Managing salmon stocks in England & Wales

updated November 2015

We use Conservation Limits to manage salmon stocks on our major rivers in England and Wales

Conservation Limits provide a standard (a lower limit) so we can judge whether stocks are doing well or doing badly. They also help us to decide the best actions to take. The way we do this is shown below.

The following procedures use information from a variety of sources including counter data, rod catch, fishing effort and survey information on the numbers of young[1] salmon in our rivers.

So how do we set the Conservation Limits?

1) We work out how many juvenile salmon can live in a particular river and how many eggs are needed to produce them – as the numbers of juvenile salmon increase, they fight for food and space and only a certain number survive. A big river will typically support more salmon than a smaller one.

2) We work out the link between;
   the number of adult salmon spawning in the river,
   the number of juvenile salmon that survive to go to sea (called "smolts") and
   the number of adult salmon that make it back into the river from the sea.
   This information helps us to set the Conservation Limit.

3) The Conservation Limit defines the minimum number of fish we want to see spawning in the river. Below this limit, the risk of the stock suffering serious decline greatly increases. To offer greater protection to the stock, we set a Management Target which ensures that, in the long run, the stock must exceed the Conservation Limit in at least 4 years out of 5. On average, the Management Target is often around 40% higher than the Conservation Limit.

How do we use Conservation Limits to manage our salmon stocks?

We work out the likelihood of a river failing to meet its Management Target in five years time.
The salmon stock is then classified into one of four categories;

"At risk"
"Probably at risk"
"Probably not at risk"
"Not at risk"

If a river is classed as "At risk", we'll try to prevent **any** salmon from being killed by any methods so that as many salmon as possible can spawn.

We have a flow chart called the **Decision Structure**, which helps us to decide what action to take depending on a river's risk category and whether it's getting worse or improving (see Figure 1). The 'Decision Structure' is applied to each salmon river annually in April following publication of the "Annual Assessment of Salmon Stocks and Fisheries in England and Wales" report.[2] Fishery managers for each river decide what changes in regulation are appropriate as guided by the Decision Structure outputs and other information, such as Water Framework Directive surveys of juvenile fish.

"Recovering" rivers that do not yet have Conservation Limits set are assumed to be 'at risk' so that they get the best protection.

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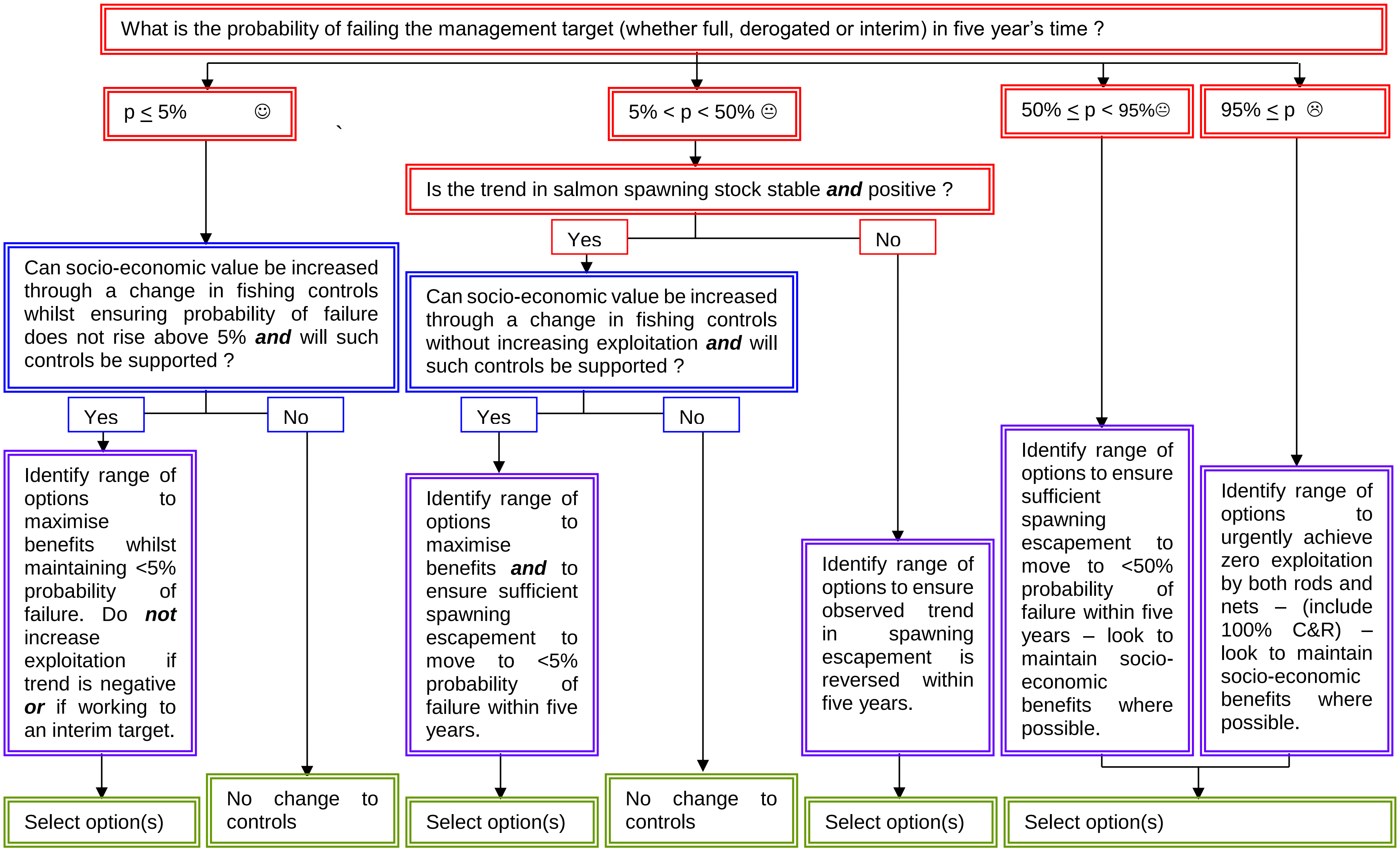
[1] referred to as 'juvenile' salmon in the rest of this document
[2] The most recent report is available from here: Salmon stocks and fisheries in England and Wales 2014 (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/450982/SalmonAssessmentReport-2014-finalrevised.pdf)

Figure 1 Developing fishing controls for salmon fisheries in England & Wales ("The Decision Structure")



Salmon management process in more detail

How does the Environment Agency use Conservation Limits?

Conservation Limits (CLs) are a type of Biological Reference Point (BRP) and are often used in fisheries management. They apply to individual rivers and we use them to help set a minimum spawning requirement, usually expressed in terms of egg numbers. We would be worried if spawner numbers fell below the Conservation Limit (CL) because it would be expected to result in fewer juvenile fish produced in the next generation.

The use of Conservation Limits in salmon fisheries management is not new and we have been instructed to use them by Government and the international North Atlantic Salmon Conservation Organisation (NASCO). The origins of CLs lie in long-standing relationships which describe how populations grow in number and how they are limited by factors such as their natural environment, for example, the amount of space available in any one river system to support juvenile salmon, and fishing pressure.

The way we derive and apply CLs is not a precise science due to the unpredictable nature of fish populations. One advantage in the way CLs are applied in England and Wales is that we use much of the information we already collect on catches and stocks and we apply that information in a standard way.

How are Conservation Limits obtained and used in salmon management?

There are 5 steps we follow to set CLs and to use them to decide what actions to take:

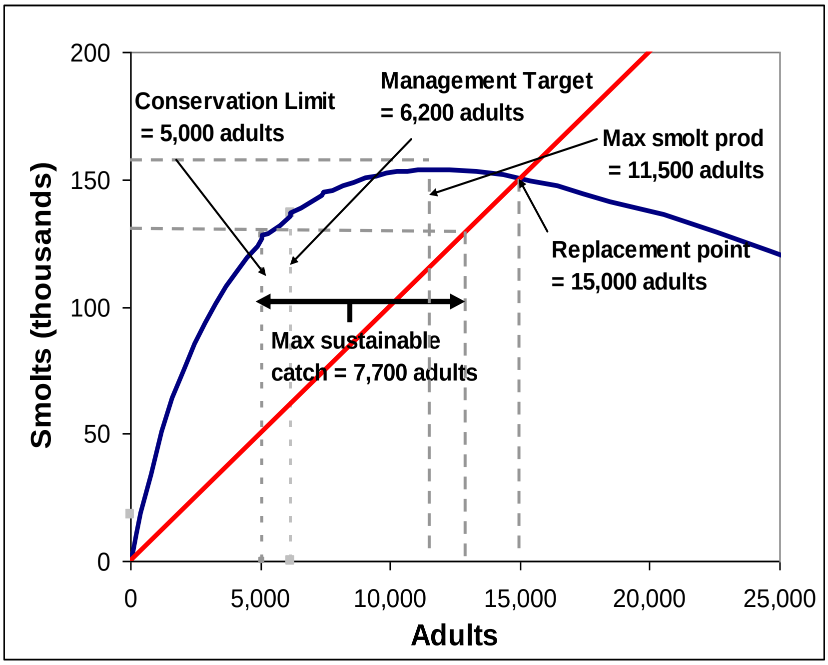
Step 1 Set the Conservation Limit
Step 2 Estimate the current spawning levels annually
Step 3 Assess their compliance against the CL annually
Step 4 Interpret the assessment in the light of other information on the stocks.
Step 5 Take appropriate action

An explanation of each of these five steps is given below

Step 1 How do we set Conservation Limits?

Two relationships are used to set CLs for each of our main salmon rivers:
- (i) the stock-recruitment curve and
- (ii) the replacement line.

The **stock-recruitment curve** describes the relationship between the number of adult spawners (or the eggs they produce, the ‘stock’) and the number of smolts resulting from those eggs (the ‘recruits’) (Fig 2).



The procedure we use to derive stock-recruitment (SR) curves for rivers in E&W takes information from one of the few rivers where long-term monitoring programmes have collected the data required to develop their own SR curves – the River Bush, N Ireland. This information is used, for example, to define the initial gradient of the SR curve.

Fig 2. Use of the SR curve (blue line) and replacement line (red line) to derive Conservation Limits

The height of the SR curve defines how many smolts a river might be expected to produce at best, known as 'maximum smolt production'. This is estimated from the physical make-up of the river for which each SR curve is developed. We base this on a procedure relating the size of streams, and their altitude, to levels of juvenile fish production. In Fig 2, the height of the SR curve shows that 'maximum smolt production' can be expected at a spawning stock of about 11,500 adults.

The SR curves defined for each of our rivers are meant to reflect a 'pristine' state in terms of environmental quality and production of juvenile fish. As a consequence, often the CL may represent a position we aim for rather than reflect the condition of a river as we find it today

The **replacement line** is the straight line relationship shown in Fig 2 and is used to convert the number of smolts leaving a river into the number of adults (or their egg equivalents) that return from the sea. To define this relationship requires an estimate of survival at sea (back to homewaters) and information about the make-up of the stock on individual rivers, for example, the proportions of 1-sea winter and multi-sea winter salmon, the incidence of female fish and the average number of eggs they carry. For rivers in England and Wales, estimates of sea survival have been taken from recent studies on the River North Esk, Scotland, with a rate of 11% assumed for 1-sea winter salmon, ("grilse"), and 5% for multi-sea winter salmon. Information on the composition of individual river stocks, etc. is based on local catch data as well findings from other studies.

We can combine the SR curve and replacement line to identify other biological reference points, including the **Replacement Point** and the **Conservation Limit**. The Replacement Point lies at the crossover of the replacement line and the SR curve. The population will move toward this point in the absence of fish being killed by homewater fisheries. In Fig 2, around 15,000 fish would be expected to return to homewaters at the replacement point.

Any catch of fish in homewaters will clearly reduce the numbers that return to spawn from the 15,000 at the replacement point. By combining the SR curve and the replacement line, the 'maximum sustainable catch' can be determined mathematically. This equates to around 7,700 salmon in Fig 2 and would occur at an exploitation rate by the combined fisheries (e.g. rods and nets) of about 40%. Exploiting the stock to obtain the maximum sustainable catch would leave 5,000 fish to spawn – the level of spawning at the Conservation Limit.

If more than 40% of the returning stock were caught then, although the total catch may increase in the short-term, the stock would soon fall below its CL of 5,000 fish and the sustainable catch would be less than the maximum. This would leave the spawning stock on the steepest part of the S-R curve where only a small increase in loss through higher catches, or other factors, could result in a rapid decline in numbers.

The Conservation Limit helps define a minimum number of spawners which significantly lessens the risk of stock collapse. If spawning levels are above the Conservation Limit then the stock will be afforded even more protection although the sustainable catch will again be less than the maximum.

In fact, the Environment Agency's Conservation Limit compliance procedures are designed to manage stocks at a level some way above the Conservation Limit. This level is known as the **Management Target** and represents the average number of spawners required to ensure that stocks remain at or above their Conservation Limit for at least 4 years out of 5 in the long run. For the relationships shown in Fig 2, the Management Target equates to 6,200 fish, more than 20% higher than the Conservation Limit. Across rivers in England and Wales, on average the Management Target is 35% higher than the Conservation Limit and means that the Management Target often falls close to the point of maximum smolt production.

The additional level of protection provided by the Management Target is built into the statistical procedure used to assess the degree to which a stock is exceeding its CL. On rivers with a highly variable adult run, the MT will tend to be much higher than the CL whereas rivers with more stable stocks will have the MT and CL closer together. The MT offers greatest protection where it is likely to be most needed. Even if stocks are consistently above the CL, the river may still fall outside the "not at risk" category because of the variability (i.e. uncertainty) in the number of fish returning.

We've selected the CL, (and its associated MT), as the Agency's Biological Reference Point to provide a compromise between maximising catch and maximising the number of fish surviving to spawn. We could have chosen a more ambitious reference point such as maximum smolt output but this wouldn't allow as many fish to be caught and we'd be forced to restrict catches at a much earlier stage.

Step 2 How do we estimate how many adult spawners we have?

On 8 of our 60+ principal salmon rivers, (the Test, Itchen, Frome, Tamar, Fowey, Dee, Lune and Kent), we can evaluate the size of the returning stock using counters or traps. Elsewhere we use rod catch data and angling exploitation rates derived from the counted rivers to estimate spawner numbers. To do this we also take account of catch reporting rates in our estimates. Since the introduction of the single national migratory salmonid licence and return reminder system in 1993, we estimate that catch reporting rates have consistently been around 90%.

Other information is used to convert spawner numbers into egg estimates - principally the weight composition of rod caught fish and the likely proportions of male and female fish. The egg contribution of rod-released fish is also included, with an assumed 80% survival rate, based on radio-tracking studies of released fish (for comparison, we assume a 91% survival rate for "uncaught" fish).

Step 3 How do we assess whether these current spawning levels comply with the CL?

Every year, we compare the estimated number of eggs that have been deposited in a river with the Conservation Limit and Management Target for that river to see how well it's doing against its target.

However, we've also developed an "early warning system" based on the probability that the river is, or is not, "at risk". This is our '**compliance assessment scheme**'. The scheme is described in full in our report "Annual Assessment of Salmon Stocks and Fisheries in England & Wales'

Our scheme uses Bayesian statistics to estimate the probability that the river is meeting its CL 4 year out of 5. Our analysis generates the following assumptions;

At risk	= less than 5% probability that it is meeting this objective
Not at risk	= greater than 95% probability that the river is meeting CL 4 years out of 5
Probably at risk	= a probability of between 5 and 50% of meeting CL 4 years out of 5
Probably not at risk	= a probability between 50 and 95% of meeting CL in 4 years out of 5.

We estimate a river's compliance annually for the year preceding each April and we also include a prediction based on the 10-year data set. This predicts what the river's category might be in 5 years time to allow for the effects of management measures to work through the salmon's life cycle. In 2014, 33% of English and Welsh salmon rivers were classified as "at risk", with the majority of rivers considered to be "probably at risk" (61%). No rivers are considered to be "not at risk" now or in 2019.

Step 4 How do we Interpret this assessment in the light of other stock information?

We do not make management decisions on the basis of CL compliance assessment alone.
We use data from fishing effort, seasonal run groups, habitat evaluation and juvenile salmon assessments alongside the CL compliance information to assess populations within catchments. These decisions are becoming increasingly complicated to make but it is made easier by the use of reference points. We now incorporate monitoring of juvenile salmon into a formal European assessment process, the 'Water Framework Directive', (WFD). We make a judgement about where our priorities should lie using the outputs from this monitoring alongside how well salmon are meeting their CLs which is through adult monitoring.

Step 5 How do we use CLs to take appropriate action?

Together with the WFD assessments for individual water bodies, we use CL compliance as a guide to determine appropriate management actions. We look at the predicted category into which a river has been classified for five years into the future to take account of the effects of current management measures. Depending on what that predicted category is for a given river, changes in fishing controls may then be considered by applying the Decision Structure (Figure 1). For rivers classified as 'At risk', the Decision Structure requires that urgent steps are taken to reduce exploitation by all fisheries to zero. This includes measures, including voluntary, to raise rod catch-and-release levels to 100%, thus allowing the value of angling to society to be maintained while conserving the stock.

Our CL compliance information is also used by ICES, (the International Council for the Exploration of the Seas), as part of the assessment of stocks across the north Atlantic. These assessments are used in international negotiations to agree how many salmon can be taken from distant water fisheries, and also to provide advice to contributing countries on conservation status and the need for protection measures.

Appendix 1 The use of Conservation Limits (CL) in the management of salmon stocks and fisheries – an example from a typical river in Wales.

The River Gwennol is a typical spate river in West Wales supporting a mixed salmon and sea trout fishery. Salmon rod catches have been declining in contrast to sea trout catches which have remained stable.

Three seine nets operate in the estuary taking mainly sea trout and a few salmon each year. Night fishing for sea trout is popular with visiting anglers. Worm fishing accounts for a high proportion of the rod catch.

The Catch & Release (C&R) rate for salmon has been increasing in recent years and in 2010 was 40% (although below the national average of 56% despite recent campaigns aimed at increasing the C&R rate to 90%+).

The main non-exploitation pressures on stocks are from diffuse pollution (agriculture) and man-made barriers to migration (weirs).

Step 1 – setting the Conservation Limit (CL)

A CL of 1,370,000 eggs has been set for the river based on an accessible wetted area of 57 Hectares and 242 eggs per 100 m^2. The Management Target (MT) is 1,600,000 eggs.

Step 2 – estimating the spawning levels annually

The 2010 salmon rod catch (corrected for under-reporting) was 70 fish. There is no counter or trap on the river and we, therefore, use an exploitation rate model (based on rod effort and catchment size) to determine run size and spawning escapement. For example, estimates from the latter model indicate an exploitation rate of 20% is likely for this river in 2010. Assuming a corrected rod catch of 70 fish in 2010, this equates to a total run of salmon just prior to the rod fishery of 350 salmon.

Allowing for 40% C&R and assuming 60% females and an average 5,500 eggs per female, the estimated egg deposition for 2010 is just under 500,000 eggs (Figure 1). This is the lowest in the time series and represents just 36% of the CL (and less than one third of the higher MT).

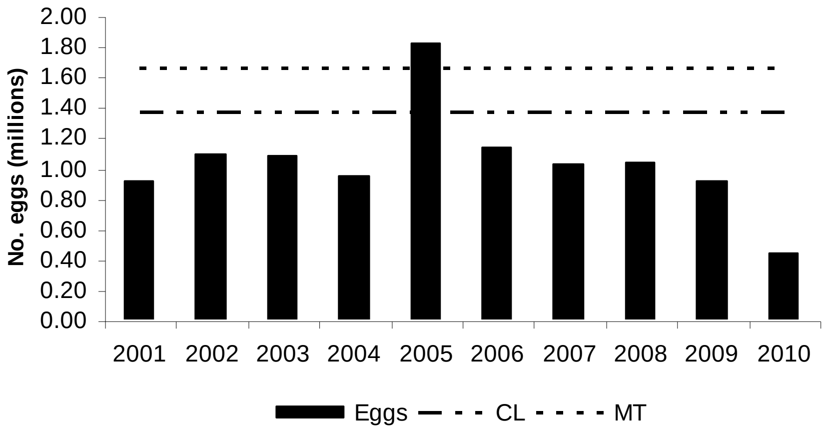


Figure 1 Annual egg deposition compared with the CL and MT (2001-2010)

Step 3 Assess compliance against the CL

Figure 2 shows the performance of the river against the its CL. The CL has only once been exceeded in the 10 year assessment period (2004). The upper bound of the regression line confidence interval (shown in yellow) is below the red CL line except in the first year of the data set. The stock is, therefore, 'At Risk' of failing the Management Objective (≥95% probability) throughout most of the time-series.

The trend (black line) in egg deposition is decreasing, although not statistically significant, and the river is predicted to remain in the 'At Risk' category until at least 2015.

Applying the 'Decision Structure', the 'At Risk' status in 2015 means there is an urgent need to identify immediate options to stop killing salmon by rods, nets and other activity whilst seeking to maintain socio-economic benefits where possible.

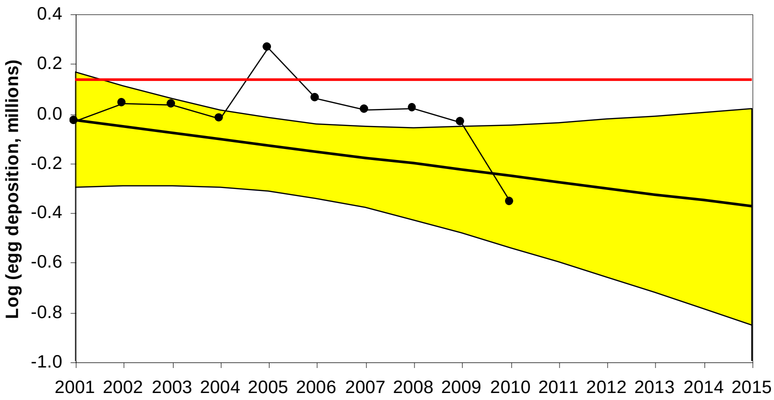


Figure 2 Estimates of egg deposition and compliance with the CL (2001-2015).

Key: Red line – CL, Black circles – annual egg deposition, black line – regression line, Shaded yellow area – upper and lower bound of the confidence interval

Step 4 Interpret the assessment in the light of other information on the stock

Given the uncertainties in the CL methodology and the compliance model we must also consider other available information on stock performance.

CPUE (Catch Per Licence Day) from angler licence returns appears to be stable, but should be interpreted with care as effort has halved since 1994 (it is possible the least efficient anglers have left the fishery).

Of the eight water bodies assessed for WFD, four fail for salmon (three are classified as 'moderate' and one in the lower river is 'good').

Six juvenile fish monitoring sites are surveyed annually for the temporal monitoring programme. Juvenile salmon are absent from two sites and moderate to poor densities are recorded in the remaining four sites (with no statistically significant trend in densities apparent since monitoring began in the early 1990's).

Step 5 Take appropriate action

Given the 'At Risk' status of the river and the extent of the WFD failures, options for achieving zero exploitation as soon as possible are considered.

The socio-economic importance of the relatively stable sea trout fishery is an added challenge as fishing for salmon and sea trout takes place at the same time and using similar methods.

WFD failures will be addressed over the coming years by building fish passes to open up access to inaccessible spawning tributaries, improving riparian habitat and working with farmers to reduce soil loss to the river. These measures will take time to bear fruit and in the meantime we must reduce exploitation to zero as soon as possible. The following options are, therefore, considered:-

Option 1

Encourage an increase in voluntary C&R rates.

Option 2

Introduce a zero Net Limitation Order (NLO) and consult on new method and/or extended close season byelaws for the rods

Option 3

Introduce a bag limit byelaw of one salmon per season for the rods

Option 4

Introduce 100% C&R byelaws for salmon (rods and nets).

Preferred option

Option 4 is judged to be the preferred option given the status of the stock and need for urgent action. Efforts to increase voluntary C&R rates to at least 90% have failed, but Option 4 will immediately achieve almost zero exploitation. A small number of fish are likely to die after release, however, we are confident mortalities can be minimised (<10%) by encouraging anglers to adopt best practice for C&R, including use of barbless single or double hooks for flies and spinners, and circle hooks for worm fishing. We believe there are benefits to the stock in keeping anglers on the bank (eyes and ears) and some of the socio-economic benefits arising from the fishery will also be maintained.

The nets will be able to release all salmon caught (as is already the case before 1st June) and keep sea trout.

The byelaws will be time limited (10 years) and will not be renewed if the stock recovers sufficiently to allow some exploitation.

We do not want to introduce mandatory C&R at this stage for sea trout because of the favourable status of the stock and socio-economic importance of the fishery.

Outcomes

As a result of the C&R byelaws we estimate an additional 100,000 eggs will be deposited in 2012 (based on the previous 5-year mean rod and net catch). Although initially this is a relatively small proportion of the shortfall in the CL we believe that over a number of years the compounded affect of C&R, together with ongoing environmental improvements, will stabilise egg deposition at c. 5 million eggs by 2020 (a run of approximately 2,000 fish). At this point we will be in a position to consider relaxing restrictions.

Next steps

We will consult on the byelaw proposals with FERAC Wales and our stakeholders and then formally advertise the new byelaws with a view to gaining Ministerial approval ahead of the beginning of the 2012 fishing season.