PART I

CONCEPTS OF SPAWNING TARGETS

- **The stock-recruitment relationship**

Spawning target setting is based on the fact that the number of smolts produced by any given river is constrained by habitat availability. This means smolt numbers depend on spawner numbers up to a point, but thereafter smolt production reaches a ceiling. It has been shown, in some rivers at least, that the relationship between egg deposition and smolt production may approximately be described by a mathematical equation. The equation will vary between rivers and there is uncertainty over its exact form.

Essentially, it is thought the relationship may be of two forms – a flat-topped curve or a dome-shaped curve. (Figs 1a & 1b). At present it is not clear how appropriate the dome-shaped curve is. The following argument will be confined to a flat-topped curve.

In the hypothetical example shown in 1a, the curve flattens when the number of eggs is around 5 million and produces around 50,000 smolts. In this example the egg-smolt survival would be 1% at the point "carrying capacity" is reached. At higher egg deposition levels, the egg-smolt survival will decrease. At really low egg deposition levels, survival from egg to smolt would be greater than 1%.

Any excess of spawners over "carrying capacity" could be considered as "surplus". This means that in good quality rivers, in times of good marine survival, salmon populations can be capable of supporting a high degree of exploitation.

The degree of surplus adults will depend on the survival of smolts to adults in the sea. It is assumed that the mortality level between smolt and adult is "density independent". This means that for a given level of survival, this relationship can be expressed as a straight line. Figure 1c shows a S-R relationship plus a smolt-adult survival line superimposed on the same graph. The amount of surplus spawners is found by subtracting the number required to reach carrying capacity (point A) from the number where the smolt survival line intersects the S-R line (point B).

When marine survival rates vary, the slope of the smolt survival line varies. Figure 1d shows what happens to this line as marine survival rates decrease. With lower survival, the intersection point gets closer to the carrying capacity, so the possible surplus reduces.

- **Maximum Gain (MG) target**

At first glance, the main principle of salmon management would be to ensure that the spawning stock remained in excess of that required to maximise smolt production. However, in reality, the potential exploitable surplus may be increased by identifying the point of Maximum Gain (MG).

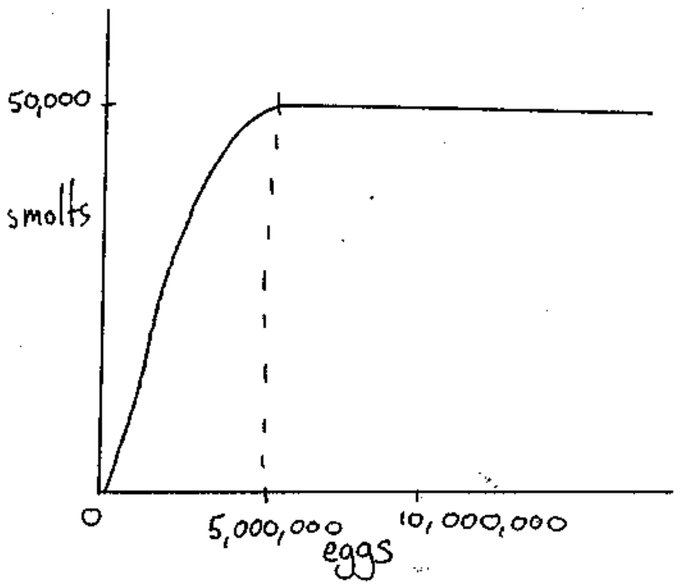


Figure 1a – flat topped stock-recruitment curve

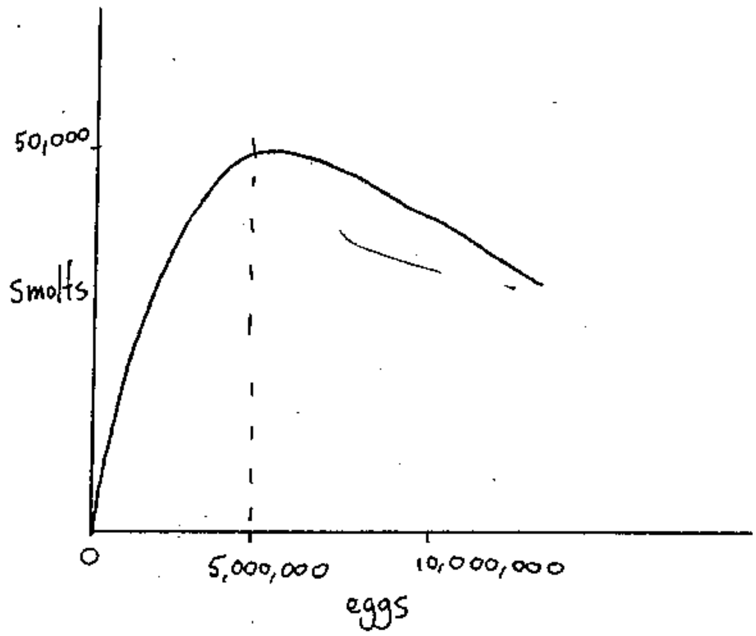


Figure 1b – dome shaped (Ricker type) stock recruitment curve

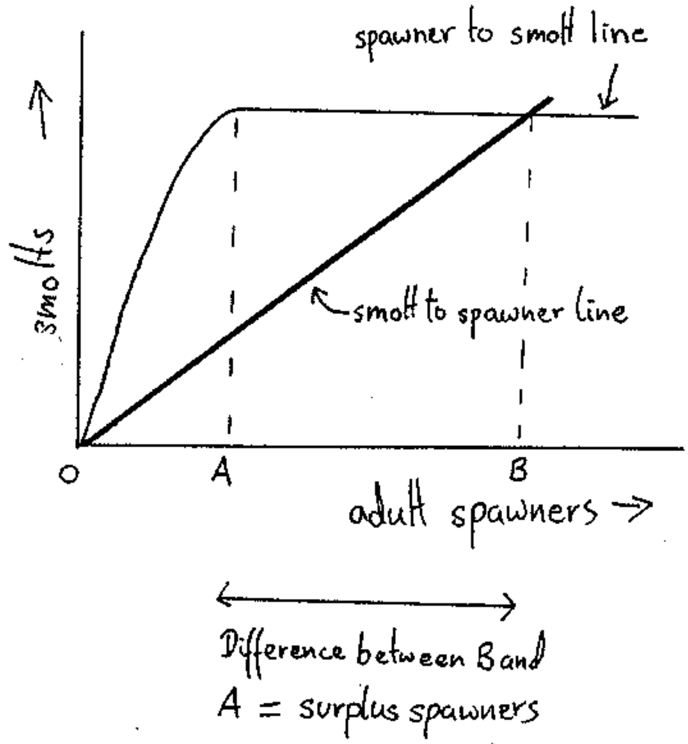


Figure 1c. How 'surplus' spawners are depicted on a stock recruitment graph.

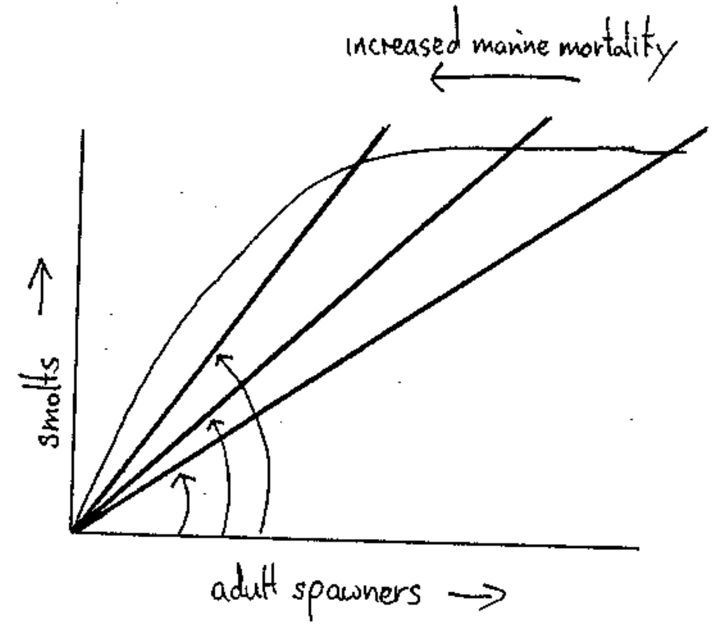


Figure 1d. Increased levels of marine and fishing mortality steepen the angle of the smolt-adult line. Thus the potential "surplus" is reduced.

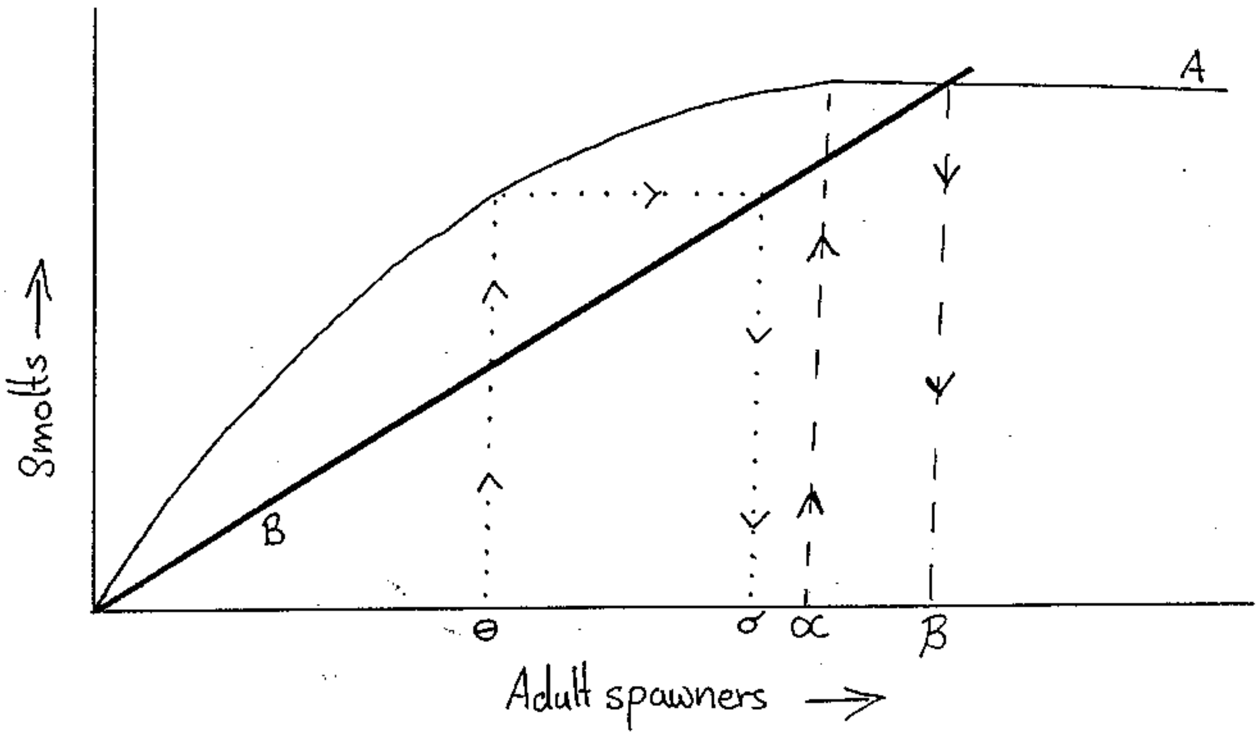
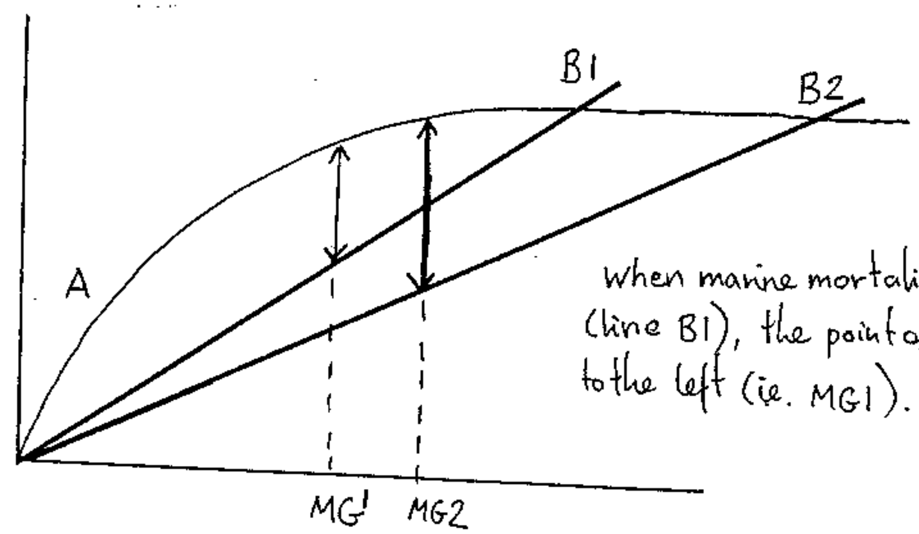


Fig. 2a. By fishing the stock to a level (θ) which is lower than that needed to fill the river to its maximum smolt output (α) it is actually possible to increase surplus adults. i.e. θ − σ is greater than β − α. (SEE PAGE 3 FOR FULL EXPLANATION).



when marine mortality is high (line B1), the point of MG moves to the left (ie. MG1).

Fig 2b. The point at which the potential surplus is maximised is the point where the vertical distance between lines A and B is greatest. This is known as the point of MAXIMUM GAIN (MG).

The concept of Maximum Gain is illustrated in Figure 2a and is described as follows.

Let the line marked A (Fig 2a) represent the relationship between the number of adult spawners and the smolt output. Let line B represent the smolt - spawner survival line.

Now, point α represents the minimum number of spawners required to stock the river to full capacity. This number of smolts will then translate into β adult spawners. As explained above, the difference between β and α amounts to the surplus production.

However, if a spawner level (θ) is selected a short way below that needed for maximum capacity, this will ultimately translate into σ adults. It can be seen that σ minus θ is actually greater than β minus α. Thus, by a mathematical quirk, the number of surplus fish (i.e. potential catch) can be increased by pushing the spawning stock below that required to reach maximum capacity. This, of course will only happen up to a particular point. This point, at which the potential catch is maximised, is called the point of Maximum Gain (MG). Put simply, the point of maximum gain occurs at the point where the vertical difference between the adult-smolt line and the smolt-adult line is greatest (Fig 2b).

Basically, what is happening, is that as a salmon stock gets close to its parr carrying capacity, the extra smolts which are produced do not compensate for the number of adults which are required to produce these last few smolts.

- **Maximum Gain and Marine Mortality**

It should be pointed out that the point of MG is not a fixed point. Figure 2b shows the position of the MG point under a scenario of varying natural marine mortality. It can be seen that when marine survival decreases, the point at which MG is achieved moves to the left.

This means that when marine mortality rates increase, although the potential catch is smaller, in order to maximise the catch, a smaller number of spawners must be left.

- **Maximum Gain and Angling**

As a theoretical concept, MG is sound from the point of view of maximising the "exploitable surplus". As has been agreed by International Council for the Exploration of the Sea (ICES), the MG point is an appropriate conservation threshold, below which a salmon stock ought not to be allowed to fall. MG has been accepted by ICES and the Environment Agency as the Minimum Biologically Acceptable Level (MBAL).

However, it must be made clear that MBAL "is a conservation threshold not a management target, which should normally be set at a higher stock level" (Potter 1996).

The nature of a "management target" will depend on how the resource is to be allocated between different types of fisheries. Basically, at opposite extremes, the optimum management target set for a netting-only fishery will differ greatly from that for an angling-only fishery.

To optimise a net catch, it is necessary to have a spawning escapement target which is as close to MBAL (i.e. MG) as is possible. Most of the communications from ICES allude to this scenario. For example, in the 1995, the ICES North Atlantic Salmon Working Group stated "ideally, stocks should be managed in order to maintain them at or close to the level corresponding to maximum gain, thus providing the best opportunities to maximise the harvest......." This view is not surprising as most fishery scientists are trained up in the concepts of maximising yield for commercial fisheries.

Angling, however, is different. An MG target is not appropriate to optimise angling.

Because angling is an inefficient method of catching salmon, good angling requires an abundance of salmon. Basically, for equivalent fishing conditions, angling catches may be expected to increase as numbers of available salmon increase, though not in strict proportion. However, even if angling catches were not to be increased at high stock levels, anglers still derive encouragement from seeing an abundance of fish in a river. "There is much more to angling than catching fish".

In practice, levels of stock around MBAL do not provide for good angling – especially in rivers where the potential smolt production per-unit-area is low (as may be the case in many English rivers). The proof of this is that, in periods like the 1960s, when MBAL must have been considerably exceeded in many rivers in England and Wales, anglers did much better than today.

For an angling fishery, it is the case that MBAL (i.e. MG) will make a sensible lower conservation limit, but above MBAL, the idea of having any defined target egg-deposition may almost be irrelevant. This is because, in a productive river, it often may be impossible for anglers to cull spawner levels to the MG point. This situation would occur once numbers of salmon entering a river exceed about 125% of MG. What we can define for angling is really a "danger level" and a "safe area".

In England and Wales the Environment Agency have selected MBAL as their target. Dr Milner states that "MBAL is synonymous with the Agency's "spawning target"". This means the EA have selected the lowest possible target they could, which means the targets optimise conditions for net fishing, as far as is possible. This will operate to the disadvantage of angling.

For example, an instance might occur where numbers of fish available to anglers may be substantially increased in the absence of a net fishery (e.g. in a river where the nets catch 50% of the stock). However, if such a river just exceeds 100% of its target after angling, no action could be taken to reduce net fishing on biological grounds, despite the fact that a greater benefit to the economy would result if the nets were removed.

This is in fact broadly the situation which exists in many rivers in England today. The use of MG targets only further reinforces the *status quo*. It will only continue to justify the existence of net fisheries in rivers which exceed the target, but will not allow higher levels of fish to be available to anglers.

I have argued elsewhere, that in England & Wales, salmon should be fished by anglers only, which would mean target setting would have less relevance. However, if there is to be some netting, then there ought to be a balance between the two opposing interests. This would need to be a "recreational target" – a level considerably above MG which ensures anglers are not always left with the rump.

As long as this imbalance exists, then I think it only reasonable that the Environment Agency must ensure that the MG targets they do use are at least accurate. This is a critical issue for the Lune NLO.

- **EA Spawning Target Methodology.**

The problem for setting Maximum Gain spawning targets is that a stock-recruitment relationship must be known for the river of interest. Unfortunately, there are only a very few rivers in Europe where this has been done - none in England or Wales.

To overcome the problem of not having any stock-recruitment relationships, the EA have devised a scheme to "transport" the S-R relationship from the River Bush, Co Antrim, where such a relationship has been established by researchers from the Department of Agriculture for Northern Ireland.

Basically, a standard mathematical equation which generates a dome-type curve was fitted to real data on egg and smolt numbers. The real Bush data provided two parameters which allow the Bush S-R relationship to be described. The first of these effectively equates to the gradient of the S-R line as it approaches the zero point of the graph (point α in Fig. 3). This is also equivalent to the survival rate which would be expected between egg and smolt if no density dependent mortality operated (i.e. the probability of survival of an egg to smolt if it were the only one in the river). This parameter is known as the Density Independent Mortality (DIM) estimate.

The second parameter is that which governs the height of the curve - the "carrying capacity" (β in Fig. 3). This is dependent on the habitat quality of the river.

In order to calculate the S-R curve for any given river in England & Wales it is assumed the same equation and DIM estimate calculated for the Bush are applicable to everywhere else. While these stay the same, an attempt is made to adjust the carrying capacity estimate between rivers. This is done by using a crude classification of habitat quality using "stream order" (an index of stream size) and altitude bands. I described this procedure in greater detail in my original submission to the Review Group.

With this information, the EA then compute a S-R relationship for any given river and then calculate a Maximum Gain target.

The jist of my original critique was that all the estimates involved in this process are subject to a great deal of error. We do know that DIM differs between rivers, never mind the appropriateness of the equation itself. Furthermore, there may be considerable errors in estimating carrying capacity.

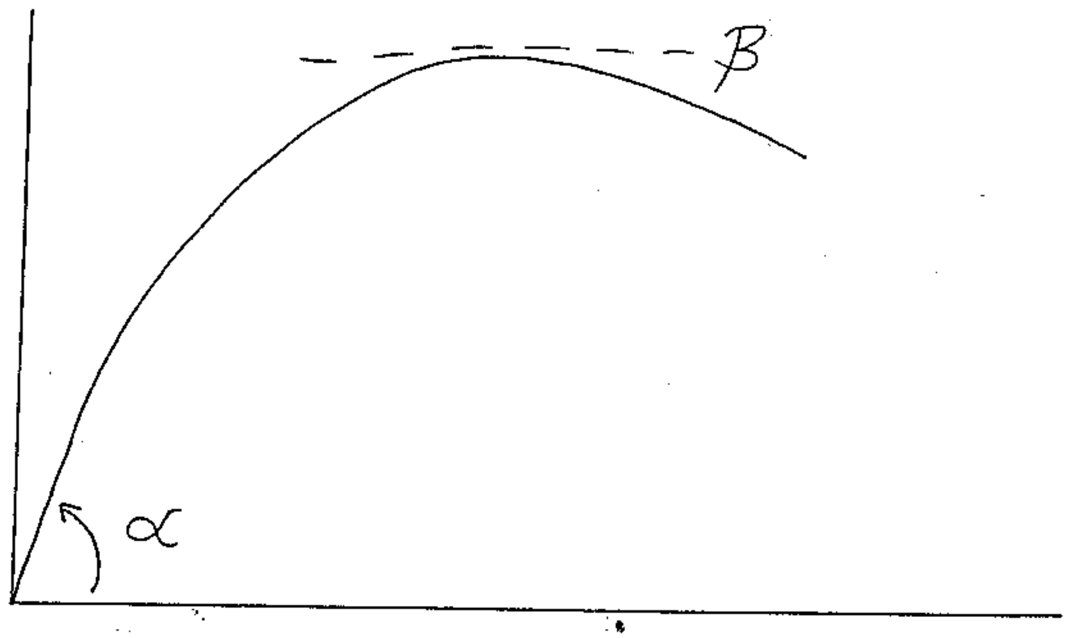


Fig 3. The 2 parameters used to calibrate the Bush model.
α is the DENSITY INDEPENDENT MORTALITY estimate
– i.e. the slope of the line at the origin.
β represents the parr CARRYING CAPACITY OF THE RIVER.

The Bush 'model' assumes α is constant between rivers but β can be adjusted.

PART II

RESPONSE TO Dr MILNER'S COMMENTS

Overview

I do not believe the response by Dr Milner addresses the fundamental criticisms I made of the Spawning Target Methodology. Instead, the real issues were avoided and the response was largely limited to trivial points. Even then, I contend that Dr Milner's analysis of my level of understanding of the points he did raise is in error.

There would appear to be four major areas of contention.

1) Is Maximum Gain (MG) an appropriate target?
2) Has the impact of Density Independent Mortality (DIM) been properly accounted for?
3) Are estimates of parr carrying capacity correct?
4) Should the target methodology be used at all, given its limitations?

In addition, Dr Milner alleges I have misinterpreted several other points:

5) Has altitude been used to approximate for habitat quality?
6) Does the model depend on transporting the "form of the Bush" stock-recruitment relationship?
7) Has HABSCORE been used?

These latter three points I contend are not material to the fundamental issues. Indeed they are little more than a play on words and could be interpreted as a diversion from the real issues.

1) Is Maximum Gain (MG) an appropriate target?

As I outlined in Part I, the use of an MG spawning target operates to the advantage of net fishing and the disadvantage of angling. Of this, there can be no doubt.

However, Dr Milner disagrees with this.

He stated that "it is wrong to suggest that a MG-based approach will favour the nets. In stock assessment a dead fish is a dead fish no matter in which fishery it is taken.....There is no scientific reason for supposing that MG drives management towards net fisheries and it is bizarre to suggest it. All MG does is to identify that point where the combined catch opportunity is greatest: which is a responsible aim for all concerned with fisheries........nor does it imply any preference of one fishery over another."

Dr Milner is correct in stating that the MG approach allows "combined catch" to be maximised. The problem is, that when the "combined catch" is maximised, anglers will take both a smaller proportion of the combined catch and a smaller number in absolute terms, then they would if a higher spawning target were insisted on.

Dr Milner states that maximising the catch will "optimise the use of the river's production potential." As I spelled out in my submission to the Salmon & Freshwater Fisheries Review Group, the opposite is rather the case. By favouring nets rather than angling, the revenue from the fishery will be reduced, and so there will be less money available for re-investing in habitat improvement work etc.

Rather, I believe the MG approach is an irresponsible use of the small but very valuable salmon resource.

It has been clearly stated by ICES that MG is primarily to be seen as a conservation threshold – the lower limit. The higher target which is then set is a political decision. In England & Wales, the political favour appears to have come down on the side of netting, not angling.

That this is so can be seen from analysing the proposals for the Lune NLO.

In late 1998 the EA had accepted a MG spawning target of 13.8 million eggs for the Lune. This was based on an assumed marine survival of 21.5%, which has been a figure used in a number of EA Salmon Action Plans. To achieve this level, it was proposed the number of net licences eventually be cut to 10 from 37. However, in the same document, an economic survey had revealed that 19 of the 37 licence holders were in some way "dependent" on the salmon netting (papers presented to North West RFERAC, Jan 1999).

In March 1999 the EA produced a revised package (Anon 1999). They had reconsidered marine survival rates and considered that a figure of 9 – 10% was more appropriate than 21.5%. Using a figure of 9 – 10%, a target of 11.9 million eggs was computed. This then meant that the number of licence holders only had to be cut to 19 – fortuitously the exact number of dependent netsmen!

Now, throughout the various calculations in the EA proposed packages, the EA have used 'precise' figures (e.g. the "assumed" smolt carrying capacity of the Lune was 2.956 / 100m^2). However, in the revised package (Anon 1999), although they give a precise figure of 11.9 million eggs, they do not give a precise figure for the marine survival used. It is merely described as 9 – 10%. It is curious why it is neither 9%, 9.5% or 10%. On reading the relevant documentation, it is quite apparent that adopting the 9 – 10% figure relies heavily on guesswork (as indeed was the 21.5% figure). *What this really looks like is that the EA have selected a marine survival rate which will give a target appropriate to preserving 19 nets. This does look for all the world like gerrymandering.*

Contrast this to what Dr Milner said: "the adjustment of the [Lune] marine survival value was a pragmatic and sensible move to improve the simulation of what was happening to the Lune stock. *It was not some conspiracy to favour one fishery against another (indeed if one fully understands what MG targets are it is obvious that they couldn't be used in that way)*".

From this I conclude that, unlike Dr Milner's assertions, it is clearly the case that MG targets can be manipulated for political ends and are not so objective as made out to be. In view of the evidence, Dr Milner's assertions hardly seem credible.

2. Has the impact of Density Independent Mortality (DIM) been properly accounted for?

My contention here is that, if in any given river, there are significant losses of eggs and alevins from siltation, redd washout, acidification etc. (i.e. an increased level of density independent mortality [DIM]), then the Bush model will not apply.

However, Dr Milner does not appear to agree. In fact he stated that "Dr Summers appears to misunderstand the implications of this [higher DIM] for spawning targets."

I do not think this is so. Rather, I think Dr Milner may be trying to obscure the issue.

It is the case that if a proportion of eggs die in the gravel, then more eggs would need to be deposited to compensate for this. The impact of this on the S-R relationship is explained in Figures 4a and 4b and Box 1. In essence, the main effect will be to "flatten" the Stock-Recruitment curve leading to a higher spawning target.

Box 1. The impact of Density Independent Mortality on the S-R curve.

If there is an increased level of DIM on salmon eggs, then a salmon stock will become less likely to fill all the available parr habitat. In effect, the number of eggs deposited will have to be increased to compensate. Assuming the parr carrying capacity of the habitat stays the same, then the S-R curve will still flatten out at the same level of smolt production, but will require a higher number of eggs. Thus the curve will become more shallow (Figure 4a)

A major impact of the flattened S-R curve is that there will be a reduction in the amount of potential surplus spawners (i.e. sustainable catch) which can ever be produced. This is shown on Figure 4b, under conditions where there is good marine survival.

However, problems really do occur when marine survivals reduce. Figure 5, shows examples of different Smolt-Spawner lines (A, B & C) under different levels of marine mortality (i.e. as marine mortality increases the slope increases). It can be seen that as marine mortality increases the potential surplus reduces. However, line C actually does not intersect with the high DIM S-R line at all. In this case, there will be a reduction of spawners between successive generations - in other words the population will collapse.

I think it is quite likely that this type of scenario has been responsible for the collapse of salmon stocks in many English rivers in recent years. Good examples are likely to be the Hants Avon, Torridge and Yorkshire Esk, when on top of a significant level of DIM, increased marine mortality in recent years, may just have been enough to tip the balance leading to population collapse.

Some fish do still survive in these rivers. These will be on the best habitats which remain. In some rivers, there may be no decent habitat remaining, hence the salmon have effectively become extinct - e.g. Axe, Dorset Stour.

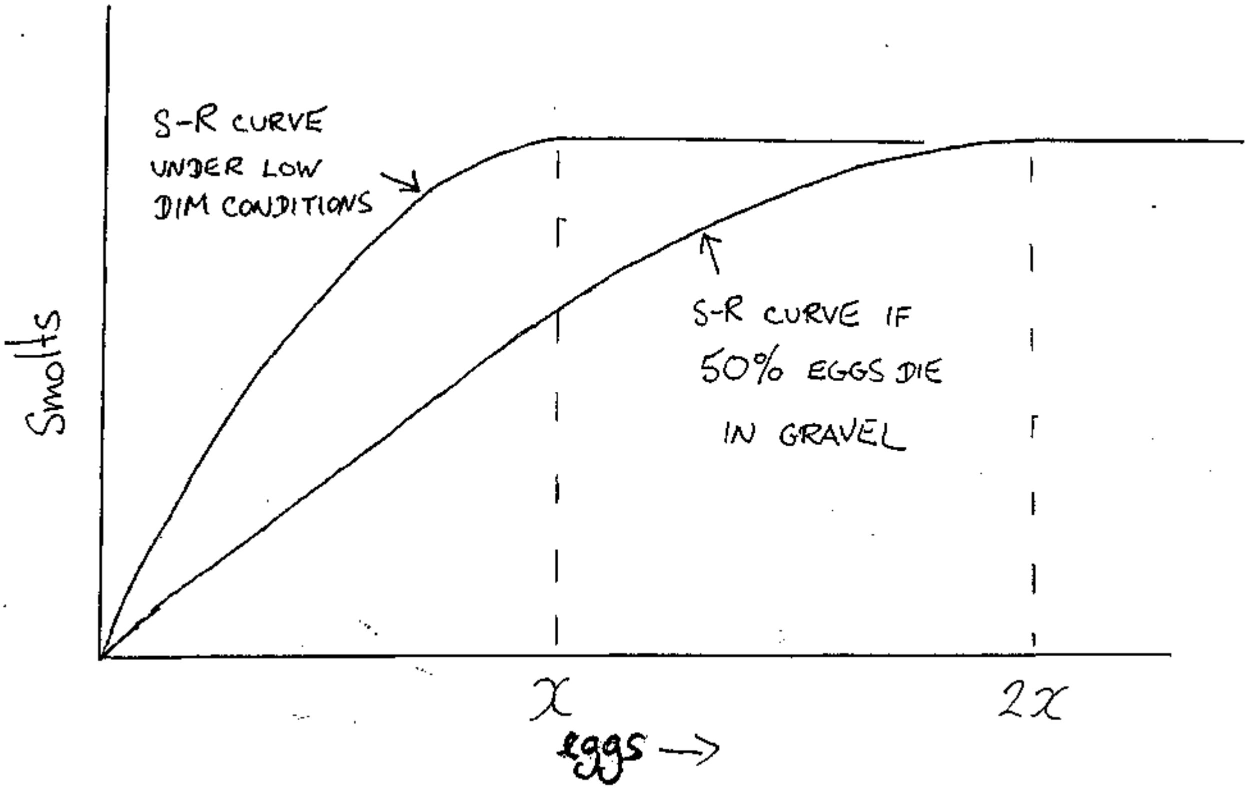


Fig 4a. If 50% eggs die in the gravel, the number of eggs that would normally be needed to reach carrying capacity (x) will need to be doubled (2x). This will flatten the S-R curve.

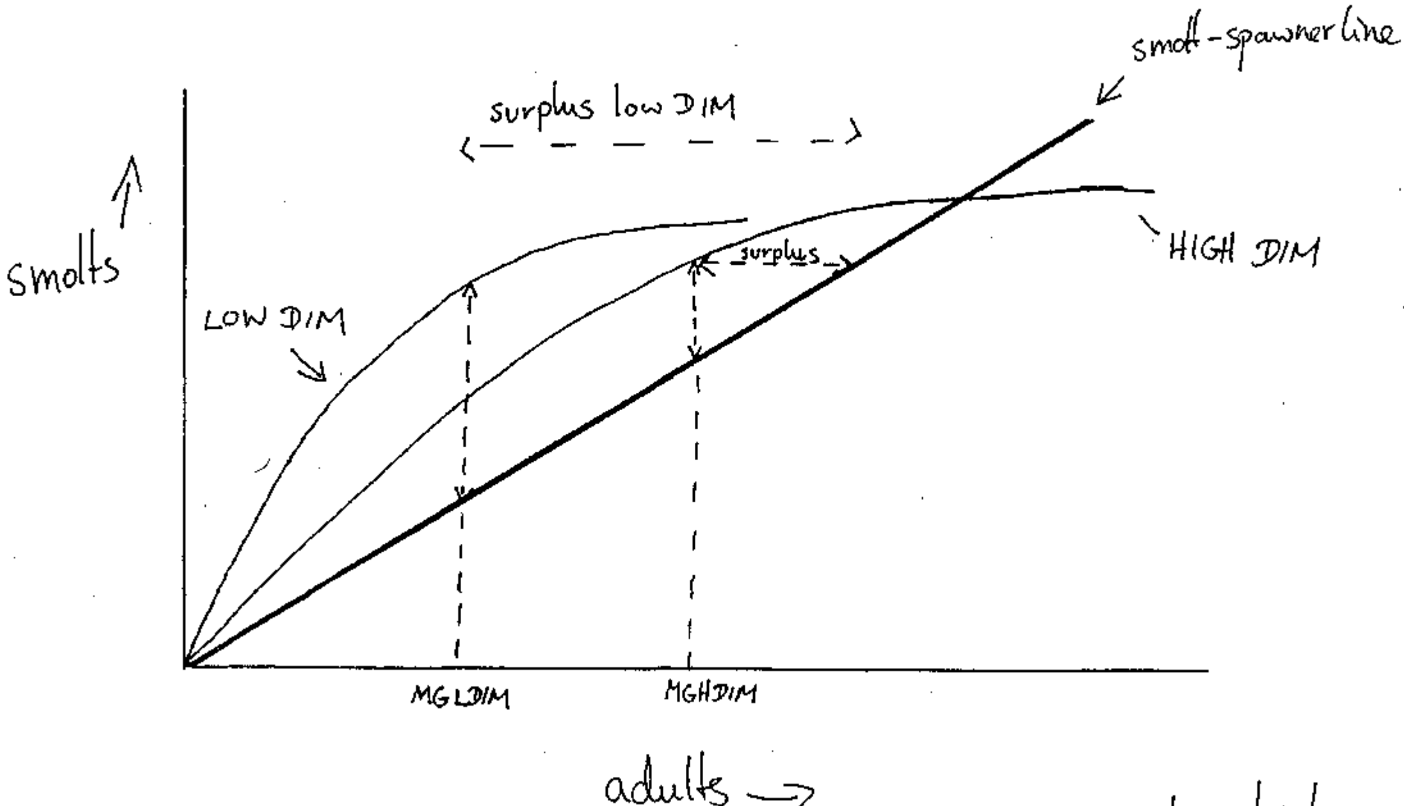


Fig 4b. Under a high DIM scenario, the Max Gain point is higher and the potential surplus (catch) is reduced.

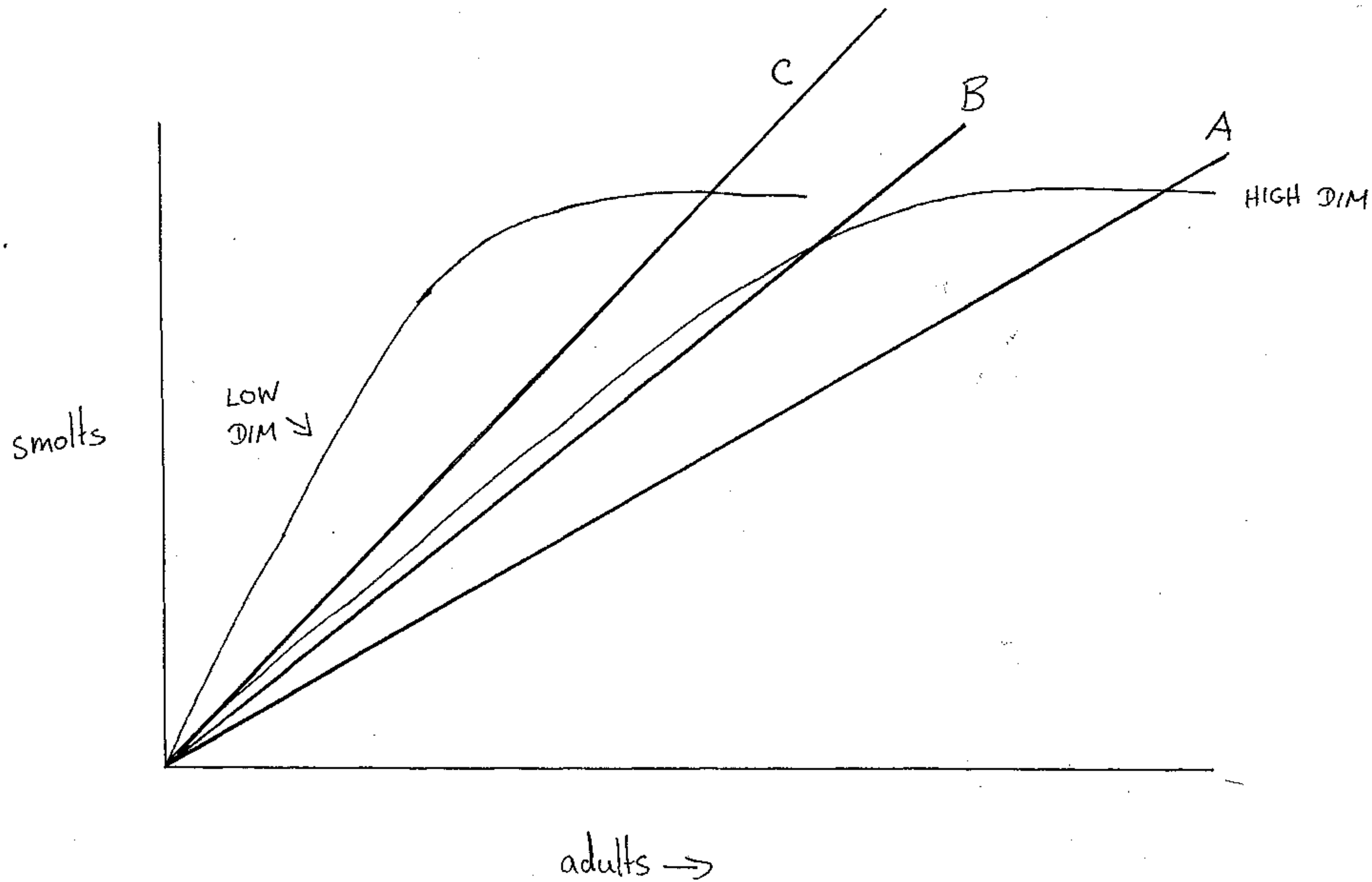


Fig 5. Lines A–C represent smolt-adult lines for different levels of marine mortality, C representing the highest mortality. Under a high DIM scenario the smolt-adult line may fail to intersect the S-R line (AS IN LINE C). This means the population would contract either to a line B scenario occurred or extinction.

That spawning targets need to include the effects of DIM was recognised by Champion (1997). He stated that "a reduction in the egg to parr survival will reduce the slope of the steep left hand section of the S-R curve and possibly move the point of maximum gain far to the right..."

This is also supported by the 1995 ICES Report of the Working Group on North Atlantic Salmon which states that 23.5 eggs per square metre are required to maximise smolt production in the River Oir, France. This figure is far in excess of EA Maximum Gain estimates (most under 5 per square metre). However, this river is affected by agricultural siltation and egg-smolt survival is low.

However, as stated, the EA methodology uses the estimate of DIM from the River Bush as a "benchmark" for other rivers. Dr Milner appears to imply that there should be no problem with this because the DIM "parameter is thought to be relatively constant between stocks", citing ICES reports. If this were the case, then the concerns I have expressed would be unfounded. However, the reality is somewhat different.

The conclusions of the 1996 ICES Atlantic Salmon Spawning Target Workshop stated that "a diverse egg to smolt data set from Europe (but not England or Wales) and Canada suggested that for most of these populations with the exception of the two rivers in France, the α parameter of the Ricker relationship [i.e. the DIM estimate] visually looked similar for all the rivers." However, the problem is, that most salmon research takes place on classical salmon rivers – i.e. rivers on hard crystalline rocks where siltation is not a problem (e.g. the Girnock Burn). Unfortunately, many rivers in England have much more in common with the French rivers alluded to. Indeed, later, Dr Milner contradicted himself by stating that the EA agrees that many rivers in England and Wales have higher rates of DIM compared to the River Bush.

Therefore, if a river has a higher level of DIM than the River Bush, then the MG target will be underestimated, meaning that the salmon stock in that river will appear to be more healthy than it actually is.

Again, Dr Milner takes an opposite view. He stated that if a river had higher DIM than the Bush, then it would be more likely to fail it's [Bush] target. "Thus this part of the procedure is conservative." This is not the case at all. In fact it is the opposite.

This is clearly shown on Fig 6. It shows two hypothetical S-R lines - the Bush Model applied to a silty river (A) and the real relationship for a silty river (B). The problem is that if the spawning stock were at point C, then it would appear from the Bush relationship that the river was above its MG point, whereas in reality it would not. I accept that the probability of the stock not even reaching its Bush target would be increased, but, even then, the gravity of the situation would be underestimated.

As stated, the issue of increased DIM, is a major problem for target setting in many English rivers. For example, it is likely to be having a significant impact on the chalkstreams, the Taw / Torridge, Tamar, Axe, lower Usk, main stem Wye, Yorkshire Esk, and possible many more.

With regard to the River Lune, the impact of DIM is currently unknown. The EA speculate that redd washout may be a problem (Anon 1999), but this does not appear

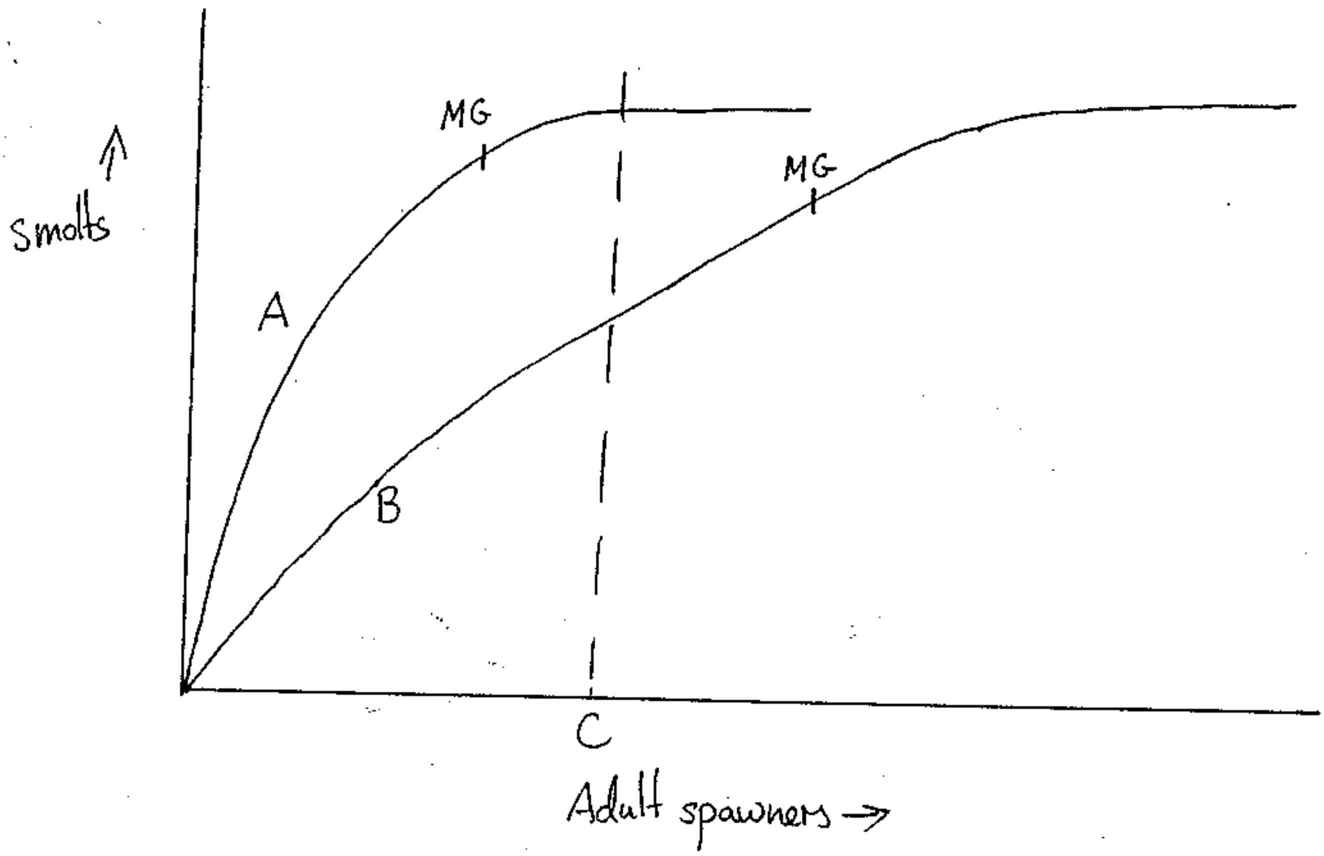


Fig6. Line A shows the S-R curve applied to a silty river using the Bush model (ie no correction). Line B shows the real S-R curve which should be applied. If the stock is at point C, it would be inferred from the Bush model that Max Gain was exceeded. In reality it would not.

Hence applying the Bush model to high DIM rivers will make the spawning stock look healthier than it really is.

to have been quantified. Clearly, if DIM is a problem on the Lune, then its impact on the S-R relationship may be profound.

In conclusion, I believe this is such a clear and simple point, that for the EA to pretend it does not exist, totally undermines the credibility of the entire process.

3. Are estimates of parr carrying capacity correct?

In my original analysis, I compared EA "benchmark" parr carrying capacities (applied as standard across all rivers in England and Wales) with observed data from the River Tweed. There was a considerable difference between the two. I pointed out that because carrying capacity was so obviously variable, any river which deviated from the "average", whether above or below, would not have an accurate spawning target.

Dr Milner obviously agrees with this contention because he stated that the EA were looking into it. However, he then tried to underplay the importance of what I said by saying that I was actually advocating the use of Scottish data. He stated "we do not agree that we should use values from Scottish rivers".

I also agree they should not use Scottish data. I agree that the Lune may differ somewhat from the Tweed. On the other hand, the Lune will also be different from average values derived from rivers all over England and Wales. What is needed are values that are appropriate to the Lune. In fact this was not a point which was lost on the original designers of the methodology. Wyatt & Barnard (1997) pointed out that "many of the parameter values used (e.g. for river widths and juvenile densities) are based on national average values. Target estimates could be considerably improved by utilising river specific estimates". Therefore, this is a problem which was well understood, but yet the EA still went ahead and set inaccurate targets on which management decisions are being taken.

The issue for the Lune is whether or not the Lune deviates from the average.

I used the Tweed as an example of a type of river which would be seriously underestimated using carrying capacity estimates the EA use. My contention was that it is reasonable to assume that the Lune could be in the upper bracket of English rivers. It must be admitted the Lune is more like the Tweed than the Hampshire Avon or the Taw. Furthermore, it had been established by stocking that at least some parts of the Lune are capable of holding densities as high as the Tweed.

As if to discredit my argument, Dr Milner seems to infer that rivers in England and Wales can never be capable of holding densities like the Tweed. This is incorrect. Table 1 below, shows data from the upper River Dart which are quite clearly of the order of Tweed. There is also a even a tributary of the River Wye, the Dernol Brook, which habitually holds 20 to 40 parr per hundred square metres (Betts *et al.* 1994).

	STREAM ORDER	
ALTITUDE BAND	**1**	**2**
50-99m	25.1 (1)	-
100-149m	-	-
150-199m	13.2 (1)	20.8 (1)
200-299m	23.1 (10)	-
300-399m	24.8 (16)	32.0 (3)

Table 1. Average carrying capacity density (number per hundred square metres) of salmon parr from River Dart tributaries (EA data). Number of sites included is given in brackets.

Table 1 is based on electrofishing data published by the EA from the River Dart (Steel 1996). Most of the sites fished are in small tributaries. I picked out those sites which are in areas where salmon spawning occurs (I am quite familiar with the Dart system, having walked most of it), i.e. those where it would be reasonably expected for the parr carrying capacity to be reached. Data are presented by the EA for a number of different years. What I did, was for each selected site, I picked the highest salmon parr density which had ever been recorded. Thus, for each site, a measure was obtained of how many parr that site could hold when at maximum capacity.

Sites were then placed into their respective altitude/stream order classes and average values taken.

If the Dart data are compared to the average carrying capacity estimates used by the EA – Table 2, below - (Table 4.14 in Wyatt & Barnard (1997)), it is clear there is a big difference. A significant part of the Dart production takes place in streams between 300 and 399m which have been greatly underestimated.

		Stream	Order	Category
Altitude band				
	1	**2**	**3**	**4**
0- 49m	1.9	3.5	3.9	2.7
50-99m	3.3	5.3	6.4	5.7
100-149m	6.4	7.3	7.7	7.6
150-199m	11.5	8.9	7.9	8.2
200 -299m	18.1	9.7	8.4	11.7
300 - 399m	7.0	7.4		

Table 2. The average number of salmon parr (per 100 square metres) which the EA have estimated represents carrying capacity in different stream types (from Wyatt & Barnard 1997).

Close inspection of Table 2 shows that the figure for stream order 1/200-299m (18.1) stands out from the others. For example, there is a great drop between it and the 300-399/order 1 category, but this drop was not seen on the Dart. I suspect this is partly an artefact of the type of sites the database is based on. For example, there has probably been a higher number of sites included in the 200-299/stream order 1 category. Undoubtedly, some other categories will have relatively low representation, especially those with high stream order.

It can also be seen from Table 2 that there is a considerable drop in densities between stream order 1 and order 2 for the 200-299 category. In fact, all the order 2 estimates are low. However, the limited Dart data do not suggest order 2 streams should have lower densities than order 1.

This lack of difference between stream order categories can be further seen from Tweed data (Table 3). I was unable to split these into stream order categories, but have simply arranged them in stream width categories. These data were obtained from Gardiner (1989) and exclude sites where no 0+ salmon were present (i.e. areas where access may be difficult and the stream understocked). Again, looking at these data, there are no grounds for believing there should be a systematic drop in parr densities between streams of order 1 and those of higher order.

		Stream width	
Altitude class	**< 5m**	**5 - 10m**	**> 10m**
50-99m	29.5 (2)	5.8 (7)	10.8 (7)
100-149m	15.5 (2)	44.8 (5)	19 (1)
150-199m	22 (2)	31.6 (10)	16.25 (4)
200-299m	33.8 (22)	20.9 (13)	19.9 (7)
300-399m	-	56.5 (2)	-

Table 3. Densities of salmon parr (no. per 100 square metres) in different stream types in the River Tweed in 1988. Number of sites given in brackets. Data from Gardiner (1989).

The main point I wish to make here is that what I infer from the Dart and Tweed data, and what I have seen from my own electrofishing experience, is that the big drop in densities seen in the National Database (Table 2) between the 200-299/order 1 category and those categories which immediately surround it, may have much to do with the representativeness of the sites in the database. It is likely that there is a preponderance of sites in the 200-299/order 1 class.

In conclusion, I think there can be no doubt that applying the data in Table 2 to rivers throughout England & Wales will lead to great error in some rivers at least. This could cause a spawning target estimate to be about by a factor of 2 or even more. This is very serious. This cannot be a basis for making management decisions of the type in question for the Lune NLO. I believe, therefore, that carrying capacity estimates need to be established on a river-by-river basis. This could be done initially with HABSCORE, though I would have concerns over the applicability of this method to river types which are poorly represented in the calibration database.

4. **Should the target methodology be used at all, given its limitations?**

Dr Milner claims that "targets...rapidly evolving....international effort..., but Dr Summers may be unaware of this wider context." He also stated that "We understand that Dr Summers' view is that because the science isn't perfect, then don't use it".

This is not correct.

I do believe that under existing conditions, as a principle, the use of spawning targets should continue. To suggest otherwise would be wholly irresponsible.

However, the problem as I see it, is that this is currently too blunt an instrument to manage salmon spawning escapement with the sort of surgical precision the EA are attempting. As in the case of the Lune NLO, a lot can hinge on only small adjustments of the target. Therefore, it is inevitable that this methodology will lead to continuous disputes over its accuracy. However, it can be improved, but nationally, this will incur significant extra expense or research.

My contention is simply that it would be far better to close those fisheries (i.e. salmon netting) which cause the problem to be encountered in the first place. If there were no net fisheries, there would be no NLOs. If there were no NLOs, resources and people's time could be spent on more constructive work to restore salmon rivers, rather than setting targets.

However, as long as netting of salmon continues and this management approach is maintained, then I think given the inherent inaccuracy, the precautionary approach should be adopted. This means a significant margin for error should be incorporated and a fairer playing field given to anglers.

There is one area, however, where I do think spawning targets have very real value. I actually said that the "area where spawning targets undoubtedly prove useful is in highlighting the existence of real crises.....In this respect, the preliminary analyses carried out for all rivers in England & Wales are valuable. They show 80% of rivers to be below their targets [in 1997].....this exercise has shaken complacency, which may now make the need for fundamental changes to salmon management more obvious."

I also stated that "they [the EA] must reappraise them [targets] in the context of the failings of the HABSCORE database and the potential impacts of Density Independent Mortality (e.g. siltation of redds)......It is very important this is done. It will make clear just how bad many rivers really are....."

Therefore, rather than saying targets should be discarded because of inaccurate methodology, I actually showed how the accuracy could be improved. Admittedly, this would entail the EA in more work, but this would be necessary to establish credibility of the methodology.

However, rather than accepting this advice, the EA appear to have avoided it, or pretended that no advice was given.

Furthermore, perhaps to deflect criticism from the deficiencies of the methodology, Dr Milner also tries to underplay the importance of targets. He stated that a "central plank of Dr Summers' critique of the Agency approach is to imply that decisions revolve uniquely around spawning targets". He also states that "targets form one part of a wide range of stock assessment methods used in SAPs".

I think that spawning targets are much more central to the EA's decision making than Dr Milner makes out. This is because a long standing problem in stock assessment (whether electrofishing, fish counters, catch records etc) is that no-one has ever been able to say how many fish there are "supposed to be" – i.e. there has never been any target or "benchmark". This problem was clearly shown in the MAFF Review of Salmon Netting on the East Coast (Anon 1991).

Therefore, the attempt to set spawning targets is the first time that a number has been put on how many salmon there are supposed to be. In terms of decision making, the spawning target is critical.

It is worth noting that some other reviewers have been less kind than I have. With regard to a Net Limitation Order **Public Inquiry on the Taw / Torridge**, the Technical Assessor (Champion, 1997) stated that spawning targets **"currently lack that degree of certainty required to make decisions which will affect the livelihood of netsmen and fishery owners."** Even more strongly, the Inspector (Mellor 1997) stated that **"these devices [spawning targets] were explained and examined at the Inquiry and emerged riddled with assumptions and unconvincing as a base for consistent action."** On balance, in that particular Inquiry, targets appear to have been dismissed out of hand. In reality, the target setting methodology would have underestimated the problems of the Taw and Torridge. The complete dismissal of the methodology, not only undermined the EA's case, but I believe resulted in the wrong conclusions being reached.

Dr Milner made several other points which are not material to the argument. However, we shall consider them because, though trivial, the criticisms are unjustified.

5. Has altitude been used to approximate for habitat?

Dr Milner stated that "Dr Summers is wrong in his assertion that altitude classes are used to "approximate for habitat".

This is quite an astonishing claim. This is indeed what altitude classes are used for. Furthermore, Dr Milner actually goes on to say so.

For example, he stated: "the carrying capacity is derived separately for each river using the proportion of the basic habitat (i.e. based on catchment features) categories." The "catchment features" referred to are altitude classes and stream order. He then goes on to say, "a simple river classification (based on altitude) is used to adjust MBAL for different catchment characteristics". For "characteristics", read habitat.

Furthermore, Dr Milner states, "for each river MBAL is tuned to its relative proportions of good habitat". The proportion of "good habitat" being the proportion of high altitude streams in the catchment.

If this is not using "altitude" as a rough index of habitat quality, I do not know what is!

6. Does the model depend on transporting the "form of the Bush" stock-recruitment relationship?

I stated that "the most fundamental assumption is that the form of the Bush S-R relationship applies to all other rivers." Dr Milner then stated that "this assumption is NOT made."

He then goes on to say that the Bush is used to derive a "benchmark" value of DIM, but DIM was "only one of a number of factors that describe the form of the Bush S-R relationship." In fact, as described earlier, the other two factors are the equation (which I understand to be the same throughout) and the river's carrying capacity. Of these three things, only the carrying capacity is ever adjusted between rivers.

Dr Milner then says the Bush DIM estimate is "merely the benchmark against which other rivers are compared". Might it not be deemed to be "applied" to other rivers?

It seems to me this is purely a semantic argument. Whether or not the word "applies" is taken literally is irrelevant. The point is, that the "target", "benchmark" or whatever you like to call it, is that which would be expected if DIM in any given river was the same as DIM in the Bush.

Again, this looks like a feeble attempt to discredit my argument over an irrelevant point.

7. Has HABSCORE been used?

I stated that "the use of altitude classes to approximate for habitat and the calibration of these with average HABSCORE data will lead..."

Dr Milner then said "in contrast to Dr Summers' implication HABSCORE models are NOT used in the procedures."

The original report which set out the spawning target methodology (Wyatt & Barnard 1997) makes frequent reference to the "HABSCORE database", upon which estimates of carrying capacity were based.

I had interpreted this database as being one of sites which had been "HABSCORED". From Dr Milner's comment, it appears this database is actually the electrofishing database on which HABSCORE is based. On my part, this appears a slight misinterpretation of a not overly user-friendly document. That the spawning target methodology has not been spelled out in a user-friendly fashion is a great pity. This is because it means few people have fully got to grips with what this whole exercise does.

However, whichever type of data the "HABSCORE database" represents, it does not detract from the fundamental point I made – i.e. than the carrying capacity estimate is based on an average of the database.

Again, this is a trivial point.

CONCLUSIONS

My overall conclusion from Dr Milner's response is that the EA have not in any way shown my contentions regarding DIM and carrying capacity to be false. They have provided no answers to these fundamental issues and cite no examples by way of illustrating their points.

Rather than admitting there are very serious problems, the EA appears merely to be trying to avoid the issue. It is, of course, quite easy for the EA to hide behind this methodology because it is so convoluted that lay readers may be hard pressed to follow it. It is very easy to confuse readers by trying to base a defence on points which are completely irrelevant to the argument (and not even correct anyway).

That the EA do not wish to admit the serious flaws in this methodology is probably because of the serious implications which result. Many rivers will have to have their spawning targets increased, and this will show the stock situation to be much worse than it appears to be. Rivers which definitely will be in this category are silty rivers like the chalkstreams, the Torridge, Tamar, lower Wye and the Yorkshire Esk. Rivers which have good habitat for salmon parr will also be underestimated, for example the upper River Dart.

It is, therefore, quite easy to see that the EA may wish to keep targets down for political reasons. These could include hiding what, from an International perspective, are now wholly unjustifiable levels of commercial netting on degraded rivers (e.g. Torridge, Yorkshire Esk [NE drift nets] and even the Lune). In the Lune case, the EA may even have resorted to bending the science to achieve this. This is not a basis on which to manage salmon stocks. If management is to be driven by science, then it really must be driven by science, and openly.

With regard to the Lune NLO, the data do not exist to state with certainty how inaccurate the target set by the EA is. However, many factors make it likely that the Lune spawning target has been underestimated. It is certainly the case that the target which has been set is little better than a guess. The EA already do have methods at their disposal which could improve the estimate. I think it is fundamental they do this before proceeding further. **It is already the case that the spawning target methodology has been ridiculed in one recent Public Inquiry (Taw/Torridge) which resulted in a very unfortunate conclusion. The same mistake cannot be allowed to happen again.**

REFERENCES

Anon (1991) *Salmon Net Fisheries*. HMSO, London.

Anon (1999) The Proposed Lune Net Limitation Order 1999 and Associated Byelaws, March 1999. Environment Agency North West Region.

Betts, S., Gough, P.J., Winstone, A.J. and Hilder, P. (1994) A survey of the salmonid populations of the Upper River Wye and selected tributaries. *Report Ref: PL/EAE/94/1*. National rivers Authority, Cardiff.

Champion (1997) Report of the Technical Assessor. The Environment Agency (Rivers Taw and Torridge) (Limitation of salmon and trout netting licences) Order 1996 and Fisheries Byelaws. Report of Public Local Inquiry, 21-24 and 28-31 January 1997.

Gardiner, W.R. (1989) Tweed juvenile salmon and trout stocks. In *Tweed towards 2000* (ed. D.H. Mills), pp. 105 – 114. Berwick-upon-Tweed: the Tweed Foundation.

Mellor (1997) The Environment Agency (Rivers Taw and Torridge) (Limitation of salmon and trout netting licences) Order 1996 and Fisheries Byelaws. Report of Public Local Inquiry, 21-24 and 28-31 January 1997. DP1/28/4/1.

Potter, E.C.E. (1996) Stock assessment for Atlantic salmon and target spawning requirements: the approach of the International Council for the Exploration of the Sea. Abstract of presentation at the Atlantic Salmon Spawning Target Workshop, France, 1996. (e.d. by E. Prevost and G. Chaput).

Steel, S. (1996) River Dart Fisheries Survey 1996. Environment Agency Devon Area Report DEV/FRCN/10/97.

Wyatt, R.J. & Barnard, S. (1997) The transportation of the maximum gain salmon spawning target from the River Bush (N.I.) to England and Wales. R & D Technical Report W65, Environment Agency, Bristol.

Month	1991	1992	1993	1994	1955	Average	Percentage
January	10	0	3		0	3	0
February	8	3	7		0	5	0
March	6	4	12		43	16	0
April	26	82	34		40	46	1
May	90	355	138		19	151	3
June	365	707	1478		0	638	11
July	491	655	838		1220	801	14
August	1204	781	1160		36	795	14
September	1373	1024	1915		1071	1346	23
October	587	363	1077		1484	878	15
November	1052	463	590		1028	783	14
December	110	55	1042		53	315	5
						5776	100