counts between analysts (Galbreath 2005). The use of CSOT processing eliminates waiting for fish

movement during file processing as only frames with fish movement are recorded. However, for verification the entire file must be analysed in image mode and this can be result in inaccuracies due to long wait times.

Data Analysis-Validation

Comparisons of .ddf files for each fish target tested during the validation experiments on the Deel river were 100% concurrent with that of the data recorded for the target fish. All the live fish target images were easily observed. Laboratory tests (Mueller et al, (2006), showed that the DIDSON was able to identify 100% of fish passage even in turbid waters. Target work using a tungsten sphere (-38.5 dB) was carried out regularly to ensure that all areas of the counting zone were observed. It has been assumed that once the target has been seen in all areas of the counting zone that the counting accuracy achieved in image mode prior to the use of processing software (CSOT) is equal to that measured by Holmes et al. (2006) and Cronkite et al. (2006). Visual counts cannot be carried out in Irish waters due to water turbidity and underwater cameras have been shown unsuitable for hydroacoustic validation purposes in Irish rivers (Brennan in prep.).

DIDSON lengths had a strong linear relationship with the total lengths in the Deel River validation where each total length measurement taken was compared to the DIDSON length at different ranges (Fig. 4). Length measurements were taken at different ranges were compared for each fish to test the range dependant length deviations for each fish as they moved at different ranges in the beam. The down range resolution is a function of the window length.

The cross-range resolution is:

(range/2)/no. beams

The down-range resolution is:

window-length/512 (Sound Metrics).

Therefore, a fish at a range of 5 m using a 10 m window Std HF

(Cross-range resolution) = 250/96 = 2.6 cm
(Down-range resolution) = 1000/512 = 1.95 cm

Thus for a 10 m window length the down range resolution was approximately 2 cm.

The ability to resolve fish deteriorates with range due to a decrease in image resolution associated with the decreased number of beams and the increased beam width and spacing (Belcher 2001; Belcher 2004). The maximum range at 1.8 MHz is 12 m. Increased water turbidity and the use of the silt box were noted to reduce the range of the DIDSON operating on the Deel River site to approximately 10 m. Many authors have noted that the accuracy of length estimates is influenced by the aspect of the ensonified fish (Galbreath 2005; Baumgartner 2006; Mueller 2006; Burwen 2007; Maxwell 2007). Fish lengths were easily determined when fish were perpendicular in the beam. The side aspect has a much higher target strength than head or tail aspect. This was noted on the Deel River where two fish were swimming in circles, illustrating the effect of aspect angle versus target strength (http://www.soundmetrics.com/sonar101/aspectangle.html).

Figures 4 and 5 show the length frequency distributions of test fish measured manually and using the DIDSON. They are not normally distributed as different species were used during the validation to obtain different size ranges of specimens. DIDSON fish lengths were on average 1.1 cm greater than the manually measured fish prior to entry to the water (n = 601).

The mean DIDSON (n = 601) and Total True Lengths (n = 62) had means of 68.3 cm (SD = 16.5) and 71.3 cm (SD = 17.3) respectively. The results show a positive bias for DIDSON and Total True Length using tethered fish. Burwen et al. (2007) reported a positive bias validating with tethered fish, however, tethered fish in that experiment remained stationary.

There is not yet a reliable and robust method for acoustically identifying downstream migrating kelts (MSW fish) and this may prove problematic for counts using DIDSON on Irish rivers (Cronkite 2006). When MSW stocks are low applying corrections may not greatly increase the overall estimate.

Study Area at Eagle River, Labrador

Eagle River, the fifth largest river in Labrador, flows northeasterly emptying into Sandwich Bay at Separation Point. It is one of the largest Atlantic salmon producing rivers in North America. No harvesting of the watershed's mature coniferous forest has yet been undertaken and the hydroelectric potential, estimated to be around 1000 MW has yet to be developed. Thus, the river is in a near pristine state. A portion of the watershed has also been selected for inclusion in the proposed Mealy Mountains National Park. Eagle River is fed by 81 tributaries and drains an area of 10,824 km^2 and has an axial length of 139 km. The river has its source in a series of string bogs and steadies located on a barren plateau south of the Mealy Mountains. There are no precise estimates of the productivity of this river but some rough estimates based on drainage area put it between 30,000 to 50,000 individuals annually. There are also brook trout (sea run and brook), Arctic charr, eels, sticklebacks, longnose and white suckers, northern pike, and rainbow smelt on the system.

Studies in Newfoundland and Labrador, 2008

In addition to site surveys carried out at Eagle River, the smolt fence at Campbellton River, Newfoundland was used as a validation site for the DIDSON results. At the Campbellton smolt fence there were 76 kelts released from the trap in the fence and 76 fish were observed using the DIDSON software. A total of 41 kelts were physically measured at the trap for total length and then measured with the on-screen DIDSON measuring tool.

A survey of the potential sites for locating the DIDSON at Eagle River was carried out in July 2008. Locations upstream and downstream from the chosen site were found to be too wide and/or too deep, and had salmon stationary in target zone for long periods. The site chosen is just above head of tide, about 84 m wide, has a boulder-gravel bottom, no milling salmon at least while we were there and depths ranging from 0 to 5 m depending on water levels. Water levels will fluctuate by about 1m over the counting season which will extend from 15 June to end of September.

We have two DIDSONs (a Short Range [SR] and a Long Range[LR]) along with the Big Lens that were deployed at the site at Eagle River. The intention is to deploy them as shown in Fig. 2, that is one on either bank. Since the water depth on the South Bank of Eagle River is deeper then on the North Bank, we have decided to place the SR DIDSON there pointing more steeply into the water then the LR DIDSON placed on the North Bank. Our proposal is to run the SR with a 20 m window in low frequency (LF) and the LR in a series of 20 m windows, first in HF and then two in LF extending out to 60 m. Equipment will be operated from a 10 x 12 foot cabin placed on the North Bank and a weather proof storage compartment will be used on the South Bank. Power supply is described in Enzenhoffer et al. (2007). Staff requirements are for six persons on site in shifts of three such that the sonar can be operated 24/7. The operating budget will be approximately $80,000 per annum. Overall capital budget for purchase of two DIDSONs, ROS Helios Pan & Tilts, four computers, power supplies, Large Lens set, and deployment options was CAD$250,000.

The target species is Atlantic salmon (*Salmo salar* L.). There are substantial runs of sea run brook trout (*Salvelinus fontinalis*) which will be excluded based on size (less then 40 cm) and because the major run of brook trout occurs in September when few Atlantic salmon are present. Issues are the training of staff to operate the equipment, operation in a remote location with no access to main line electricity.

Discussion

The aim of using the DIDSON in Irish waters was to develop methodology that are easy to operate, maintain and obtain count data. Unlike the use of split beam hydroacoustics in fisheries stock assessments, the interpretation of DIDSON data required less technical training and user experience. Processing methods tested were used to count and trace the migration pattern of salmon in the Deel and to establish a total count for the Moy catchment. The testing of the DIDSON SMC software and CSOT processing allowed for the development of a method that is easy to use for both field staff and scientists. From experience gained on the Deel River, analyst experience is vital to ensure fish detection and accurate determination of direction during processing. It is recommended that technical training is provided and that during an analysts first three months of processing DIDSON data, regular verification testing is carried out to ensure quality control of the data being processed. The percentage of files that will require verification will be site specific, as the bed profile and fish behaviour in the counting zone will determine the effectiveness of CSOT processing. Holmes et al (2006) noted some variability in counts of migrating salmon among analysts and that the precision of counts produced from the DIDSON system increased as the number of fish counted increased. Precision with accuracy is required for count data. Fish that were migrating upstream, but did not pass through the beam prior to turning in the beam and moving back downstream, may have caused variability between analysts. This was observed in the data when the upstream, downstream and nett counts were assessed.

The assessment of three different analysts shows that the quality of data is dependant on analyst experience. It is important to have speed with accuracy when processing to enable real time counting to be achieved. The reduction in both analysis time due to a reduction in the number of frames saved and thus a reduction in file size, after processing using CSOT was very good. This allows the user to save only the shorter CSOT files for back up where a percentage of continuous files have been stored for verification. This should only be done once the percentage accuracy has been calculated for using CSOT.

The number of files and/or hours of verification data required is site specific (Suzanne Maxwell, pers.comm..). Test files comparison showed that with files where fish were milling

and backsliding downstream at an angle, CSOT processing cannot ‘see’ fish or the motion detection is not triggered. When it is triggered where fish are milling, often not enough frames are saved to determine direction due to the aspect angle the fish are swimming. This also resulted in possibly greater variation in the percentage accuracy of counts, depending on how much milling behaviour was observed in test files for verification. It was difficult in some instances to determine actively migrating fish from milling fish as other authors noted in previous studies (Cronkite 2006). Some of the difference could be account for between author and trainee analyst due to their inability to determine fish direction and thus logging a fish as an unknown movement. In these instances the author had determined direction of movement and/or had detected fish that the trainee analysts had missed. The technique is obviously transferable but like Holmes et al (2006), it takes time to train the users eye to ’see’ all movement and to allocate the direction of that movement. The maximum counting speed of 20 frames/sec may have been too high a frame rate limit for analysers with less experience. However, other operators applied this setting to ‘smooth out’ the image making fish easier to see (Galbreath 2005; Hateley 2006). Time analysis showed the important need for some form of automation to the processing of this data for counting Atlantic salmon. This emphasises the need for the semi-automated approach developed here. It is not possible to carry out partial counts eg. 10 min every hour (ADFG), due to the large time differences between fish movements/peak migration in Irish rivers as Atlantic salmon migrate twelve months of the year in much lower numbers then Pacific salmon. (Hateley 2006) tested motion detection methods in SMC to develop for data collection and processing with mixed results. These methods are not recommended for data collection until significant baseline data has been collected and the methods fully verified.

The validation of DIDSON lengths was essential, as the length frequency data from the DIDSON was used to differentiate between fish of over lapping size ranges, Brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*) in the Deel River system. The bimodal length distribution obtained was used to estimate the probability of fish being brown trout or Atlantic salmon, where there was a cross-over in the length frequency distribution. This method is under development for use in Irish large river systems using DIDSON lengths to enumerate and as a method of species apportioning (Brennan in prep.).

The method developed on the Deel River for the validation of DIDSON was the best method that could be operated under weather and hydrological conditions during the salmon run. It is recommended that radio tracking is carried out (where possible) for a more effective method of DIDSON validation (Jim Gregory, pers. comm.). However, this method would require greater man-power and is more expensive. Burwen et al (2007), effectively used the release of fish from fish traps through the DIDSON beam to validate DIDSON. The analysis produced fish length, direction and behaviour data for all fish that were detected in the beam. The development of an effective post-processing tool increases the operational potential for DIDSON for the assessment of Atlantic salmon. The DIDSON has proved to be a valuable tool for the assessment of salmon stocks on the Deel River, Moy Catchment.

The ability to obtain fish length estimates using DIDSON means that there is no handling of the fish and the technique is non-intrusive. There is a need to further test the DIDSON to determine the effectiveness of these methods at greater ranges using the standard DIDSON and using a long range DIDSON, in Irish riverine catchments.

The two DIDSONs purchased by Fisheries & Oceans were tested on four rivers in 2008: Campbellton, Salmonier on the island and Eagle and Sand Hill in Labrador. At Campbellton River, 76 salmon kelts were individually released from a smolt trap and all 76 were observed by the DIDSON. Further testing occurred at both Sand Hill for smolts and Salmonier for extended windows use. At Eagle River, a site was chosen for the operation of the DIDSONs in 2009 with reasonable characteristics for operation and counting. Characteristics included no milling salmon, the least amount of acoustic noise, and appropriate bottom profile.

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Table 1. Raw fish counts from 73 .ddf files in Image Mode (IM). *Reference data (Louise Brennan).

Analyst	**Upstream Count (IM)**	**Downstream Count (IM)**	**Unknown Movement (IM)**	**Net Count (IM)**
Analyst 3	175	106	2	69
Analyst 1	148	104	13	44
Analyst 2	137	86	18	51

Table 2. Raw fish counts from 73 .ddf files after CSOT processing.

Analyst	**Upstream Count (CSOT)**	**Downstream Count (CSOT)**	**Unknown Movement (CSOT)**	**Net Count (CSOT)**
Analyst 3	150	80	1	70
Analyst 1	113	53	12	60
Analyst 2	102	45	0	57

Table 3. Percentage Accuracy of the Upstream, Downstream and Net Upstream counts using CSOT Processing with the reference data.

Analyst	Upstream	Downstream	Nett Upstream
Analyst 3	86%	76%	99%
Analyst 1	76%	51%	87%
Analyst 2	74%	52%	83%

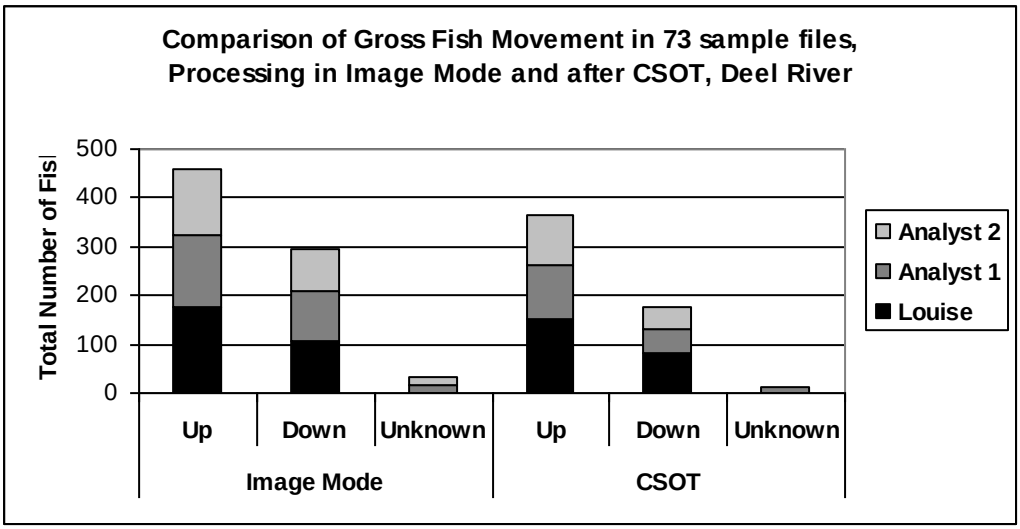

Fig.1: Comparisons of the Gross Fish Movement for each Analyst using Image Mode and after CSOT Processing. (Note: Analyst 3 is "Louise")

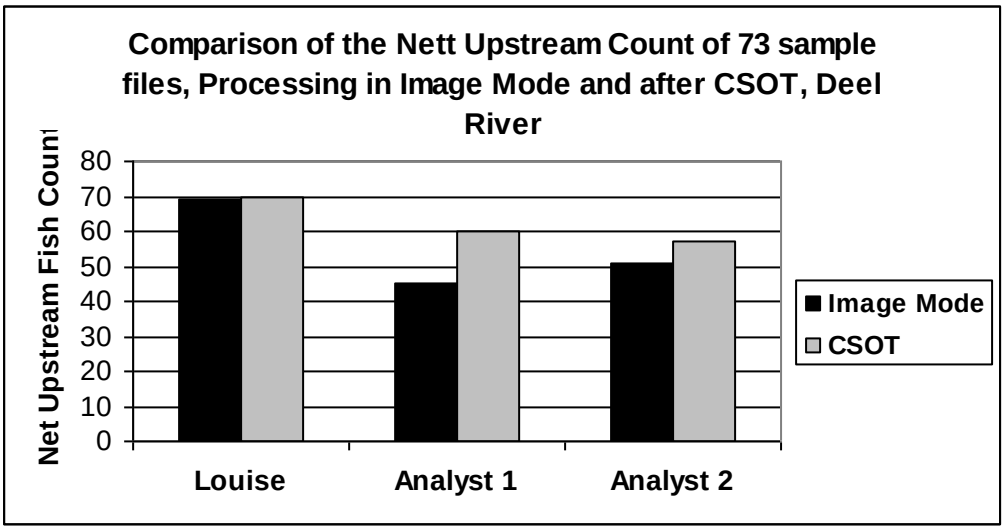

Fig.2: Comparisons of Nett Upstream Count for each Analyst using Image Mode and after CSOT Processing. (Note: Analyst 3 is "Louise")

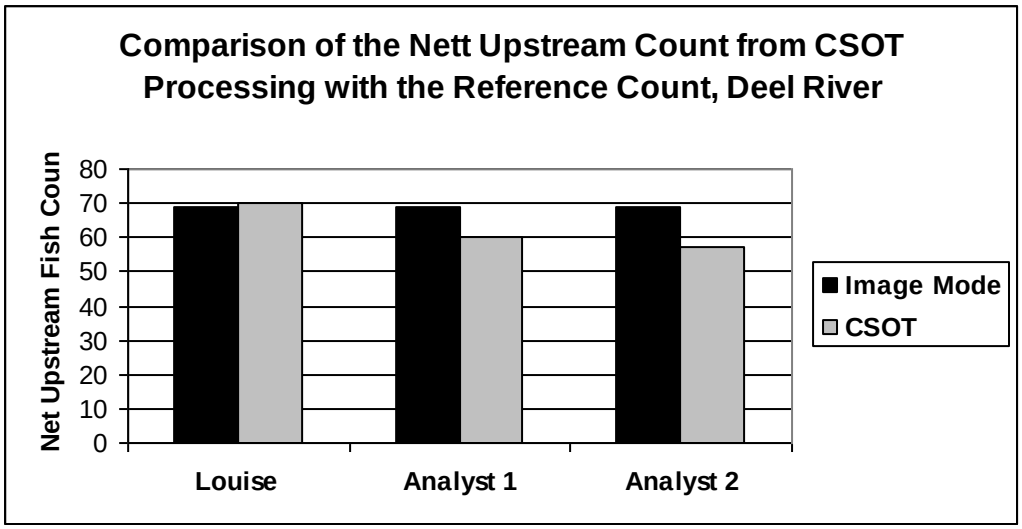

Fig.3: Comparisons of the Net Fish Movement for each Analyst using CSOT Processing with the reference data. (*Image Mode here is Reference data). (Note: Analyst 3 is "Louise")

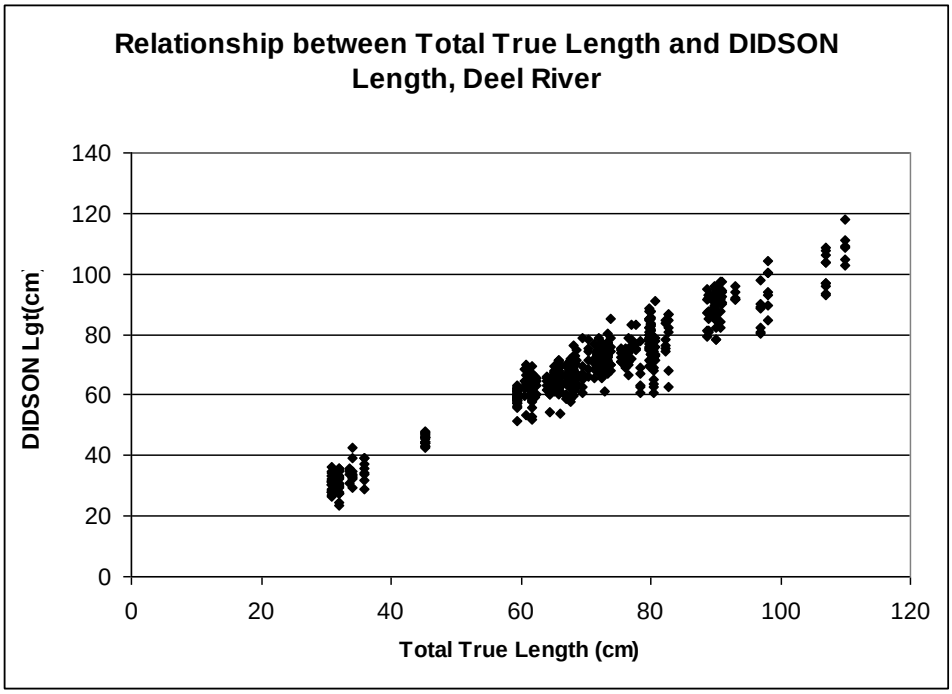

Fig. 4: Linear relationship between DIDSON length (cm) and the Total True length (cm) of each fish, Deel River, Moy Catchment, Ireland. $R^2 = 0.9232$ and n = 601.

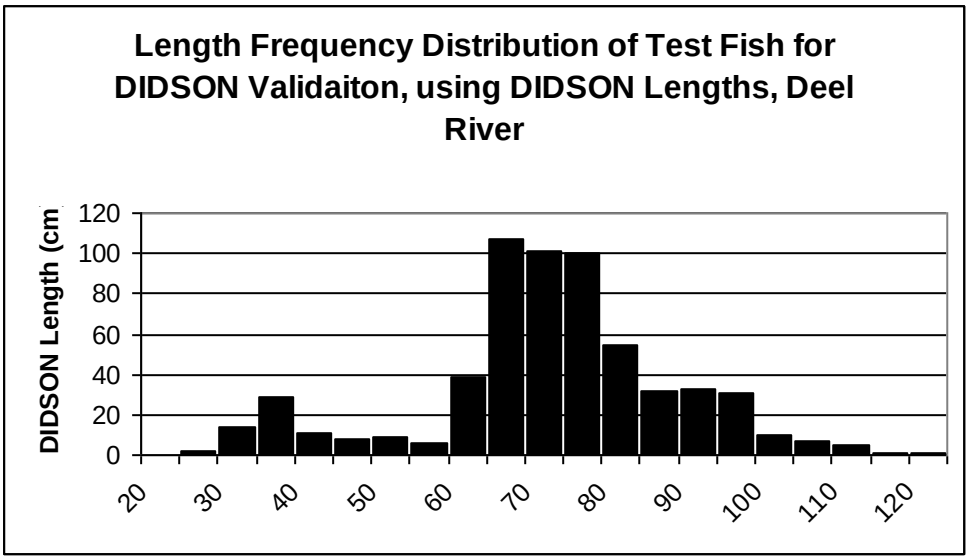

Fig. 5: Length Frequency Histogram of test fish DIDSON Length Measurements. DIDSON sample size, n = 601.

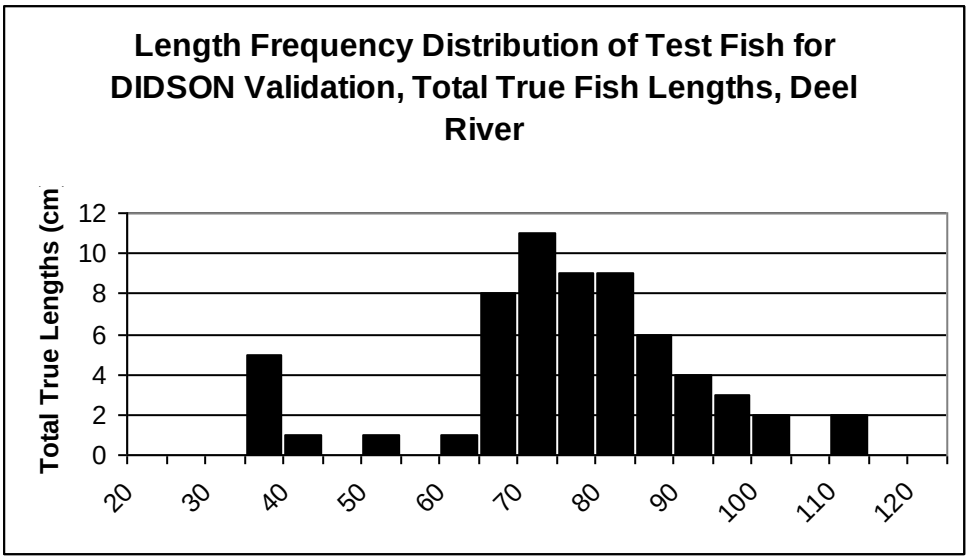

Fig. 6: Length Frequency Histogram of test fish Total True Length Measurements. Manually measured live fish sample size, n = 62.

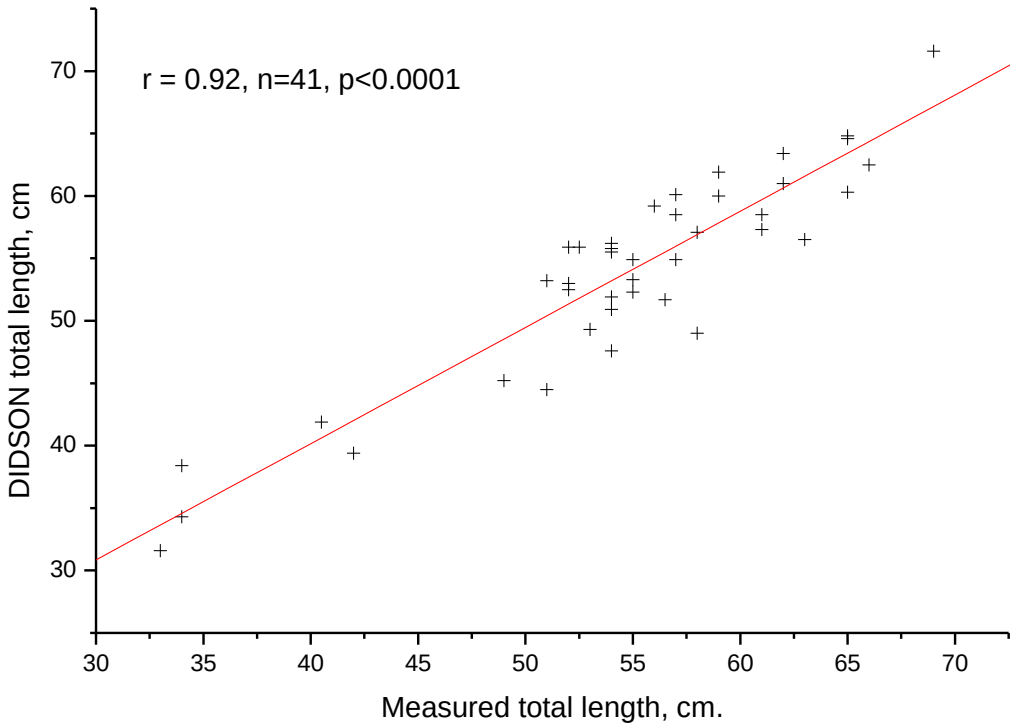

Fig. 7. Results of measuring salmon kelts at Campbellton River, Newfoundland in 2008 for physical total length compared to DIDSON measured total length.

Section III – (A) Maps & (B) Photographs

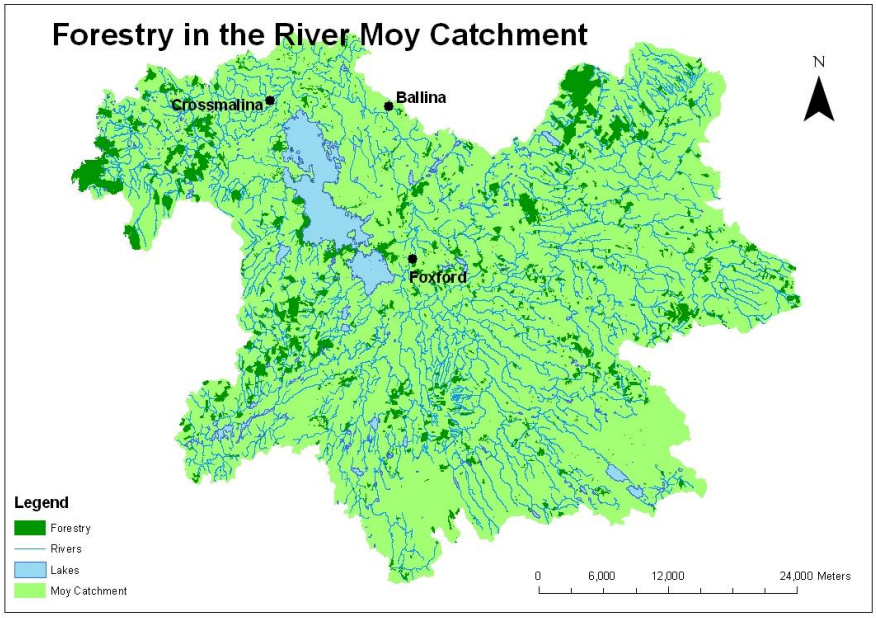

Figure A1: Forestry within the River Moy catchment (Map data sourced from EPA).

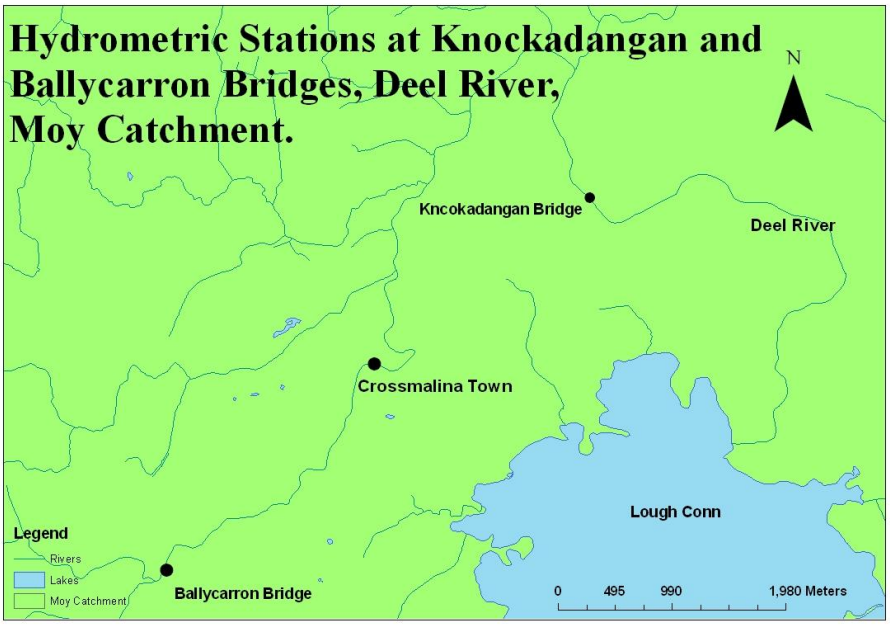

Figure A2: Hydrometric stations at Knockadangan Bridge (EPA) and Ballycarron Bridge (OPW), River Deel (Map data sourced from EPA).

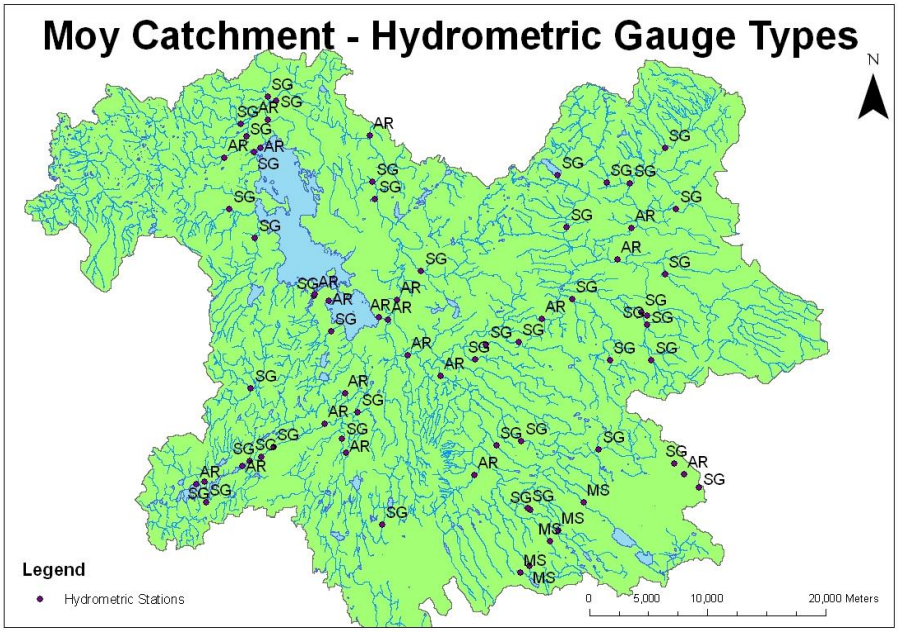

Figure A3: Hydrometric stations within the River Moy catchment (AR = Automatic Recorder; SG = Staff Gauge) (Map data sourced from EPA).

Plate B1: Fish image (salmon) recorded on the Vaki counter, Ballina Traps, River Moy (Louise Brennan, 03/11/06)

Plate B2: Debris loading, Ballina Traps, River Moy (Louise Brennan, 01/05/07)

Plate B3: Debris loading Blocking Traps with fish counters, Ballina Traps, River Moy (Louise Brennan, 19/02/08)

Plate B4: Narrow passage for fish migration, Vaki counter, Ballina Traps, River Moy (Louise Brennan)

PlateB5: Walkway with 'pully system' for camera array at Hollister's (Louise Brennan, 2006)

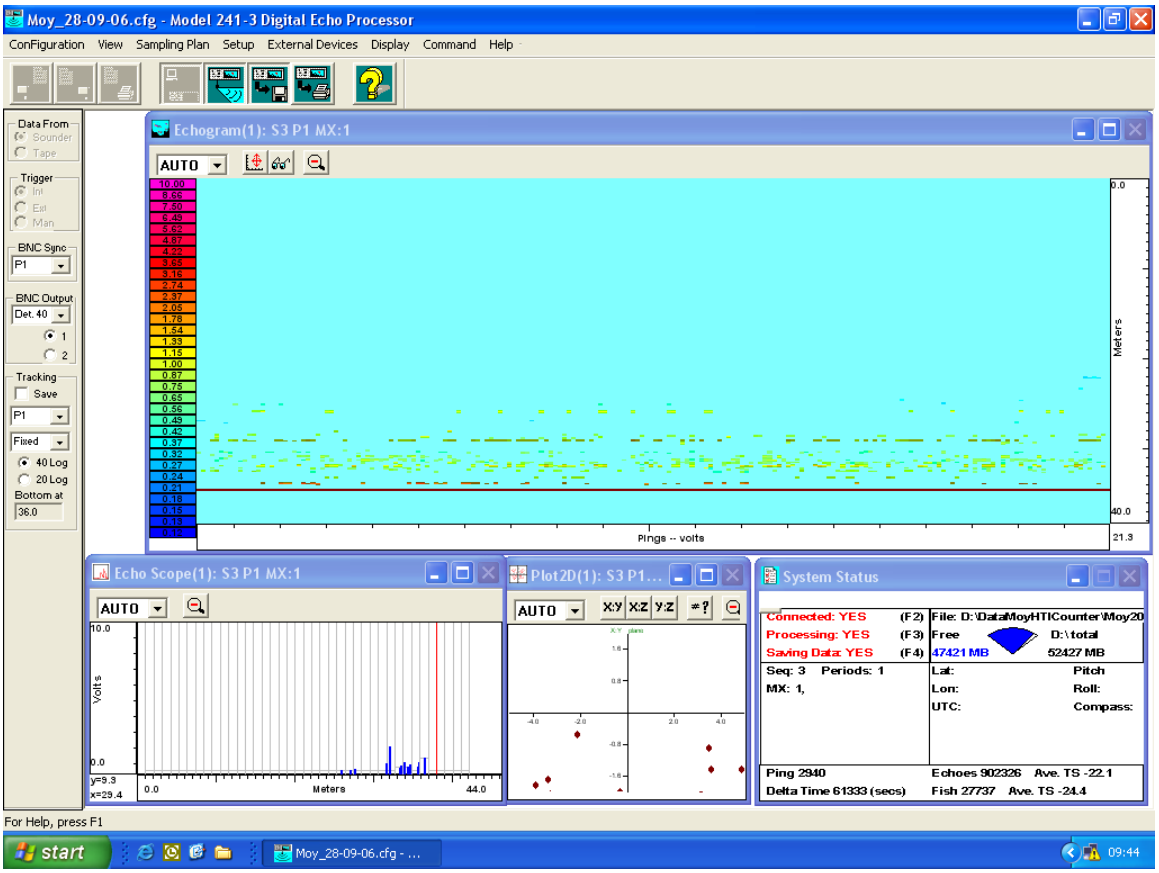

Fig. B1: Full screen view on the 04/10/06 of the display while the hydrosacoustic counter was operational (Louise Brennan, 04/10/06)

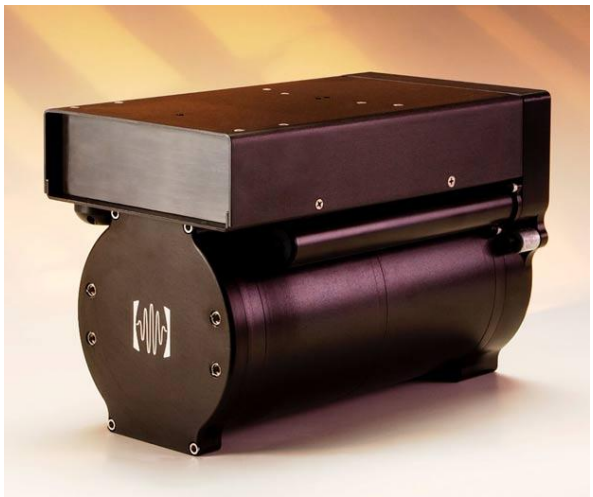

Plate B6: DIDSON (Dual-frequency Identification Sonar) (Image from Sound Metrics).

Site 7

Plate B7: River Deel looking upstream where bed profiling was undertaken, showing site 7 at the single groin on the left bank, River Deel (Louise Brennan, 27/04/2007).

Plate B8: Fish fence construction, showing construction of debris deflector fence, DIDSON Site, River Deel (Louise Brennan)

Plate B9: Deflector fence installed on the right bank to prevent erosion, River Deel (Louise Brennan, 26/09/08)

Plate B10: Flood conditions on the 28th March 2008, River Deel DIDSON site, deflector fence nearly covered. Water level at approximately 1.2 m when photograph was taken (Data from EPA Staff Gauge at Knockadangan Bridge) (Louise Brennan, 28/03/08)

Plate B11: Bank erosion after spring flood (Louise Brennan, 23/04/08)

Plate B12: Silt collected in the DIDSON lens, 19th February 2008, DIDSON site, River Deel (Louise Brennan, 19/02/08)

Plate B13: Cleaning after flood (Louise Brennan, 21/08/08)

Plate B14: Cleaning DIDSON lenses with soft paint brush DIDSON site, River Deel, 2008 (Nigel Bond, 21/08/08)

Plate B15: Cleaning DIDSON lens using soft paint brush, DIDSON site, River Deel, 2008 (Nigel Bond)

Plate B16: Silt Box opened showing DIDSON inside (Nigel Bond)

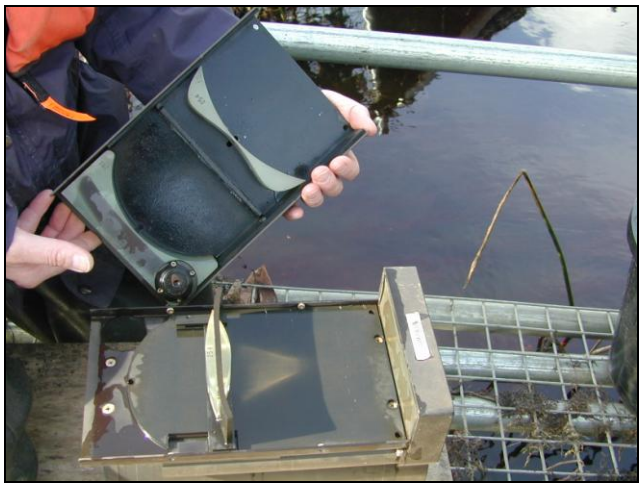

Plate B17: Very little silt found on DIDSON lenses when using the Silt Box (Louise Brennan)

Plate B18: Cleaning fish fence after flood, 21st August 2008 (Eddie Doherty, 21/08/08)

Plate B19: Cleaning fish fence after flood, 21st August 2008 (Louise Brennan, 21/08/08)

Plate B20: Rupture in seal of lens, making it difficult to reposition lens after cleaning, DIDSON, Deel River (Louise Brennan, 23/04/08)

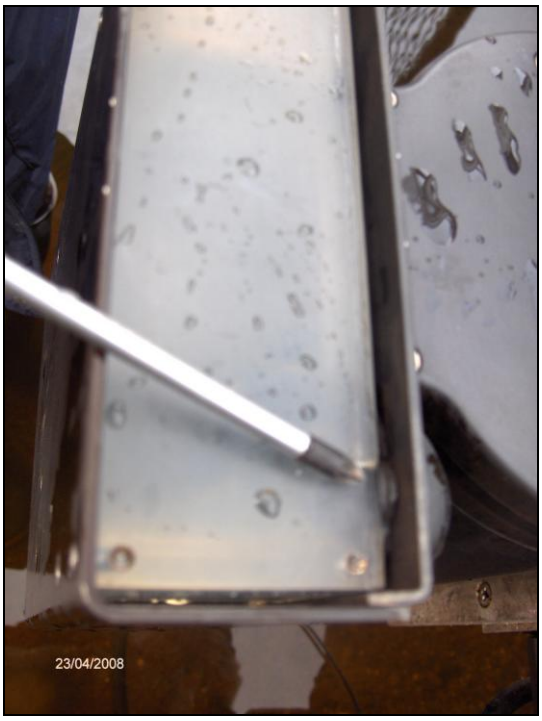

Plate B21: Rupture in seal 'leaking' out over lens, making it difficult to reposition lens after cleaning, DIDSON, Deel River (Louise Brennan, 23/04/08)

Plate B22: Monitoring fish movement during the validation experiment, inside portable hut at DIDSON Monitoring Station, River Deel (Louise Brennan)

Plate B23: River Deel DIDSON Site prior to the peak Atlantic salmon migration, showing walkway, fish fence and both deflector fences, 26th September 2008 (Louise Brennan)

Section IV

(A). Bimodal Model – Testing of the Bimodal Model: Determination of the Best Fit Model to determine Probabilities.

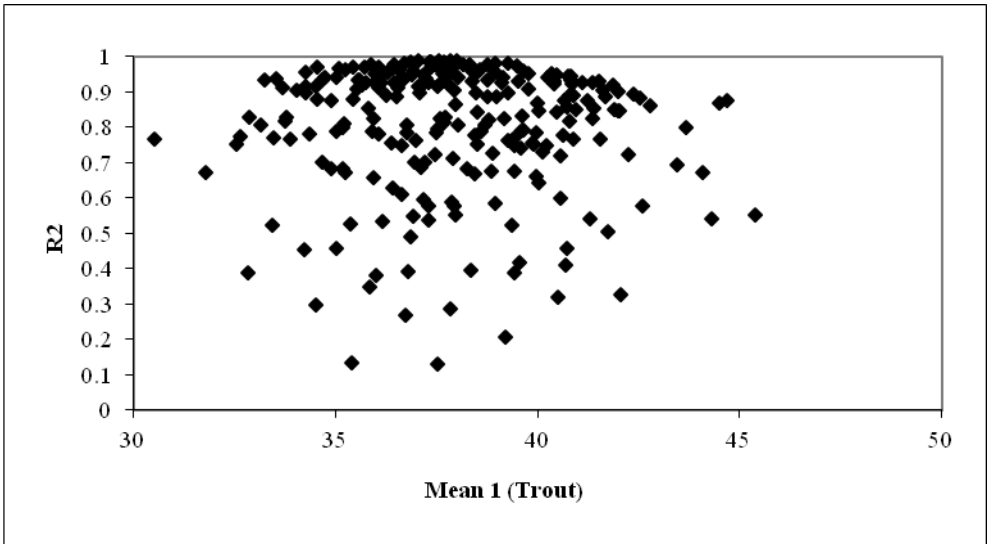

Figure A1: The Relationship between R^2 and Mean 1 (Trout), River Deel Bimodal Model.

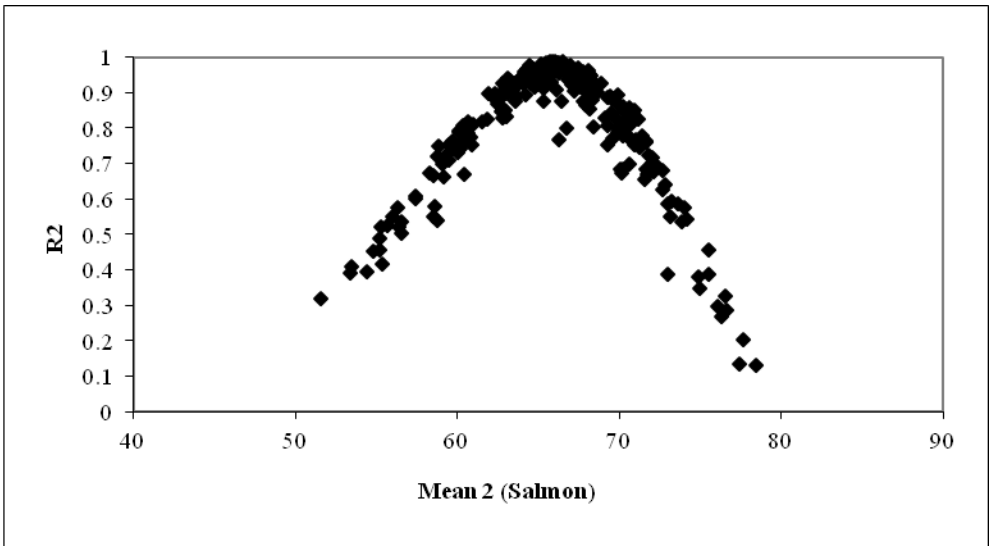

Figure A2: The Relationship between R^2 and Mean 2 (Salmon), River Deel Bimodal Model.

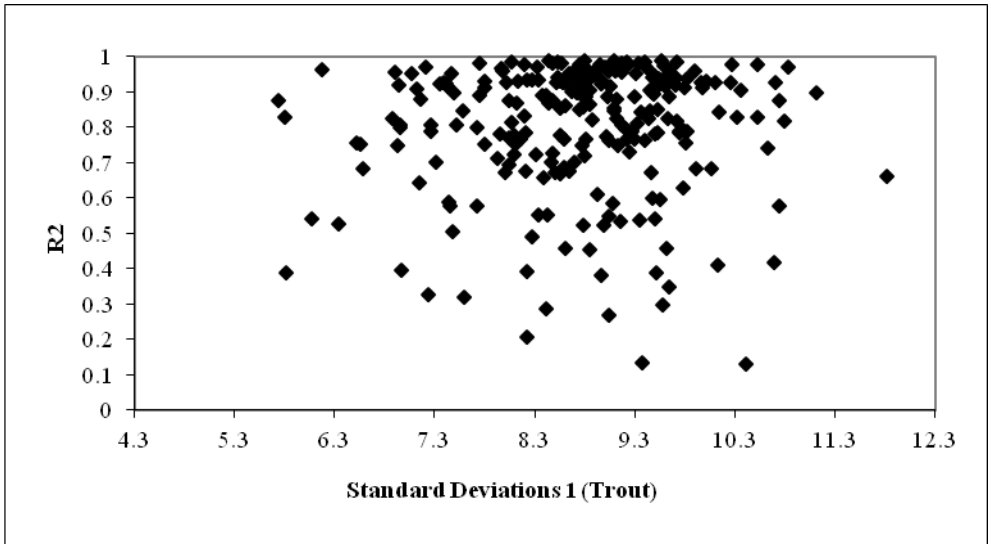

Figure A3: The Relationship between R^2 and the Standard Deviation 1 (Trout), River Deel Bimodal Model.

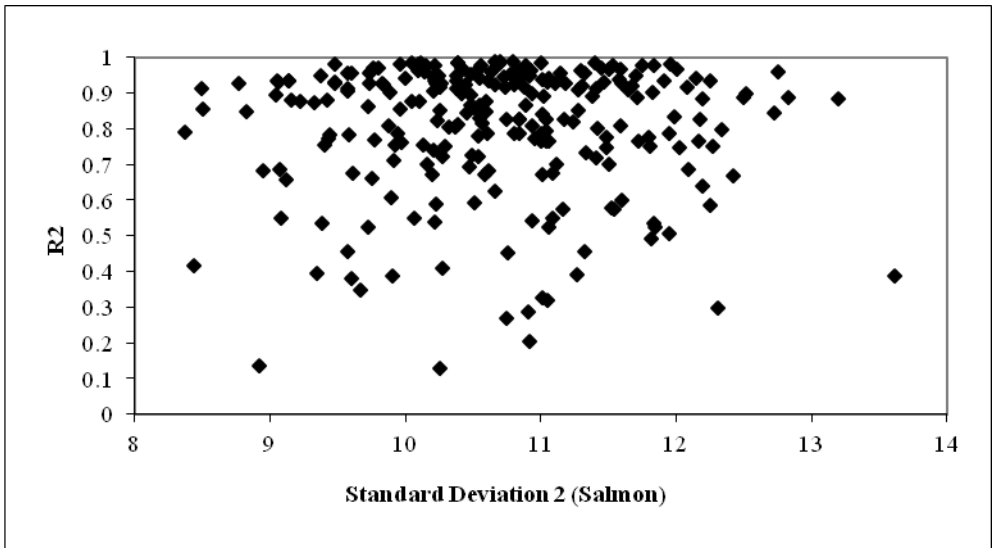

Figure A4: The Relationship between R^2 and Standard Deviation 2 (Salmon), River Deel Bimodal Model.

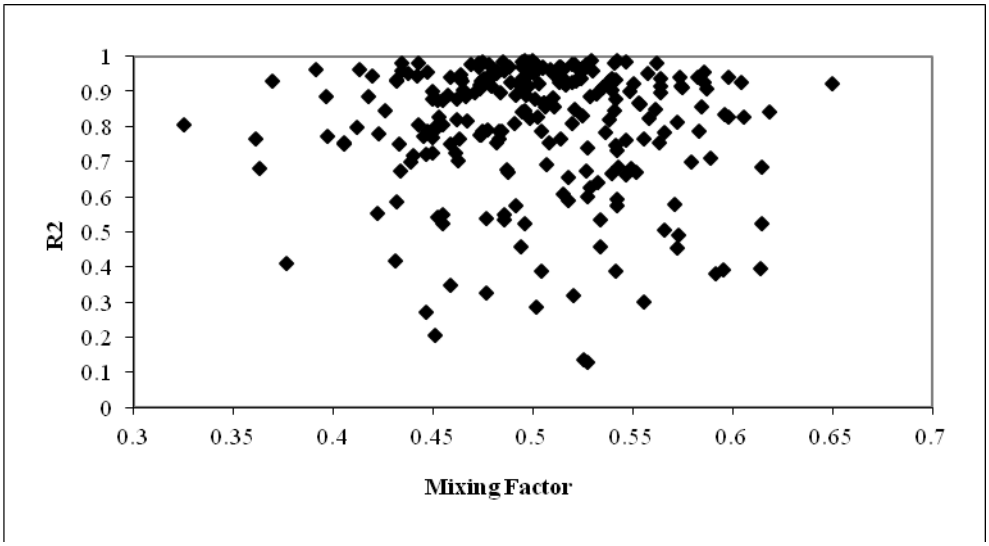

Figure A5: The Relationship between R^2 and the Mixing Factor, River Deel Bimodal Model.

Bimodal Model – Determination of the Probabilities of the Observed Data being salmon or trout.

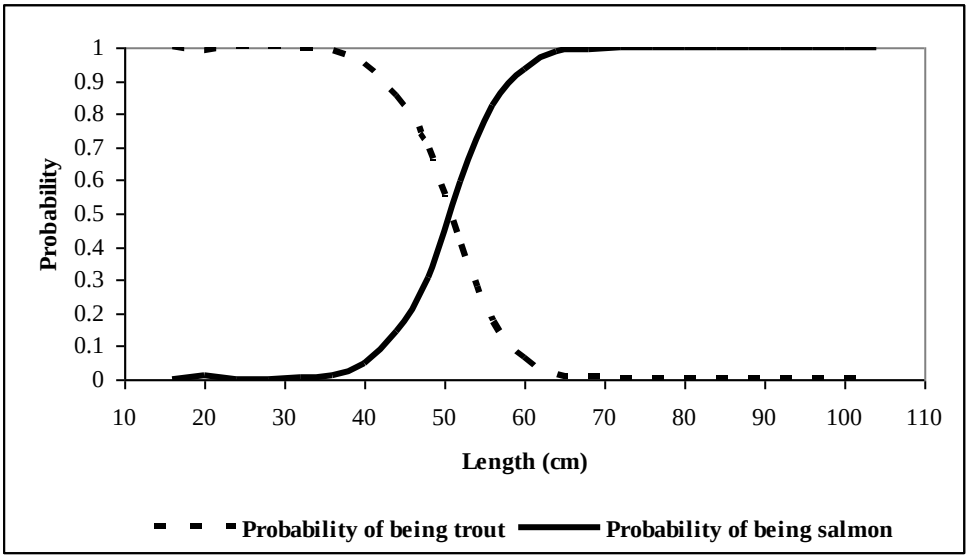

Fig. A6: The probability of the observed data being salmon or trout, River Deel Bimodal Model.

(B). DIDSON Data Processing: Verification Tests - Time Analysis

Table B1: Time analysis to estimate the processing time using image mode and after CSOT processing during verification, Deel DIDSON, River Deel.

	Analyst 1		Analyst 2	
File Name	**Image Mode (mins sec)**	**After CSOT (mins sec)**	**Image Mode (mins sec)**	**After CSOT (mins sec)**
2007-11-18_180001_HF	7.16	1.44	9.50	2.35
2007-11-18_190001_HF	8.14	1.46	12.45	3.53
2007-11-19_180001_HF	7.58	3.14	14.46	6.26
2007-11-20_010001_HF	6.15	1.11	10.02	1.55
2007-11-20_040001_HF	6.58	1.41	8.09	2.39
2007-11-20_053000_HF	8.07	3.43	13.04	5.04
2007-11-21_080001_HF	6.20	1.03	7.58	0.57
2007-11-22_144500_HF	5.23	0.12	5.54	0.01
2007-11-23_054500_HF	6.10	0.35	6.02	0.53
2007-11-23_123000_HF	9.29	5.58	19.55	5.51
2007-11-23_171500_HF	5.43	0.57	6.33	1.32
2007-11-24_170001_HF	7.00	1.35	8.13	1.14
2007-11-24_183000_HF	9.19	3.53	11.56	6.28
2007-11-25_231500_HF	6.23	0.19	5.37	0.43
2007-11-26_074500_HF	6.24	1.27	6.11	3.25
2007-11-26_080001_HF	6.48	1.21	7.29	1.25
2007-11-30_124500_HF	6.32	0.37	5.47	0.34
2007-12-01_110001_HF	7.50	2.18	12.16	3.21
2007-12-18_144000_HF	1.49	No CSOT File	2.19	No CSOT File
2007-12-18_161500_HF	6.43	2.22	7.42	2.34
2007-12-18_180001_HF	5.15	No CSOT File	5.15	No CSOT File
2007-12-18_181500_HF	5.15	No CSOT File	5.15	No CSOT File
2007-12-18_183000_HF	5.31	0.18	5.53	0.32
2007-12-18_233000_HF	5.16	No CSOT File	5.15	No CSOT File
2007-12-18_234500_HF	5.15	No CSOT File	5.23	No CSOT File

File Name	**Image Mode (mins sec)**	**After CSOT (mins sec)**	**Image Mode (mins sec)**	**After CSOT (mins sec)**
2007-12-19_041500_HF	6.06	0.17	6.27	0.45
2007-12-19_053000_HF	5.57	0.15	6.07	0.29
2007-12-19_070000_HF	5.57	0.28	6.48	1.10
2007-12-19_084500_HF	6.37	1.35	10.39	2.53
2007-12-19_090000_HF	5.54	0.10	7.40	0.45
2007-12-19_091500_HF	6.53	2.26	10.56	2.34
2007-12-19_093000_HF	9.57	4.13	12.08	5.47
2007-12-19_094500_HF	6.26	2.01	7.53	2.41
2007-12-19_100001_HF	8.56	2.41	13.54	2.50
2007-12-19_101500_HF	5.50	1.10	6.48	1.48
2007-12-19_103000_HF	6.20	1.06	8.13	2.47
2007-12-19_104500_HF	6.27	1.15	9.47	2.40
2007-12-19_110000_HF	6.17	1.48	7.32	1.08
2007-12-19_111500_HF	6.15	1.28	10.04	3.50
2007-12-19_113000_HF	6.01	0.04	4.51	0.16
2007-12-19_114500_HF	6.48	0.51	6.55	1.36
2007-12-19_120000_HF	5.24	0.15	5.02	1.05
2007-12-19_121500_HF	6.05	0.41	5.42	0.27
2007-12-19_123000_HF	5.42	0.18	6.06	0.39
2007-12-19_124500_HF	6.28	1.02	9.27	2.16
2007-12-19_153000_HF	5.38	0.29	5.40	0.41
2007-12-19_161500_HF	5.46	0.14	6.55	0.48
2007-12-19_163000_HF	5.32	0.21	5.16	0.31
2008-04-25_090001_HF	5.17	0.03	5.14	0.03
2008-06-11_113000_HF	6.03	1.33	9.56	4.09

(C). DIDSON Detection of Riverine Biodiversity, River Deel

Numerous fish species were detected passing through the DIDSON beam at the River Deel site. Bird life were also noted on the water surface, including ducks and swans and what were thought to be comorants (*Phalacrocoax carbo*) diving for fish. Native otter (*Lutra lutra*) and non native species such as mink (*Mustela lutreola*) are known to frequent the River Deel catchment and images of these species were logged moving up and downstream in the DIDSON beam. The number of otter or mink observations moving upstream and downstream in the beam over the 14 month period was 482 images. The peak movement was on the 21st July 2008, where 23 images of the otter or mink were counted passing through the beam. Eel (*Anguilla anguilla*) and Lamprey (*Petromyzon marinus*) were also observed migrating past the DIDSON beam (Vol. II Appendix Section VIII CD: Image 3.5). Other non-target fish species present in the River Deel were described during the operation of the screw trap (Chapter 6). Thus operators need to be aware of the number and size of non-target species present.

The Identification of Eel Migration using a DIDSON, River Deel

DIDSON was shown to have the ability to detect eel and lamprey in Irish waters but discriminate between the two was not possible, thus for these results both images were assumed as eel. The number of eel migrating downstream during DIDSON data processing for the River Deel over the 14 months of data collection was 401 eel. The eel run for 2007 was captured by the DIDSON (Fig. C1 below), from the 18th November to the 31st December 2007, where 140 eel migrated downstream with a peak in the run of 38 and 39 eel detected on the 13th and 14th December 2007. Count data for eel in autumn/winter 2008 were more limited due to the increased flooding. It was more difficult in 2008 to distinguish eel from fish migrations observed using the DIDSON (Fig. C2 below), with a total of 98 eel migrating downstream. The peak of the downstream migration was on the 4th September 2008 with 16 eel. For both study years, eels when migrating favoured the first 5 m of the counting zone and 548 eels were recorded from this zone. A total of 268 eels moved at a distance of $\geq$ 5 m. The minimum range at which an individual eel was measured in the DIDSON beam at was 0.88 m and the maximum 10.67 m. Eel length measurements ranged from a minimum length

of 10 cm to a maximum of 90 cm. The average eel length measurements was 50.4 cm (SE = 0.3982, SD = 10.48) (n = 692).

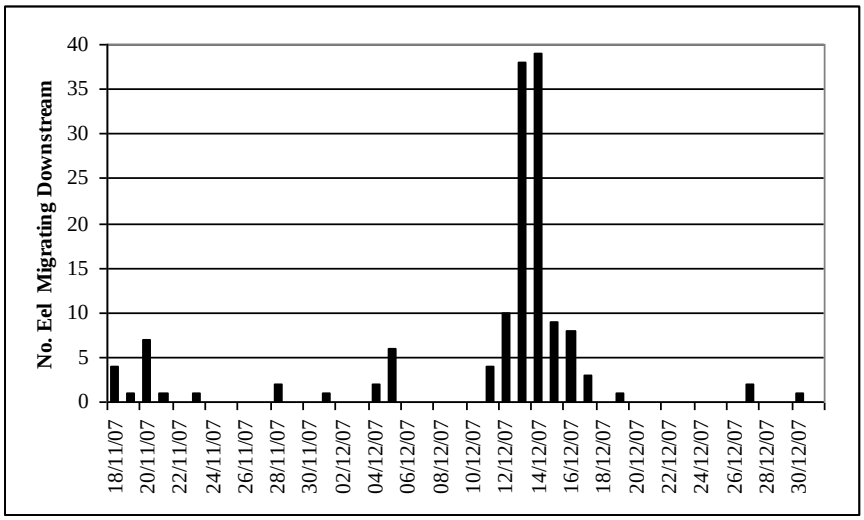

Figure C1: The total downstream migration of Eel, Deel DIDSON site, River Deel, November to December 2007.

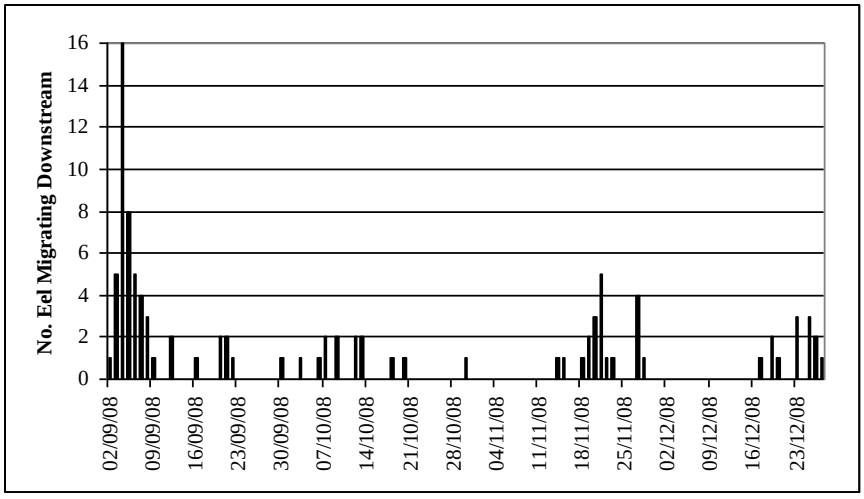

Figure C2: The total downstream migration of Eel, Deel DIDSON site, River Deel, September to December 2008.

DIDSON allowed for the run timing of eel migrations to be detected for 2007 and 2008 and this added to the knowledge of the system. This is the first in-river estimation of eel migration using DIDSON in Ireland. Due to the quantity of data for the processing of fish migrations, eel lengths were not taken for all eel detected by the DIDSON but the analysis of

the data shows that it is possible to obtain estimates of eel migration using DIDSON. However in 2008, eel migrations were very difficult to discriminate from fish migrations. Other non-target species present in the River Deel system include pike (*Esox lucius*), occur in very small numbers and display very limited movement. However, they were believed to have similar size range to salmon in the River Deel (IFI). DIDSON was unable to discriminate for pike but there were occasions when fish behaviour (as observed in the DIDSON beam) could be used to determine species such as pike (due to their tendency to hold in the water column while waiting for prey) but this was arbitrary and un-reliable. The salmon stock assessment for the River Deel was not influenced by the presence of resident non-target species such as pike, as their behaviour over the counting period, where they were present, was indicative of slowly milling up and downstream from Lough Conn to the River Deel, thus cancelling out their movement (Cronkite et al, 2006). This nullified their effect on the net upstream salmon count. Smaller shoaling fish were observed and thought to be roach, as numerous roach were trapped during the operation of the screw trap, the majority of these smaller fish were all below 25 cm (Chapter 6). In some DIDSON images different fish species can be identified by their swimming patterns and shape in the beam but this would not hold true for all fish images seen and therefore unreliable for discriminate. Increased viewing of images increases the strength of the analyst ability to detect what image are observed. Mueller *et al* (2010) has developed a method of using tail beat counts from DIDSON imagery to identify species. Such methodology for species discrimination in Ireland has not yet been tested but could be examined using the River Deel DIDSON data.

Section V

Indirect Stock Assessment Methods for Adult & Juvenile Atlantic salmon

(A). Redd Counts

In collaboration with the IFI, Ballina Office, redd counts were carried out on the River Deel where water levels permitted in December and January 2008 where 207 redds were identified. Known spawning sites were assessed with the IFI and the count data compiled by the IFI. These data were used to provide an indication of spawning times and in which months spawning ceased (Plate A1 & A2). Redd count data was used to support the determination of the 2008 cohort for population estimates from the DIDSON counter.

Plate A1: Salmon redd located during redd counts, River Deel, (Louise Brennan, 04/01/08).

Plate A2: Spawned salmon (Male) located during redd counts, River Deel, (Louise Brennan, 04/01/08).

(B). Adult Floy Tagging – River Moy

Adult tagging was also undertaken on the River Moy to determine the exploitation rate at the Moy Ridge Pool, Moy Fishery, Ballina, Co. Mayo. In conjunction with the IFI, a floy tagging programme was initiated the floy tagging of rod caught fish at the Ridge Pool commenced on the 19th June to the 20th September 2007. Floy tagging at the Ballina traps was also undertaken from the 28th June to the 21st September 2007. Due to greater than average monthly rainfall (Section VI: Fig.6.1) weather conditions in the summer of 2008, only one day of fishing at the Ballina traps was possible, despite the traps being operated on several occasions between 4th June to August 2008. No salmon were trapped in 2008.

Double tagging was undertaken using numbered floy tags and these were inserted into the side and behind the dorsal fin of adult salmon (Plates B1 & B2). The date and time of capture, floy tag numbers, location, and weight (lbs) were recorded (Table B1). Scale samples were taken for genetics analysis as part of the genetic stock identification. To enable the return of rod caught floy tagged fish, the tagging programme was advertised using information flyers (sample of the flyer below) and through fishery proprietors, angling clubs and angling shops within the Moy catchment. The programme was advertised via both local and national media through newspapers, IFI newsletter and website, and the Irish Anglers Digest.

However, limited recaptures were obtained. For rod caught and tagged fish in 2007, 96 fish were tagged with 7 recaptures and in 2008, 26 fish were tagged with 7 recaptures (Fig. B1). Water levels were very high in 2008 and limited that amount of angling and thus opportunities for the catching of fish for tagging and the number of recaptures. These flood conditions also prevented the operation of the Ballina traps due to the increased discharge and debris loading entering the traps. No fish tagged from the Ballina traps were recaptured. In-sufficient numbers of fish were tagged and no returns were obtained for the adult mark recapture programme for a detailed analysis. Details of the floy tagging programme and the numbers of fish tagged and the number of returned floy tags are outlined in Fig. B1 and Table B1.

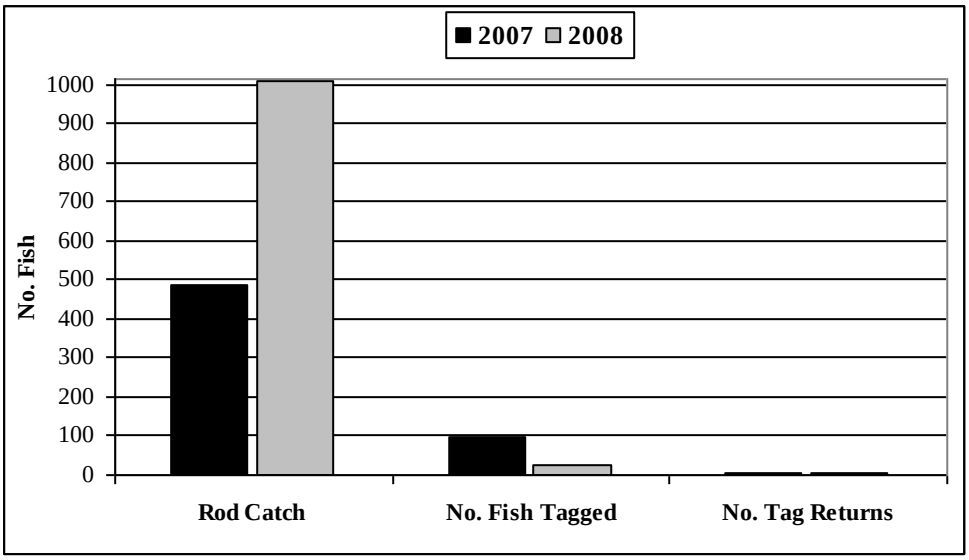

Figure B1: Adult floy tag mark recapture programme, 2007 & 2008, showing the total rod catch, number of Atlantic salmon tagged and tag returns, from the Weir Pool, Ridge Pool to Cathedral Beat, River Moy.

Table B1: Floy Tagging Programme - Results Sheets 2007 (Shaded Numbers indicate higher reward tagged fish).

No.	Date	Time	Tag No.	Tag No.	Weigth Est. (lbs)	Released	Returned Tags 2007
1	28/06/2007	09:35	2251	2252	4	Trap 2	No Return
2	28/06/2007	09:38	2253	2254	7	Trap 2	No Return
3	28/06/2007	09:40	2255	2256	3	Trap 2	No Return
4	19/07/2007	14:20	2257	2258		Trap 2	No Return
5	19/07/2007	14:27	2259	2260		Trap 2	No Return
6	19/07/2007	14:28	2141			Trap 2	No Return
7	19/07/2007	14:32	2261	2262		Trap 2	No Return
8	27/07/2007	09:49	2263	2264	4	Trap 2	No Return
9	27/07/2007	09:51	2265	2266	4	Trap 2	No Return
10	27/07/2007	09:55	2267	2268	6	Trap 2	No Return
11	27/07/2007	10:02	2270	2271	4	Trap 2	No Return
12	27/07/2007	10:13	2272	2273	7	Trap 3	No Return
13	27/07/2007	10:16	2274	2275	3	Trap 3	No Return
14	27/07/2007	10:10	2145	2146	4.5	Trap 3	No Return
15	27/07/2007	10:18	2276	2277	3	Trap 3	No Return
16	27/07/2007	10:18	2278	2279	3	Trap 3	No Return
17	27/07/2007	10:20	2280	2281	3.5	Trap 3	No Return
18	27/07/2007	10:25	2282	2283	5.5	Trap 3	No Return
19	27/07/2007	10:31	2284	2285	2.5	Trap 3	No Return
20	27/07/2007	10:31	2286	2287	4	Trap 3	No Return
21	27/07/2007	10:33	2288	2289	2.5	Trap 3	No Return

No.	Date	Time	Tag No.	Tag No.	Weigth Est. (lbs)	Released	Returned Tags 2007
22	27/07/2007	10:37	2290	2291	4.5	Trap 3	No Return
23	27/07/2007	10:11	2147	2149	6	Trap 3	No Return
24	27/07/2007	10:24	2151	2152	4	Trap 3	No Return
25	27/07/2007	10:40	2292	2293	4.5	Trap 3	No Return
26	27/07/2007	10:45	2294	2295	2	Trap 3	No Return
27	27/07/2007	10:26	2153	2154	3	Trap 3	No Return
28	27/07/2007	10:48	2296	2297	7	Trap 3	No Return
29	27/07/2007	10:57	2298	2299	4	Trap 3	No Return
30	27/07/2007	11:00	2300		6	Trap 3	No Return
31	27/07/2007	11:05	2201	2202	6	Trap 3	No Return
32	27/07/2007	10:26	2155	2156	4	Trap 3	No Return
33	27/07/2007	11:10	2203	2204	2	Trap 3	No Return
34	27/07/2007	11:11	2205	2206	3	Trap 3	No Return
35	27/07/2007	11:14	2207	2208	5	Trap 3	No Return
36	27/07/2007	10:51	2157	2158/2160	3	Trap 3	No Return
37	27/07/2007	11:16	2209	2210	4	Trap 3	No Return
38	27/07/2007	11:18	2211	2212	5	Trap 3	No Return
39	27/07/2007	11:19	2213	2214	5	Trap 3	No Return
40	10/08/2007	12:15	2215	2216	4	Trap 2	No Return
41	10/08/2007	12:17	2217	2218	4	Trap 2	No Return
42	10/08/2007	12:19	2220	2221	4	Trap 2	No Return
43	10/08/2007	12:20	2222	2223	4.5	Trap 2	No Return
44	27/07/2007	10:55	2161	2162	3.5	Trap 3	No Return
45	10/08/2007	12:22	2224	2225	5	Trap 2	No Return
46	10/08/2007	12:24	2226	2227	4.5	Trap 2	No Return
47	10/08/2007	12:26	2229	2230	5.5	Trap 2	No Return
48	10/08/2007	12:28	2231	2233	3	Trap 2	No Return
49	10/08/2007	12:30	2235	2236	3	Trap 2	No Return
50	10/08/2007	12:43	2237	2238	6	Trap 3	No Return
51	10/08/2007	12.44	2239	2240	3	Trap 3	No Return
52	10/08/2007	12.48	2241	2242	2.5	Trap 3	No Return
53	10/08/2007	12.54	2243	2244	3.5	Trap 3	No Return
54	27/07/2007	11:01	2163	2164	6	Trap 3	No Return
55	27/07/2007	11:04	2165	2166	7	Trap 3	No Return
56	10/08/2007	12.58	2245	2246	3.5	Trap 3	No Return
57	04/09/2007	11.06	2247	2248	4	Trap 2	No Return
58	04/09/2007	11.09	2249	2250	7	Trap 3	No Return
59	05/09/2007	12.25	2401	2402	7	Trap 3	No Return
60	05/09/2007	12.38	2403	2404	5	Trap 3	No Return
61	21/09/2007						No Return
62	27/007/07	11:19	2167	2168	3.5	Trap 3	No Return
63	10/08/2007	12.51	2170	2171/2172	4.5	Trap 3	No Return

Plate B1: Floy tagging Adult salmon, Ballina Traps, River Moy, 27th July 2007.

Plate B2: Floy tagged Adult salmon, Ballina Traps, River Moy, 27th July 2007 (Louise Brennan).

Salmon Tagging

The Marine Institute, in association with The North West Regional Fisheries Board, is carrying out a salmon tagging survey on the River Moy. Two orange tags are being inserted in salmon released by anglers on the Moy Fishery in Ballina. Two green tags are being inserted in a number of salmon caught and released at the Moy Fishery traps. The tags are located just beside and/or behind the dorsal fin. Any angler who catches a tagged salmon is asked to participate in the survey and rewards of €10 and €20 are payable for returned tags. If a tagged salmon is caught and killed, both tags should be removed. If the fish is being released, only one tag should be removed and this should be done very carefully by cutting the tag off close to the flesh. The fish must be kept in the water in accordance with the law.

On capture of a tagged salmon the angler should record the following details:

(1) Time, date and location where the fish was caught.
(2) The number on the tag(s).
(3) Total Length (cm) of the fish (where possible).
(4) Method of Capture.

Reward

Offered, as detailed below:
€20 per Salmon returned with Green Tag (or pair) and capture details complete.
€10 per Salmon returned with Red Tag (or pair) and capture details complete.

Contact: **Louise Brennan, Aquaculture & Catchment Management Section, Marine Institute**
Furnace, Newport, Co. Mayo.
098 42300 **087 207 1169**

The results of this survey will greatly assist in future management of salmon stocks in the Moy system.

Marine Institute
Foras na Mara

NDP
NATIONAL DEVELOPMENT PLAN

(C). River Deel Ecology – Non-Target Species Sampled in the Screw Trap, 2007 & 2008

An additional advantage of the operation of the screw trap was that it provided information on the overall health of the River Deel system. Screw traps are not species or size selective and any species migrating downstream in the system can potentially be sampled (Chaput & Jones, 2004). A total of seven non-target species were captured during the operation of the screw trap in 2007 and nine in 2008. Atlantic salmon smolts comprised of 51 % and 35 % of the total catch in 2007 and 2008 (note that not all non-target species were sampled in 2007). Tables 6.1 showed the wide variety of species that were sampled over the two year operation of the trap. The overall diversity was broader in 2008 year as indicated by the greater number of each species collected that year. This demonstrated the diversity of species and their abundance in the River Deel and was presented here purely as additional information. The main bulk of non-target species identified and sampled in 2008 were brown trout (12 %) and roach (27 %). This was thought to be as a result of their influx into the River Deel from Lough Conn. Lampreys trapped in the screw trap were not identified to species and lamprey, eels and crayfish were very difficult to measure. The majority of non-target species were noted to be in good condition with only approximately five perch for both study years showing signs of an unidentified fungus growing on their bodies. One of the three adult salmon capture in the screw trap in 2008, was trapped migrating downstream on the 6th May 2008, measuring approximately 57 cm. This salmon had not yet spawned and was obviously moving downstream prior to spawning and was thought to be an early grilse migrating downstream to hold in the Lough Conn.

Table C1 Non-target species trapped during screw trap operation, 2007 and 2008, River Deel (In 2007 not all non-target species were counted).

Species	Common Name	Trapped 2007	% of Capture 2007	Trapped 2008	% of Capture 2008
Salmo salar	**Adult salmon**	0	0	3	0.20%
Salmo salar	**Atlantic salmon Parr/Fry**	74	8%	307	10%
Salmo trutta	**Brown trout**	276	16%	526	12%
Salmo trutta	**Brown trout Parr/Fry**	30	2%	74	2%
Rutilus rutilus	**Roach**	226	13%	1151	27%
Scardinius erythrophthaimus	**Rudd**	2	0.10%		0
Phoxinus phoxinus	**Minnow**	188	11%	246	6%
Perca fluviatus	**Perch**	18	1%	111	3%
Austropotamobius pallipes	**Crayfish**	7	0.40%	14	0.30%
Anguilla anguilla	**Eel**	2	0.10%	13	0.30%
Petromyzon marinus	**Lamprey**	11	1%	167	4%
***Salmo trutta* L.**	**Sea Trout**	0	0	11	0.30%

Plate C1: Brown trout kelt found dead near Knockadangan Bridge, River Deel. Shows upper size range Brown trout migrating in the River Deel (Louise Brennan).

(D). Aging of the Atlantic salmon Smolt Migration, River Deel, 2007 and 2008

During sampling, smoltification was noted in smolts ranging from approximately > 6 cm to > 16 cm. Thus the determination of the average smolt age of the sample was necessary. Twenty-five samples from both 2007 and 2008 were aged by wet mounting to determine the age cohort of smolts sampled from the screw trap (Table D1 & D1). The mean smolt age was 2 years with approximately 88 % of the run for 2007 composed of 2 year old smolts and the remainder of 1 and 3 year olds and approximately 96 % of the run for 2008 composed of 2 year old smolts and the remainder of 1 and 3 year olds

Table D1: Atlantic salmon smolt aging 2007 & 2008, River Deel.

Date	Species	Length (cm)	CaptureDetails	ID No.	Scale Age
09/04/2007	SAsmolt	11.4	SmoltTrap Deel	D0001	2
09/04/2007	SAsmolt	13.3	SmoltTrap Deel	D0008	3
09/04/2007	SAsmolt	12.2	SmoltTrap Deel	D0009	2
09/04/2007	SAsmolt	9.2	SmoltTrap Deel	D0013	1
09/04/2007	SAsmolt	10.4	SmoltTrap Deel	D0015	2
10/04/2007	SAsmolt	10.5	SmoltTrap Deel	D0068	2
10/04/2007	SAsmolt	12.5	SmoltTrap Deel	D0070	2
10/04/2007	SAsmolt	11.2	SmoltTrap Deel	D0072	2
10/04/2007	SAsmolt	10.6	SmoltTrap Deel	D0074	2
10/04/2007	SAsmolt	12.5	SmoltTrap Deel	D0077	2
11/04/2007	SAsmolt	11.3	SmoltTrap Deel	D0100	2
11/04/2007	SAsmolt	12.7	SmoltTrap Deel	D0102	2
11/04/2007	SAsmolt	10.4	SmoltTrap Deel	D0104	1+
11/04/2007	SAsmolt	11.6	SmoltTrap Deel	D0107	2
11/04/2007	SAsmolt	11.0	SmoltTrap Deel	D0114	2
14/04/2007	SAsmolt	11.5	SmoltTrap Deel	D0118	2
14/04/2007	SAsmolt	11.6	SmoltTrap Deel	D0120	2
14/04/2007	SAsmolt	11.2	SmoltTrap Deel	D0122	2
14/04/2007	SAsmolt	10.0	SmoltTrap Deel	D0124	2
14/04/2007	SAsmolt	12.2	SmoltTrap Deel	D0126	2
15/04/2007	SAsmolt	12.4	SmoltTrap Deel	D0138	2
15/04/2007	SAsmolt	11.4	SmoltTrap Deel	D0140	2
15/04/2007	SAsmolt	10.0	SmoltTrap Deel	D0143	2
15/04/2007	SAsmolt	13.4	SmoltTrap Deel	D0148	2
15/04/2007	SAsmolt	11.2	SmoltTrap Deel	D0136	2

Table D2: Atlantic salmon smolt aging 2007, River Deel.

Date	Species	Length (cm)	CaptureDetails	ID No.	Scale Age
30/03/2008	SAsmolt	15.5	SmoltTrap Deel		2
30/03/2008	SAsmolt	11.8	SmoltTrap Deel		2
10/04/2008	SAsmolt	13.8	SmoltTrap Deel		2
10/04/2008	SAsmolt	10.8	SmoltTrap Deel		2
11/04/2008	SAsmolt	11.7	SmoltTrap Deel		2
11/04/2008	SAsmolt	14.4	SmoltTrap Deel		2
22/04/2008	SAsmolt	11.0	SmoltTrap Deel		2
22/04/2008	SAsmolt	11.6	SmoltTrap Deel		2
23/04/2008	SAsmolt	9.7	SmoltTrap Deel		2
23/04/2008	SAsmolt	12.5	SmoltTrap Deel		2
25/04/2008	SAsmolt	10.5	SmoltTrap Deel		2
25/04/2008	SAsmolt	11.8	SmoltTrap Deel		2
26/04/2008	SAsmolt	12.5	SmoltTrap Deel		2
26/04/2008	SAsmolt	11.6	SmoltTrap Deel		2
28/04/2008	SAsmolt	12.2	SmoltTrap Deel		2
28/04/2008	SAsmolt	13.6	SmoltTrap Deel		2
01/05/2008	SAsmolt	11.6	SmoltTrap Deel		2+
01/05/2008	SAsmolt	14.6	SmoltTrap Deel		2
02/05/2008	SAsmolt	11.5	SmoltTrap Deel		2
03/05/2008	SAsmolt	10.8	SmoltTrap Deel	08/220	1+
06/05/2008	SAsmolt	13.1	SmoltTrap Deel		2
06/05/2008	SAsmolt	11.5	SmoltTrap Deel		2
09/05/2008	SAsmolt	12.2	SmoltTrap Deel	08/237	2
09/05/2008	SAsmolt	13.6	SmoltTrap Deel	08/236	2+
10/05/2008	SAsmolt	11.1	SmoltTrap Deel		2

Section VI

(A). Rainfall & Temperature Data – Ireland

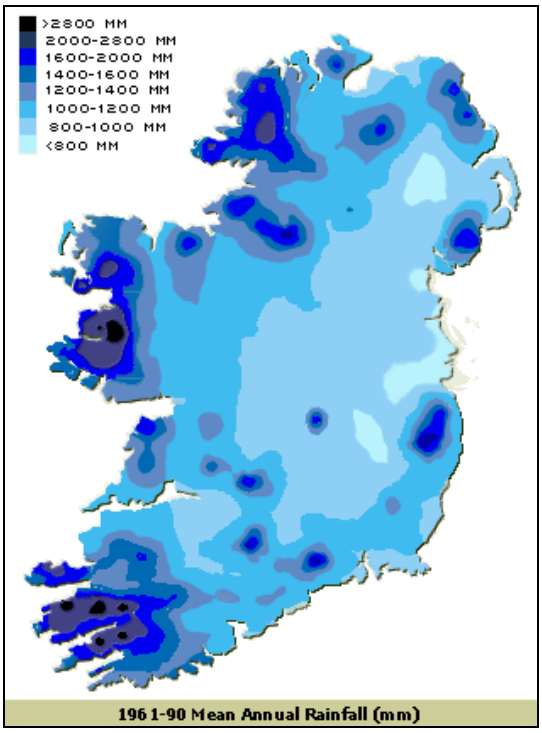

Figure A1: The mean annual rainfall (mm) for Ireland, 1961-1990 (Met Eireann).

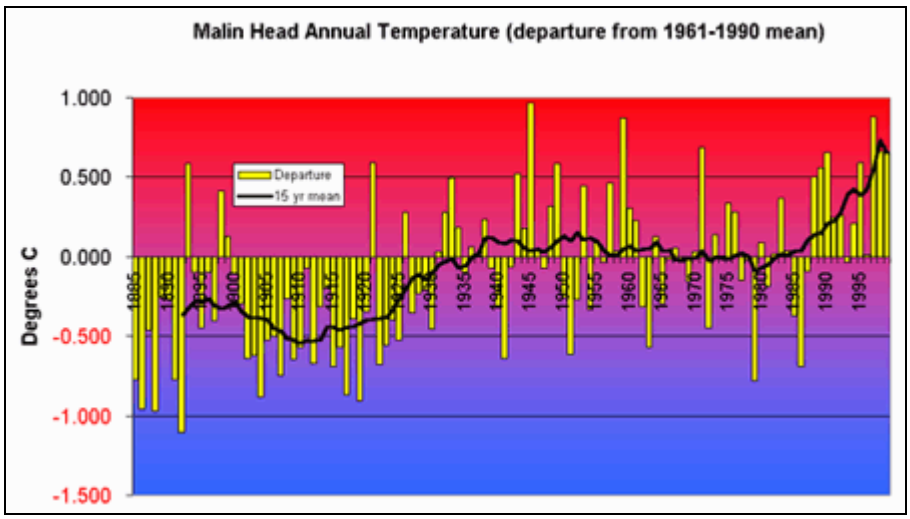

Figure A2: The annual temperature (Degrees C) at Malin Head, Ireland, 1961-1990 (Met Eireann).

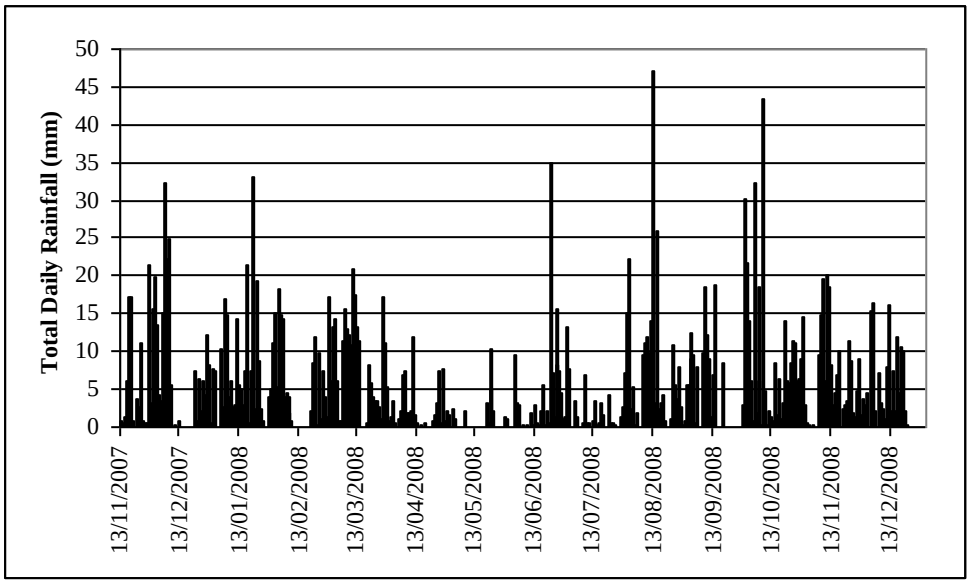

Figure A3: The total daily rainfall (mm) at Furnace, Newport, Ireland, November 2007 to December 2008 (Met Eireann).

(B). Comparison of River Deel and the Rough River Average Daily Water Temperature (°C), April to June 2007

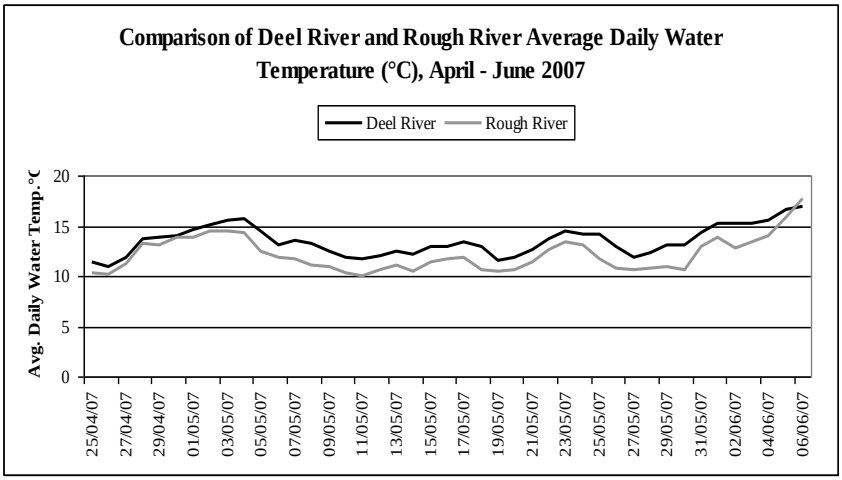

Figure B1: Comparison of the average daily water temperature (°C) for the River Deel, Moy Catchment and the Rough River, Burrishoole Catchment, 2007.

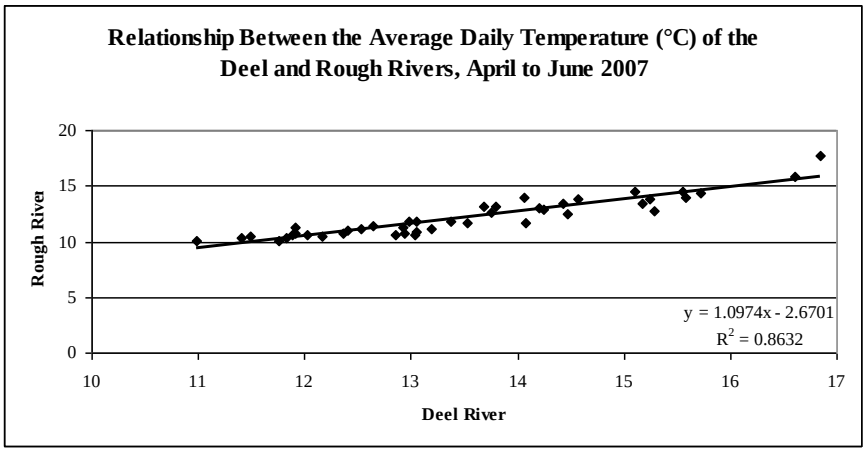

Figure B2: The linear relationship between the average daily water temperature (°C), River Deel, Moy Catchment and the Rough River, Burrishoole Catchment, 2007.

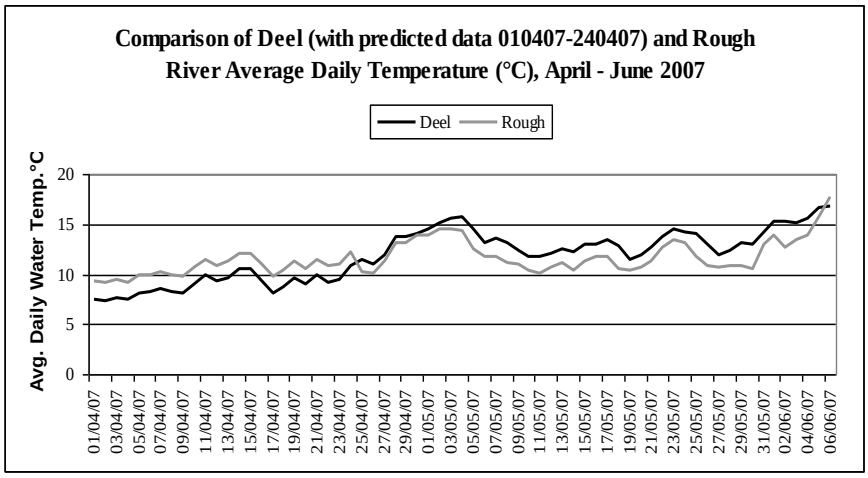

Figure B3: Comparison of the average daily water temperature (°C) for the River Deel, Moy Catchment with predictions and the Rough River, Burrishoole Catchment, 2007.

Section VII

DNA extraction using extracted using the Illustra tissue & cells genomicPrep Mini Spin Kit (GE Healthcare):

Sample Preparation

Batches of 48 individuals were analysed together for both the tissue and scale sample analysis. Tissue samples that were stored in ethanol were blotted on tissue paper and rinsed with distilled water to remove alcohol prior to analysis and to dry the sample. The remaining material was retained in the ethanol tube for long term storage. Scale samples were cut in half, using two scales where possible.

Extraction of DNA from tissue and scales samples

1. Using a sterile blade, 1-2 mm^3 of tissue was taken and the tissue sliced and transferred into the bottom of a 2 ml microcentrifuge tube. All tubes were kept on ice prior to use.
2. 50 µl of PBS (Phosphate buffered saline, pH 7.4) was added to each tube.
3. 50 µl of Lysis buffer type 1 was added to each tube.
4. 10 µl of Proteinase K (20mg/ml) was added to each tube which was then vortexed for 15 seconds to assist the breakup of any solid tissue present.
5. The tubes were then incubated overnight at 56°C.
6. 500 µl of Lysis buffer type 4 was added to each tube and vortexed for 15 seconds.
7. The samples were then incubated for 10 min at room temperature.
8. For each sample, one tissue & cells mini column was placed inside one collection tube.
9. Each sample was then applied to a separate column and centrifuged for 1 minute at 11000 x g.
10. Flow through was discarded and the spin column was placed back in the collection tubes.
11. 500 µl of Lysis buffer type 4 was then added to the spin column and centrifuged for 1 minute at 11000 x g. Discarding the flowthorugh.

12. Flowthrough was discarded and the spin column was placed back in the collection tubes.
13. 500 µl of Wash buffer type 6 was applied and the sample centrifuged for 3 minutes at 11000 x g
14. The collection tube was discarded and the spin column was transferred to a fresh 1.5 ml DNAase-free microcentifuge tube.
15. 100 µl of pre-warmed (70C) Elution buffer type 5 was added to the column and incubated for 1 minute at room temperature
16. The sample was centrifuged for 1 minute at 11000 x g to collect the purified genomic DNA
17. The DNA was stored at -20°C until required for analysis.

Section VIII – Enclosed CD

DIDSON Images

Image 2.1: NPWS snorkel survey, Deel DIDSON site, River Deel.

Image 2.2: Algal movement downstream, Deel DIDSON site, River Deel.

Image 3.1: Three Salmon Migrating, Deel DIDSON site, River Deel.

Image 3.2: Flood Conditions and Debris going downstream, Deel DIDSON site, River Deel.

Image 3.3: Fish Movement upstream around the right bank deflector fence, Deel DIDSON site, River Deel.

Image 3.4: Fish Backsliding and Holding, Deel DIDSON site, River Deel.

Image 3.5: Eel Migration and an otter, Deel DIDSON site, River Deel.

Image 4.1: Three Spring fish, Upstream Migrations, Deel DIDSON site, River Deel.

Image 4.2: Spring fish migrations, Deel DIDSON site, River Deel.

Powerpoint Presentations

Presentation prepared for the IFI, Ballina, Co. Mayo, General Meeting, December 2007: Photo series of Screw Trap Installation, Operation and Removal, River Deel.

Presentation to the IFI, Ballina, Co. Mayo, General Meeting, December 2008: Photo series of DIDSON Installation, Operation and Data Processing, Deel DIDSON site, River Deel.