Annex 6 – RIVERS – Fish – FCS2 and Fish Barrier Tool.

Contents

A1 Description of method

(i) FCS2

FCS2 for Scotland and Ireland are methods which classify fish fauna quality in rivers. The tools enables classification of fish quality from high to bad, to comply with Water Framework Directive (WFD) requirements. FCS2 is a statistical model, based on the Environment Agency Fisheries Classification Scheme 2 (FCS2) method. The models uses a suitable statistical distribution torelate the number of fish caught on a survey to the abundance and prevalence of the species there, as well as the survey area and a parameter that describes the shape of the statistical distribution. A classification is then provided based on an Ecological Quality Ratio (EQR), which is calculated by comparing observed fish catches with the fish catch that would be expected under reference conditions.

Comparison with other UK methods

The main modifications between this tool and the English and Welsh model are the way in which barriers to migration are accounted for, the type of fish catch data that can be used in the model and the automation of procedures that were previously done manually. There are also differences in how results from individual sites are combined to give classification values at the waterbody level.

A further important difference is that the Scottish model has been developed using salmonid data only, as initial results showed that there were not enough reliable data from other fish species to allow an accurate all-species model to be built. In future it is hoped that additional data of suitable quality for non-salmonid species will be available to allow additional extensions to the model to be used, but this is not possible at present.

Atlantic salmon and brown trout are separated into 0+, and older fish in the FCS2 tool, to give four pseudo-species in total. This allows age structure to be included in the results. The Scottish tool can also account for multiple-pass fish survey data, by incorporating terms for the joint catch probability into the model.

How the FCS2 tool works

The abundance and prevalence terms are calculated within the model based on regression relationships between a selection of covariates and corresponding parameters. Typical covariates include altitude of survey site, geology class and distance to source. The regression relationships can include linear terms, non-linear terms and spatial terms. The selection of covariate terms is achieved by identifying the environmental, geographical and pressure variables that are expected to be important for fish abundance and prevalence. A model fitting process then determines whether the covariates and collection of terms used in the regression relationships do provide predictive power for fish catch. The model fitting process is carried out to find the probability distribution (called the posterior distribution) of each of the unknown parameters in the model, based on known fish observations and corresponding parameters including the survey area and each covariate (the environmental, geographical and pressure variables that come from the fisheries database).

The main model fitting process is carried out with Markov Chain Monte Carlo (MCMC) in WinBUGS or OpenBUGS. A faster fitting process called INLA is first fitted to approximate models to identify the parameters that are most likely to be significant terms in the model. The parameters selected through the INLA process can then be fitted in the full MCMC process to give the full version of the statistical model that can then be used for classification.

The success of the model fitting process is analysed with a statistical test that checks how well the model fit represents the data. The test shows that the model fits produced by WinBUGS match the data well and we can, therefore, assume that the model's comparison of observed and expected fish catches will be carried out appropriately.

The EQR is found by comparing observed fish counts to the catch that the model predicts would be found under reference conditions (the 'expected' catch). To predict the expected catch, the model needs information on the reference condition values for the variables in the model that are 'pressure variables'. The pressure variables are characteristics of the watercourse that can be influenced by human activity and that can have an impact on fish populations. The classification model evaluated EQR by comparing the observed fish catches to the expected fish catches under reference conditions. The EQR is a value between 0 and 1, where 0 is a bad quality water body with observed fish counts being much lower than those expected at reference conditions, and 1 is a high quality water body where the observed fish counts are what could be expected at reference conditions.

The results are given as a probability distribution, representing the uncertainty associated with the EQR calculation. This distribution shows the range of EQR values that the water body may take, given the probabilistic nature of the data. EQR results are given for a single species, combined species for a single survey and combined species and surveys in a water body.

Environmental pressures are intrinsically incorporated within the final EQR outputs from FCS2, because the model uses pressure variables to compare observed results with expected results under reference condition. These are variables which are expected to be related to human activity, and which also have a significant effect on fish populations in the model fitting process. For the final model fit, the following pressure variables were selected: *Artificial impassable barriers*, *Salmon stocking*, *Ammonium*, *SRP/MRP*, *Coniferous forests percentage* and *pH*. Reference

values for continuous variables were not taken as the published High/Good boundary values, since the boundaries correspond to the limit of values accepted as *High* whereas the reference value should be a typical *High* value. The reference values are therefore defined to be the median value of all observations at the fish survey sites within the *High* class range. Either UKTAG or REFCOND guidance values were used, as appropriate.

Determination of class boundaries and relationship to biological change

The EQR results from the classification model are used to provide a WFD classification of bad, poor, moderate, good or high by selecting appropriate class boundaries. Boundary setting is achieved by creating an artificial dataset with the fish counts for each class, by following the normative definitions provided by the Water Framework Directive. This is possible because for each survey and site record in the database, the model provides expected presence and abundance. For the classification of our data, we compare the actual catch with this expected modelled catch. For the purposes of creating the artificial dataset of WFD classes, we want to compare artificial catch numbers (that represent the WFD classes) with the expected modelled catch numbers, to produce EQR values of the artificial dataset. These EQR values broadly represent the EQRs that would result from applying the model to surveys and sites of the specific WFD classes.

- For *High*, we assume all expected species are present in addition to all of the typespecific disturbance-sensitive species (salmon and trout for Scotland). We also assume that all age classes are present (e.g. 0+ and 1++ salmon and trout). For each of these species, the total catch is set to the expected total catch rounded to the nearest whole number. If this would round to 0, we instead round up to 1 to ensure each selected species is present.

- For *Good*, we again assume all expected species are present in addition to all of the type-specific disturbance-sensitive species (salmon and trout) for sites with no barrier. For sites above a barrier, we ensure at least trout are present and in both cases we assume all age classes are present. For each selected species, the total catch is set to 80% of the expected total catch, rounded as with *High*.

- For *Moderate*, we assume 55% of expected species are present and for these the catch equals 55% of the expected total catch. When selecting which of the expected species to include, we take species in order of likelihood of presence. We also ensure that at least one age class for trout are present above a barrier and one of each of salmon and trout present at sites without a barrier.

- For *Poor/Bad*, we assume 30% of expected species are present (the most likely) and for these the catch equals 30% of the expected total catch.

- For *Bad,* we assume that 10% of expected species are present, and for these the catch equals 10% of the expected total. In effect this means that no salmonids are expected at any Bad staus sites.

The EQRs of each dataset is then calculated to give a spread of EQR values that can be expected for each class. Plots of these datasets enable the placement of class boundaries so that the scores for each class range fall mostly within the allocated boundaries. The results of this are shown in Figure 4 below, showing clear separation between different classes.

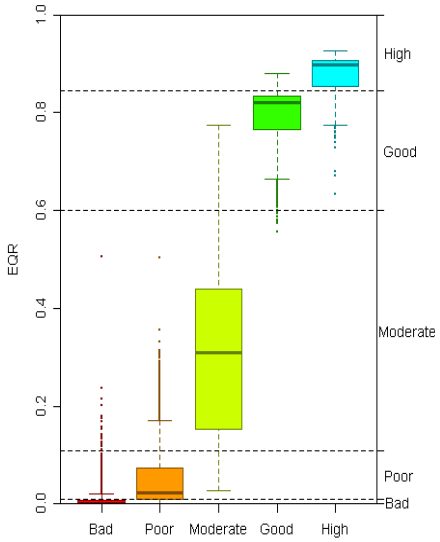


Figure 1. Plots of EQR values from idealised artificial datasets, used to set boundary conditions.

Testing of the tool outputs has shown that the tool performs poorly at differentiating between sites which are expected to be Poor, and those expected to be Bad. Several waterbodies with salmonids were classified as Bad, for example. This type of result would not accord well with the normative definitions of Bad provided by the Water Framework Directive, and the principles used for classifying other biological quality elements, where a status of Bad is reserved for sites which are close to being unable to sustain biological activity. This result was not unexpected, because the reliance on salmonids means that the FSC2 tool alone would be unlikely to be capable of differentiating between the most impacted classes, as salmonids are unlikely to be present at many of these sites. It is therefore proposed to use the FCS2 tool to classify into one of four bands (High, Good, Moderate and Poor/Bad) and then use an absence of fish to differentiate Bad status waterbodies. This then provides a classification methodology which corresponds most closely with the normative definitions required.

The version of the tool used in Ireland has slightly different EQR values, but both the Ireland and Scotland versions of FCS2 have been successfully inter-calibrated.

(ii) Fish Barrier Tool

UKTAG produced a 2008 report on assessing the effect of fish barriers. The principles of this approach were adopted by the UK environment agencies. The implementation across the agencies has varied according to data availability.

SEPA developed a GIS-based barrier classification tool which classifies water bodies based on the proportion of their catchment which migratory fish are prevented from entering due to artificial barriers. Areas which are naturally inaccessible due to waterfalls are taken into account and removed from the calculations. This approach is used in rivers where no survey data exists.

In Northern Ireland the principles are applied manually to relevant water body assessments where the required data exists, and in England and Wales the assessments are made in FCS2

The tool requires reliable data on both natural and artificial barriers. This includes large features such as waterfalls, weirs and dams, and also smaller but significant features such as culverts, fords and bridge aprons. This information has been supplied by SEPA staff and other groups. SEPA now holds a georeferenced, fish barrier database that includes many of the major barriers of concern, particularly for salmon and sea trout which have historically received the most attention from fishery ecologists. Work is ongoing to improve and extend this database to include problematic obstacles for all species and all areas of Scotland.

The general opinion appears to be that the tool is pitched at the correct level and that it has been useful in reflecting most problem barriers. It is not proposed that the boundary values between different classes are changed. A new quantitative barrier assessment method is available, following the successful completion of the SNIFFER WFD111 R&D project[1], and there is an opportunity to incorporate this standardised method into the classification tool.

There is also a need to better incorporate information on barriers to a wider range of migratory species, particularly lampreys and eels. The wording of the Scottish Ministers Direction to SEPA allows fish barrier classification to take the movement of *any* fish species into account, but in practice this has not happened and barrier classifications are effectively based on Atlantic salmon at present. In some cases, this has probably led to classifications failing to reflect high impact barriers to non-salmonid species.

The UKTAG report uses the following limits for classification:

High status	Good status	Moderate status	Poor status
Severe loss of fish access to less than 1 % of catchment area	Severe loss of fish access to less than 5 % of catchment area	Severe loss of fish access to less than 20 % of catchment area	Severe loss of fish access to greater than 20 % of catchment area

"Severe loss" is defined in the SG Classification Direction as being *"more than 80 % of fish that would otherwise be able to move upstream to, or downstream from, the river or part concerned"*.

Inclusion of other species, partial barriers and standardised assessments

It is not clear whether "80% of fish" in this definition is meant to refer to 80% of the overall number of individuals of all species, or to 80% of the total number of species, or to 80% individuals of any one species. Consideration of the WFD normative definitions and the natural paucity of fish species in Scotland would suggest that it should be applied to mean more than 80% of any one migratory species. This would agree with the interpretation underpinning the fish ecology tool, which would downgrade a waterbody to below good if either salmon or trout are found to be absent from sites where they would normally be expected to be present. It is proposed to adapt the wording of the next version of the Directions to clarify this.

It is also proposed that the interpretation of "severe loss" should be expanded to include any barrier which is classified as either "passable high impact" or "impassable" when using the WFD

[1] http://www.sniffer.org.uk/knowledge-hubs/resilient-catchments/water-framework-directive-and-uktag-co-ordination/fish-obstacles-porosity/

111 barrier assessment method. It is also recommended that the definition should also be interpreted to allow barriers which are already accepted as being impassable to continue to be used for classification without requiring additional survey work to be carried out.

For some barriers, particularly weirs, dams and long culverts, a streamlined approach to using the WFD111 method is proposed, because the method uses a one-out-all-out approach. In cases where the physical dimensions alone would be sufficient to put a barrier into the impassable or high impact category, then a detailed assessment of water depth and velocity across the barrier would not be needed to show evidence of "severe impairment". This will allow desk-based assessments where detailed drawings exist, and will potentially also remove some of the more subjective parts of the WFD111 method. Where physical dimensions do not provide evidence of severe impairment, a full survey will be required to show whether the barrier is likely to be passable or not.

This streamlined approach is not currently possible for eels, because their ability to pass obstacles is quite different to other species and the passability of a barrier cannot be generalised from physical dimensions in the same way. A full WFD111 barrier assessment will therefore be required to assess all potential eel barriers.

The output from the WFD111 method has not yet been "ground-truthed", although projects are underway to attempt to test this. Until this is completed, it is recommended that only medium confidence is given to resulting classification results. High confidence should only be used where additional electrofishing data support the conclusion that the barrier is preventing migratory species from occurring at sites where they would otherwise be expected.

The ability of lamprey and eels to pass barriers is considered particularly difficult to predict with confidence. Figures for lamprey in particular also suggest that many relatively small barriers may prevent migration and cause many waterbodies to be downgraded, Errors in interpreting the potential effects of barriers on lamprey therefore carry the risk of having a very large effect on the number of downgraded waterbodies. It is proposed to reduce this risk by only downgrading for eels and lamprey when there is supporting evidence to show that the species is absent from areas where it would normally be expected to be present. This will be achieved by incorporating an additional rule in the fish ecology classification tool to downgrade to less than good if either species is absent from areas where they would otherwise be expected to be present. Species specific electrofishing surveys, particularly for lamprey, will be required to provide sufficient evidence for this rule to be applied. The barrier tool will therefore only be used to directly classify on the basis of salmonid barriers. It will be used as a risk assessment procedure for lamprey and eel.

A2 Summary of changes between 1st and 2nd RBMP

Across the UK river fish classification takes account of two factors, the condition of the fish populations in response to pressures, and the impact of man-made barriers on fish migration.

SEPA currently produces an overall river fish classification result, which is the product of two separate classification tools, the fish barrier tool and the fish ecology tool. The lowest result for each tool is used as the overall river fish classification. This approach recognises that there may be aspects other than barriers reflected in the fish ecology result, and equally that the fish ecology result may not necessarily reflect the impact of barriers if these are situated upstream of the fish

survey sites, or on side tributaries. The Fish Classification System 2 (FCS2) (Scotland) model takes account of man-made fish barriers, but the separate barrier test is used where fish sampling data is not available in taking this approach it is possible to provide a fish classification for all river water-bodies in Scotland.

In Northern Ireland the overall fish classification is the product of the fish ecology tool FCS2 (Ireland), and a barrier assessment. At present the barrier assessment is made using expert judgement, but it is proposed to further develop the approach, and work towards the adoption of the updated method described in this annex.

In England & Wales barrier assessments and fish ecology assessments are made within the FCS2 procedure. As there are no proposals to revise this method it will not be considered further here.

(i) FCS2

Scotland and Ireland have developed fish classification methods based on similar principles to the FCS2 model that the Environment Agency uses is England & Wales. The Scottish and Irish methods share common a development model with the exception of the following issues.

- In Scotland only salmon and trout are used, in Ireland all species are used.
- The catch data used. NI/ROI include the total number of fish caught in each run of a multiple pass survey or a single pass survey. Scotland include this and also other sources of data - density and ranges.
- In the Scotland model an Impassable barrier variable was included whether natural or man-made. In the NI/ROI model natural barriers only were considered but no data has yet been included from NI.
- The inter-calibrated EQR class boundaries are slightly different since they are derived from each specific model.
- Scotland uses a manual step to upgrade sites containing salmonids from Bad to Poor.

Method performance is illustrated using the Scottish version of the model.

(ii) Fish Barrier Tool

The proposed process is summarised in Figure 2 below. Values in Table 1 are taken directly from the output from the WFD111 project. For the avoidance of doubt, it is recommended that if a barrier is failing the criteria identified in Table 1 for **either** salmon, trout, or lamprey, it should be considered as potentially impassable for that species.

It is important to stress that this approach would not require a reassessment of all current barriers. The assumption would be that all identified impassable barriers which are currently downgrading waterbodies would remain, as they are impassable for salmon, at least. Additional downgrades based on other species would apply whenever third parties request SEPA to review a classification, and sufficient evidence can be provided to show that a problem exists for any of the other species involved.

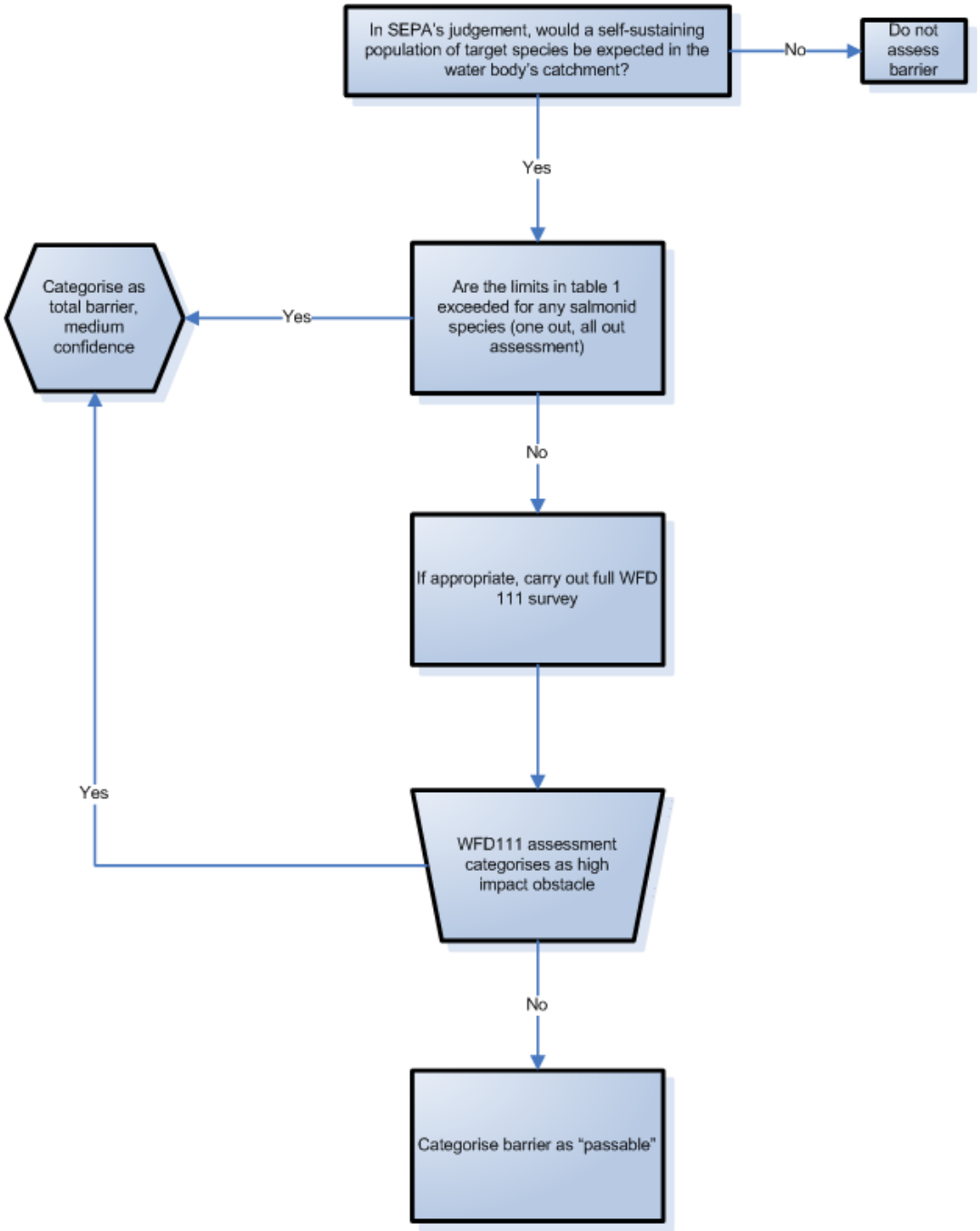
No immediate changes to classification are therefore expected, although over time this change is likely to result in additional downgrades for some high impact salmon barriers as more evidence

becomes available. The new classification rule testing for the absence of lamprey or eel above barriers is also expected to cause additional downgrades. In many cases, these measures are also likely to be required through other legislation (the Eel Management Plans, and Natura 2000).

Table 1: Critical physical limits for barriers to the main species. If dimensions of a barrier are greater than any of these limits, it should be considered to be a "severe impairment" to the species. Values are taken from the relevant tables in the WFD111 project manual.

Barrier type	**Criteria**	**Brown trout and sea trout**	**Atlantic salmon**	**Adult lamprey (sea/river)**
Obstacle presenting a vertical drop	Vertical hydraulic head	≥1 metre	≥1.4 metres	≥0.3 metres
Obstacle presenting a slope (including culverts)	**% Slope of structure** o Structure effective length ≤ 3m o Structures effective length 4-9m o Structures effective length ≥ 10m	≥ 60% ≥40% ≥ 15%	≥ 60% ≥40% ≥ 15%	≥ 40% ≥20% ≥ 15%
	Effective length of obstacle (the distance which would have to swum by a fish to pass the barrier)	≥100 metres	≥100 metres	≥50 metres

Figure 2. Flowchart showing how the WFD 111 project outputs could be used to assess barriers for classification for salmonids.



Changes from catchment area to linear river length

The current obstacle to fish migration WFD classification method is based on the proportion of catchment area from which migratory fish are excluded by a man-made barrier. It is proposed that Scotland will use proportion of river length instead for future classification.

This has technical advantages, as there is no requirement to maintain a dataset of catchment boundaries for the impassable obstacles and it can be applied to the detailed river network when it becomes available from Ordnance Survey. River length could be regarded as a more appropriate indicator of available habitat, due to the large variation in drainage density throughout Scotland which the catchment area metric ignores. If assessments of the impact of multiple barriers are developed in the future, river length is also a more appropriate method on which to base these assessments.

This change means that parts of the river network have to be restricted from taking part in the analysis where man-made channels cross catchment boundaries. This is expected to be a minor effect however, and to date, only 15 river segments out of over 250,000 have had to have been restricted.

Northern Ireland - Fish Barrier

In Northern Ireland, work is ongoing to develop a rule based approach using available data on barriers, fish survey data and local knowledge in applying an expert judgment override to fish classifications from FCS2. This will consider the impact of natural and manmade barriers. It is proposed to further develop the approach for barrier assessments, working towards the adoption of the above method.

A3 Consequences of changes

(i) FCS2

The current interim classification tool and new revised FCS2 tool have been run on comparative dataset of 116 waterbodies. A direct comparison of result between the old new tools is complicated, because the old approach could not differentiate between High and Good status. In effect, this meant that most waterbodies were given a class of High/Good. For comparative purposes, all High and Good results from the new FCS2 tool have been merged into a single class. It should be emphasised that this is not the proposed approach for future classification, but has only been done to allow comparisons to be carried out. Even after grouping High and Good results into the same High/Good bandings, it is not possible to accurately quantify changes in class. For example, we cannot be sure whether an identified change from High/Good with the old tool to Moderate with the new tool, (or *vice versa*) should be considered as a change of one class or two classes.

Fifteen sites were electro-fished in Northern Ireland in 2011 and classified by expert judgment. The raw data was also used for the FCS2 model. Overall agreement between expert judgment and the FCS2 model was good although this was a small dataset. Where discrepancies occurred, expert judgement and local knowledge may be necessary to override the tool at some locations. This is

particularly true for sites thought to be impacted by natural or manmade barriers to fish movement as no detailed barrier information for Northern Ireland has been input to the model at this stage.

Scotland

Table 2. Comparison of classifications of ecological status determined by original (interim) and revised (FCS2) versions of the fish tool.

		Revised				
		High	Good	Moderate	Poor	Bad	Grand Total
Current	High						
	Good		46	22	1		69
	Moderate		3	17	14		34
	Poor				9		9
	Bad					4	4
	Grand Total		49	39	24	4	116

Table 3. Percentage of water bodies in each class, determined using original (interim) and revised (FCS2) versions of the fish tool.

Class	Current Method	Revised Method
High	0.0%	0.0%
Good	59.5%	42.2%
Moderate	29.3%	33.6%
Poor	7.8%	20.7%
Bad	3.4%	3.4%

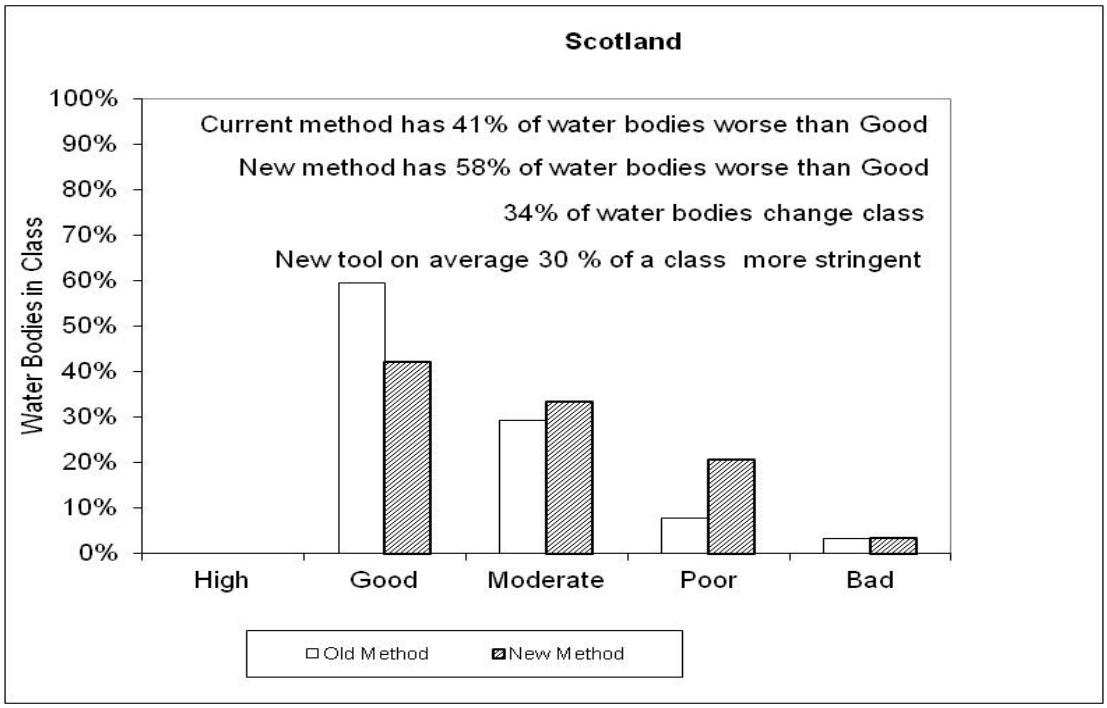


Figure 3. Percentage of water bodies in each class, determined using original (interim) and revised (FCS2) versions of the fish tool.

Table 4. Number and percentage of water bodies that change class when using the revised version of the fish tool, FCS2.

	Number	Percentage
Current 4 class worse	0	0.0%
Current 3 class worse	0	0.0%
Current 2 class worse	0	0.0%
Current 1 class worse	3	2.6%
Same class	76	65.5%
Revised 1 class worse	36	31.0%
Revised 2 class worse	1	0.9%
Revised 3 class worse	0	0.0%
Revised 4 class worse	0	0.0%

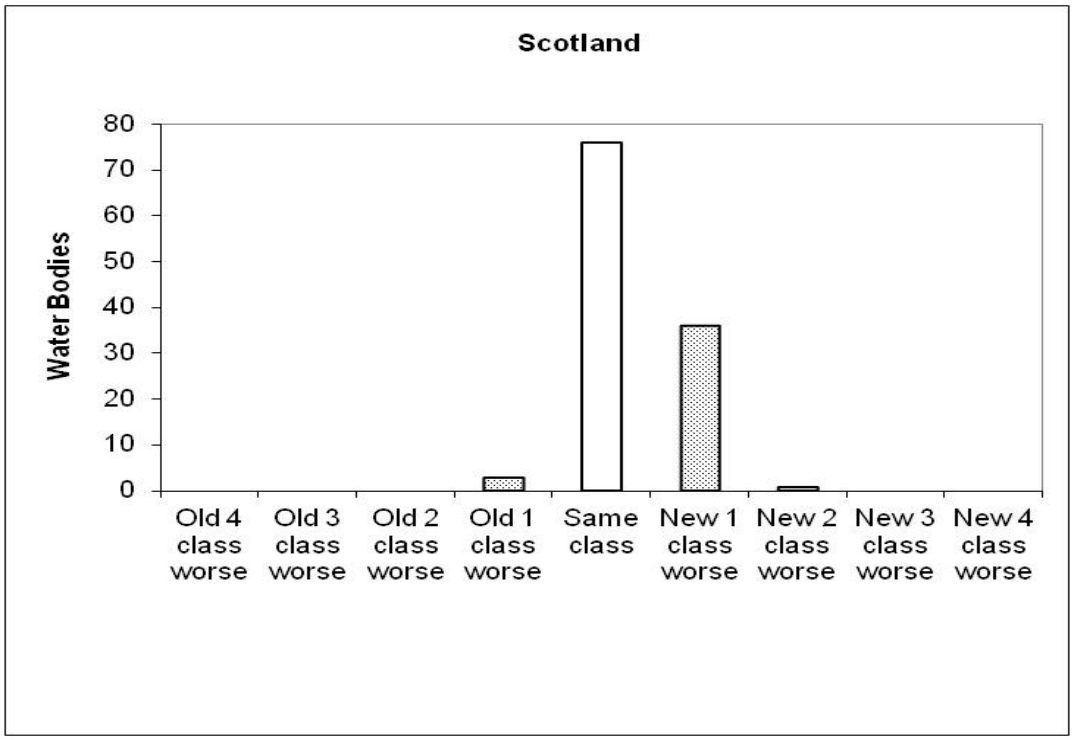


Figure 4. Number of water bodies that change class when using the revised version of the fish too, FCS2.

Northern Ireland

Table 5. Comparison of classifications of ecological status determined by original (interim) and revised (FCS2) versions of the fish tool.

		Revised					
		High	Good	Moderate	Poor	Bad	Grand Total
Current	High	1		1			2
	Good		3	3			6
	Moderate	1	1	1	1		4
	Poor				3		3
	Bad						
	Grand Total	2	4	5	4		15

Table 6. Percentage of water bodies in each class, determined using original (interim) and revised (FCS2) versions of the fish tool.

Class	Current Method	Revised Method
High	13.3%	13.3%
Good	40.0%	26.7%
Moderate	26.7%	33.3%
Poor	20.0%	26.7%
Bad	0.0%	0.0%

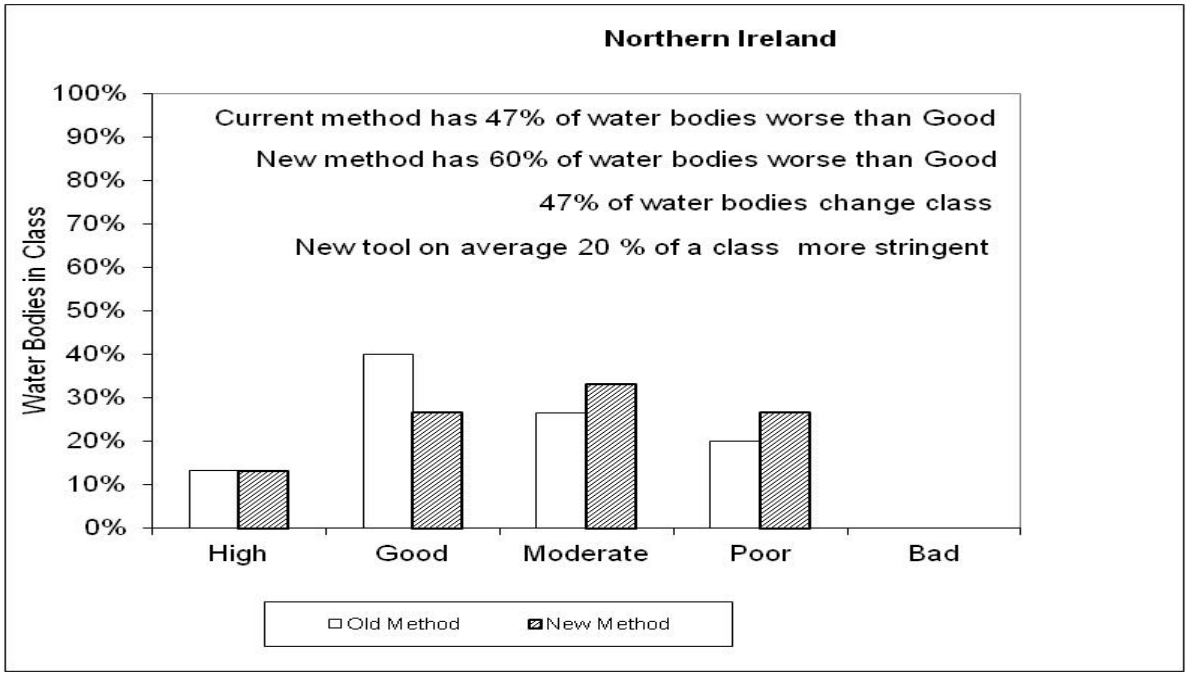


Figure 5. Percentage of water bodies in each class, determined using original (interim) and revised (FCS2) versions of the fish tool.

Table 7. Number and percentage of water bodies that change class when using the revised version of the fish tool, FCS2

	Number	Percentage
Current 4 class worse	0	0.0%
Current 3 class worse	0	0.0%
Current 2 class worse	1	6.7%
Current 1 class worse	1	6.7%
Same class	8	53.3%
Revised 1 class worse	4	26.7%
Revised 2 class worse	1	6.7%
Revised 3 class worse	0	0.0%
Revised 4 class worse	0	0.0%

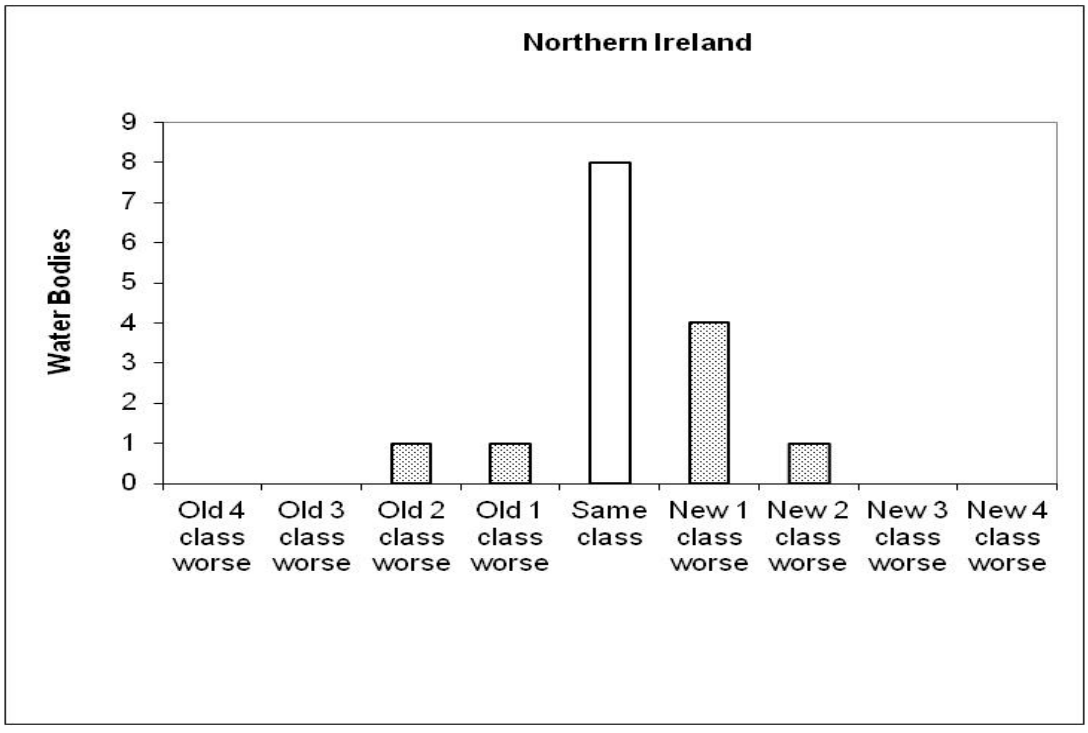


Figure 8. Number of water bodies that change class when using the revised version of the fish tool, FCS2.

(ii) Fish Barrier Tool

The changes are not expected to make a large difference to classification results, as shown in Table 8 below.

Table 8. The impact on classification of using river length instead of catchment area when assessing the proportion of habitat blocked by impassable barriers.

No. of WBs	Impact of classification results compared with current method
1171 (c.97%)	No change in class
7 (<1%)	Upgrades due to change in method
17 (<2%)	Downgrades due to change in method

A4 Key documents

Key documents

River fish method statement	Detailed description of method used for 1st RBMP in England and Wales (survey method unchanged, changes to calculations for 2nd RBMP)

Fiona L. Kelly, Andrew J. Harrison, Michelle Allen, Lynda Connor, Robert Rosell, *Development and application of an ecological classification tool for fish in lakes in Ireland*, Ecological Indicators 18 (2012) 608–619

Rosell, R., *Water Framework Directive Fish monitoring –Supplementary report 2012*, Agriculture Food and Environmental Sciences Division Fisheries and Aquatic Ecosystems Branch, Report for NIEA

Sampling Fish for the Water Framework Directive Lakes 2010 Lough Macnean Upper, Inland Fisheries Ireland[2], Swords Business Campus, Swords, Co. Dublin, Ireland.

Sampling Fish for the Water Framework Directive Lakes 2010 Upper Lough Erne, Inland Fisheries Ireland, Swords Business Campus, Swords, Co. Dublin, Ireland.

Kelly, F.L., Connor, L., Morrissey, E., Wogerbauer, C., Matson, R., Feeney, R. and Rocks, K. (2012), *Water Framework Directive Fish Stock Survey of Lough Melvin, July 2011*, Inland Fisheries Ireland, Swords Business Campus, Swords, Co. Dublin, Ireland.

Sampling Fish for the Water Framework Directive Lakes 2010 Lough Macnean Lower, Inland Fisheries Ireland, Swords Business Campus, Swords, Co. Dublin, Ireland.